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CONTENTS

Opening Session. **The Past: Prologue or Prospect**

Opening Remarks 1
Rollin D. Sparrowe

New Times, Old Questions, Tough Answers 6
Mike Hayden

U.S. Coastal Habitat Degradation and Fishery Declines 11
James R. Chambers

The Challenge of Biological Diversity:
Professional Responsibilities, Capabilities and Reality 20
David L. Trauger and Russell J. Hall

A Bridge to the Future: The Wildlife Diversity Funding Initiative 37
Herbert E. Doig

Presentation of the 1992 Guy Bradley Award 42
Whitney C. Tilt

Special Session 1. **Wildlife Damage Management**

Bridging Traditional Barriers and Achieving Balances 45
John P. Weigand

The Complexities of Implementing Wildlife Damage Management 47
Jack H. Berryman

Decision Making for Wildlife Damage Management 51
Dennis Slate, Rick Owens, Guy Connolly and Gary Simmons

Risk Management Concepts for Improving Wildlife Population Decisions
and Public Communication Strategies 63
Barbara A. Knuth, Rebecca J. Stout, William F. Siemer,
Daniel J. Decker and Richard C. Stedman

Survey Use and Landowner Tolerance in Wildlife Damage Management ... 75
Scott R. Craven, Daniel J. Decker, Scott E. Hygnstrom and
William F. Siemer

Michigan Deer Crop Damage Block Permit Study 89
Charles M. Nelson and Tom Reis

Factors Influencing Game Damage Complaints in Montana 96
Raymond J. Adkins and Lynn R. Irby

Future Challenges of Suburban White-tailed Deer Management 104
Paul D. Curtis and Milo E. Richmond

Professionalism in Wildlife Damage Management: Issues and Directions ... 115
Robert H. Schmidt, Bobby R. Acord and Donald W. Hawthorne

Closing Comments 125
James E. Miller

Special Session 2. **A New Era of Conservation Information**

A Field Guide to "The New Era" in Conservation Information 129
Chris Madson

Evaluating Citizen Participation:
Creating Communication Partnerships that Work 135
Rebecca J. Stout, Daniel J. Decker and Barbara Knuth

Responsive Management: Finding the Right Tool for the Job 141
Mark Damian Duda

Reaching the New Constituency—One Agency's Approach 147
Larry L. Kruckenberg, Dave Lockman and Walt Gasson

Successful Communication and Education Strategies for Wildlife
Conservation 156
Gerri A. Pomerantz and Kathleen A. Blanchard

Market Information: Matching Management with Constituent Demands 164
David H. Thorne, Edward K. Brown and Daniel J. Witter

Special Session 3. **Conservation Education: Investing in the Future**

An Evaluation of Volunteerism
in Selected Conservation Education Programs 175
Janice Schnake Greene and Clark E. Adams

New York's Sportfishing and Aquatic Resources Education Program:
What We've Learned About Working with Volunteers 185
*Marianne E. Krasny, Bruce E. Matthews, Karen L. Edelstein,
Glenn Applebee and H. David Greene*

What Teachers Want from Agencies 194
Eugene Decker and Donald J. Brown

Effects of Wildlife Cartoons on Children's Perceptions of Wildlife
and Their Use of Conservation Education Material 197
Cynthia J. Wong-Leonard and R. Ben Peyton

Youths Communicating with Youths:
The Outdoor Writers Association of America's Youth Writing Contest 207
Glenn L. Sapir

Evolution of the 4-H Wildlife Habitat Evaluation Program
into a National Tool for Integrated Learning 212
Edward L. Neilson, Jr., and Delwin E. Benson

Special Session 4. **Wetland Conservation**

Status of Wetlands Legislation in the 102nd Congress 219
Claudia Copeland

Private Property and Wetland Conservation 225
Jack M. Payne and W. Alan Wentz

Wetland Protection Programs:
Direction and Outlook of the U.S. Army Corps of Engineers 234
Major General Arthur E. Williams

U.S. Wetland Protection Programs:
Direction and Outlook of Stewardship Agencies 238
Peter F. Bontadelli

Special Session 5. **Biological Diversity in Wildlife Management**

Focusing Conservation of a Diverse Wildlife Resource 241
Fritz L. Knopf

Genetics and Biodiversity in Wildlife Management 243
Michael H. Smith and Olin E. Rhodes, Jr.

Population Processes and Biological Diversity 252
Michael S. Gaines, J. Foster, J. E. Diffendorfer, W. E. Sera,
R. D. Holt and George R. Robinson

Managing Genetic Diversity
in Captive Breeding and Reintroduction Programs 263
Katherine Ralls and Jonathan D. Ballou

Landscape Considerations for Viable Populations
and Biological Diversity 283
Thomas E. Martin

Temporal Scale Perspectives in Managing Biological Diversity 292
Peter B. Landres

Conserving Biological Diversity in Sustainable Ecosystems 308
Fred B. Samson

The International Component of Managing Biological Diversity 321
Mercedes S. Foster

Faunal Mixing, Faunal Integrity and the Biopolitical Template 330
Fritz L. Knopf

Special Session 6. **Biological Diversity in Aquatic Management**

Opening Remarks 343
Jack E. Williams and Richard J. Neves

Introducing the Elements of Biodiversity in the Aquatic Environment 345
Jack E. Williams and Richard J. Neves

Ethical Considerations in Conservation Biodiversity 355
Edwin P. Pister

Crimes Against Biodiversity: The Lasting Legacy of Fish Introductions 365
Walter R. Courtenay, Jr. and Peter B. Moyle

Fisheries Management and Biological Diversity:
Problems and Opportunities 373
David Wilcove, Michael Bean and Philip C. Lee

Functional Coastal-marine Biodiversity 384
G. Carleton Ray and M. G. McCormick-Ray

Maintaining Marine Biodiversity: The Missing Link in Global
Ecosystem Management 398
Albert M. Manville II

An Ecosystem Approach to Conservation and Management of Freshwater
Habitat for Anadromous Salmonids in the Pacific Northwest 408
Gordon H. Reeves and James R. Sedell

Bring Back the Natives: A New Strategy for Restoring Aquatic Biodiversity
on Public Lands 416
Cindy Deacon Williams and Jack E. Williams

Protecting the Biodiversity of Riverine and Riparian Ecosystems:
The National River Public Land Policy Development Project 424
Thomas C. Dewberry

Special Session 7. **The Potential and Promise of Wildlife Disease Study and Control**

Wildlife Health: When to Intervene 433
Paul L. Barrows

Oral Rabies Vaccination: Development of a Recombinant Virus Vaccine ... 439
Charles E. Rupprecht, C. A. Hanlon, H. Koprowski and A. N. Hamir

Brucellosis, Wildlife and Conflicts in the Greater Yellowstone Area 453
E. Tom Thorne and James D. Herriges, Jr.

Relocation of Wildlife: Identifying and Evaluating Disease Risks 466
William R. Davidson and Victor F. Nettles

Overcoming Disease Problems
in the Black-footed Ferret Recovery Program 474
Elizabeth S. Williams, E. Tom Thorne, Don Kwaitkowski and Robert Oakleaf

Influence of Disease on a Population Model of Mid-continent Mallards 486
Michael D. Samuel

History and Progress in the Study of Hemorrhagic Disease of Deer 499
Victor F. Nettles and David E. Stalknecht

Environmental Influences on Major Waterfowl Diseases 517
Milton Friend

Toxicity of Bismuth Shot Compared with Lead and Steel Shot
in Game-farm Mallards 526
Glen C. Sanderson, Susanne G. Wood and Jeffrey D. Brawn

Special Session 8. **The Dilemma of the National Wildlife Refuge System**

Opening Remarks 541
William Ashe

Refuges 2003—A Plan for the Future 545
Robert Schallenberger

Water Rights for Wildlife: The Challenge Facing Western Wildlife Refuges 554
Robert K. Oser

The Water Crisis in the Western Refuge System:
An Environmental Response 560
David L. Harrison

Refuge Management and Biological Diversity:
A Refuge Manager's Perspective 571
Jim Clark

Biological Diversity and the Refuge System:
Beyond the Endangered Species Act in Fish and Wildlife Management 577
Michael J. Bean

Managing Refuges for Waterfowl Purposes and Biological Diversity:
Can Both Be Achieved? 581
W. Alan Wentz and Frederic A. Reid

Alternatives to Hunting 586
John Grandy, Susan Hagood and Kirsten Berger

The Manager's Tool Kit: Alternatives for Reducing Unhealthy Wildlife
Concentrations on National Wildlife Refuges 592
Joseph P. Mazzoni and Jim Clark

The Efficiency of Public Hunting in Maintaining Balanced Wildlife
Populations on Refuges 596
William A. Molini

Bold Actions in Refuge System Law to Maintain Compatibility 601
Pamela Pride Eaton and James R. Waltman

Biological Farming: An Effective Program for Wildlife Agriculture 607
George E. Gage

Grazing on National Wildlife Refuges:
Do the Needs Outweigh the Problems? 611
Ronald E. Kirby, James K. Ringelman, David R. Anderson
and Richard S. Sojda

Special Session 9. **Endangered Species: Conservation or Accommodation**

Accommodations With Socio-economic Factors
Under the Endangered Species Act—More Than Meets the Eye 627
Jack Ward Thomas and Jared Verner

The Endangered Species Act: Prospects for Reauthorization in 1992 642
William Robert Irvin

Conservation on a Grand Scale 648
Peter W. Stangel and Amos S. Eno

Impacts on Private Forestry of Conservation Strategies
for Threatened and Endangered Species 657
Larry L. Irwin and T. Bently Wigley

Endangered Species Protection through Local Land-use Regulations 665
Lisa Britt Dodd

Protection of Threatened and Endangered Species and Their Habitats
by State Regulations: The Massachusetts Initiative 674
Curtice R. Griffin and Thomas W. French

Economic Values of Threatened and Endangered Wildlife:
A Case Study of Coastal Nongame Wildlife 684
John C. Whitehead

Red-cockaded Woodpeckers and Hydric Slash Pine Flatwoods 693
James W. Beever III and Kimberly A. Dryden

Special Symposium. **Wildlife and American Wildlife History: Insights from the Past**

Gazing Across the Gulf: Environmental History and American Wildlife 701
Dan L. Flores and Eric G. Bolen

Outlaw Gunners and Hunting Law in the English Colonial South 706
Timothy Silver

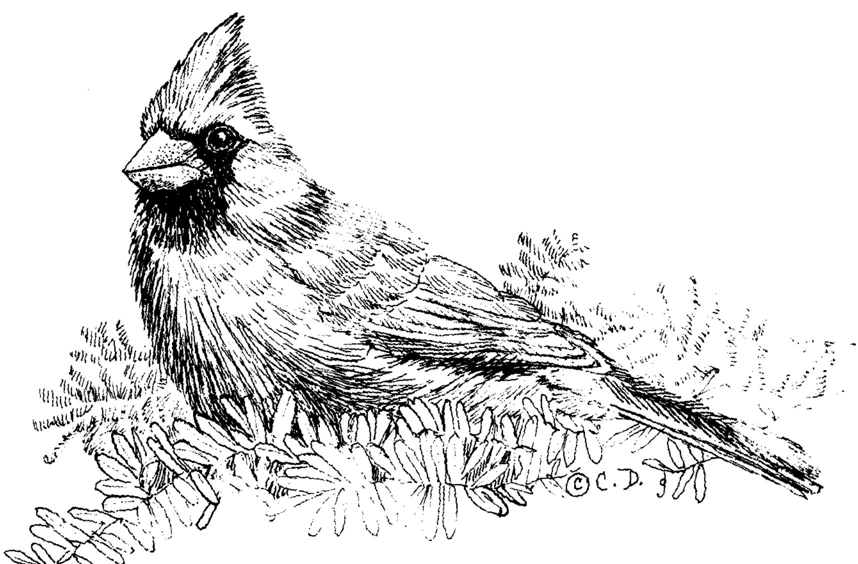
Poachers, Conservationists and Ecosystems:
Local Struggles Over American Wildlife 711
Louis S. Warren

Searching for the Roots of the Conservation Movement:
Fish Protection in New England 1865–1900 717
Richard W. Judd

Wildlife and Irrigation Systems Along the Snake River, Idaho 724
Mark Fiege

The Evolution of American Wildlife Policy 733
Thomas R. Dunlop

Registered attendance 738



Opening Session. *The Past: Prologue or Prospect*

Chair
LARRY K. MONTEITH
Chancellor
North Carolina State University
Raleigh, North Carolina

Cochair
PETER S. DUNCAN, III
President
International Association of Fish and Wildlife Agencies,
and Executive Director
Pennsylvania Game Commission
Harrisburg, Pennsylvania

Opening Remarks

Rollin D. Sparrowe
President
Wildlife Management Institute
Washington, D.C.

It is a pleasure to welcome all of you to the 57th North American Wildlife and Natural Resources Conference. The Conference theme this year, **Crossroads of Conservation: 500 Years After Columbus,** leads to a natural focus on some of the history of conservation—how we got where we are today—as well as a look to the future.

Conference sessions over the next three days will focus on wetland conservation, wildlife diseases, wildlife damage management, conservation information, biological diversity in wildlife and aquatic management, national wildlife refuge management, and the trade-offs faced in protecting endangered species. Tremendous insight and energy toward management of natural resources already have gone into more than 100 related meetings during the past three days, bringing together a wide array of natural resource professionals from agencies, academic institutions and private organizations. Actions on nearly all of the topics on the formal program have been discussed, debated and, in some cases, decided upon through these related meetings.

It is easy to see in these topics an expansion of concern from local, to regional, national and global scope. Many are suggesting that "new" thinking is required to solve new problems, and many individuals, organizations and disciplines purport to have the answers we all need to do the right thing in managing our natural resources. It should be apparent to many who are deeply involved with these issues that the conservation movement itself has changed dramatically, but really faces the same old problems within a changing social context. There now are more organizations striving to answer these problems and representing more different constituencies than ever before. Whether any of the issues are "new" is debatable.

The issues presented to me 30 years ago upon my entry into wildlife biology courses at Humboldt State College in California were: overgrazing of public lands; the scandalously low fees charged for use of public forage; the cutting of old-growth redwood; the attendant destruction of salmon spawning streams; threats of extinction of some species of wildlife; and even suggestions that there might be too many people in the world. None of these problems have been solved, but some are receiving attention that we all hope will lead to solutions.

Now, in 1992, there certainly are new environmental needs of a global nature and for the management of fish and wildlife. Most of the issues, however, are not dissimilar from those to which I was first exposed three decades ago. One of the most dramatically different things is the vision of organizations and government about what truly constitutes conservation. Last week, a representative of one of our government's most important environmental entities told me that management of marshes, forests and grasslands for fishing, hunting and trapping wasn't really conservation. Unfortunately, that comment is a sign of our times.

Nowhere does this disparity of views become more evident than in the unfortunate debate and preoccupation over hunting and traditional management of wildlife habitats. I maintain that many in active natural resource conservation today—individuals and organizations—have lost their perspective on the past and how we got to where we are today. Certainly, broader perspectives are needed in land management to accommodate the needs of more people and a changing environment. Certainly, there are global problems that require the attention of governments and organizations. Change, however, is not necessary all at once, from the top down and in all cases. We need to revisit the history of conservation in America and examine the roots of our existing programs to maintain and manage a resource base for fish and wildlife.

I have recently reviewed the history of national forest protection, national wildlife refuges, rangelands, and state and private land-based programs. Most of these major land-protection activities in the United States began in the late 1800s, and resulted primarily from the energy of traditional hunting, fishing and outdoor recreation interests. Organizations played a role, but the issues and organizations themselves were driven largely by individuals of intense conviction, focus and commitment. With the exception of fairly recent activities by the Nature Conservancy, I couldn't recall a single truly major program without such roots. For that matter, much of the core support for Farm Act conservation provisions—a truly large-scale land management program—has come from traditional fish and wildlife interests.

We are currently besieged with suggestions that traditional management programs should be supplanted by those that adopt preservation of biological diversity as their primary purpose. There is a great difference between advocating a more balanced approach to cutting timber, moderating grazing on public lands, or limiting some forms of recreation on public lands to achieve specific objectives, and the adoption of biological diversity as the main objective of all of those lands.

National wildlife refuges are a current center of debate over management. Their history of acquisition and intended purposes is complex, and the quality of information being given to the public is variable.

In addition to allowing various human activities on refuges as long as wildlife values are protected, national wildlife refuge management already provides for biological diversity more than is generally known. Since 1983, biological diversity has been one of the four main goals of refuge management. If refuges need to be managed differently to reach their full potential and meet clearly defined biological diversity objectives, that can be done. It should be done based on real information about what is being done on refuges, not assumptions. For example, refuge managers reported to the U.S. Fish and Wildlife Service that:

- 237 refuges have all or part of their program geared to ecosystems or communities, and not species management.
- 192 refuges are restoring native vegetation communities on 1.2 million acres.
- 206 refuges provide wildlife corridors linking fragmented habitats.
- less than 10 percent of the wetland acres on refuges outside Alaska manipulate water levels.

So much for national wildlife refuges being managed as duck factories! There may well be specific sites that could be managed for a more important purpose than they are, but there are good things happening on refuges now.

Public use and other activities on national wildlife refuges have received much attention, with exaggerated claims of great problems needing legislative fixes. Few specifics are presented which would warrant the expense and bureaucracy that would be required by pending legislation. Claims that more than 60 percent of refuges have activities called "harmful" in someone's opinion must be balanced by knowledge that only 2 percent had activities ruled incompatible with refuge purposes. Examine closely the soundness of what you hear about this issue. If two dozen out of more than 450 refuge units need help, do we need new laws that affect all of them?

Attention to neotropical migratory birds has been stimulated in the past two years through a fine program catalyzed by the National Fish and Wildlife Foundation and now is proceeding through federal land-management agencies, the states, and a wide array of people and organizations interested in songbirds. We need to foster greater participation at the state level. The dilemma since the Fish and Wildlife Conservation Act was passed in 1980 has been finding funding for such needed programs. The Administration and Congress have not provided funding to carry out their mandates under the law. Wide support for a funding mechanism to expand traditional programs at the state level into truly broad, comprehensive management of all fish and wildlife would be a giant step toward achieving greater diversity in America's renewable natural resources.

For some perspective, wildlife conservation programs funded almost exclusively by hunters, through hunting licenses, permit fees, excise taxes and duck stamp sales provide about $600 million each year for state and federal wildlife conservation programs. This is an average of about $32 per hunter. If all nonhunters 16 years of age and older in the U.S. paid an equivalent rate, more than $6 billion would be available for wildlife conservation each year. Unfortunately, contributions by nonhunters to wildlife programs are very small when compared with those of hunters. Accusations of misuse of the public's funds to foster wildlife for hunting are misplaced. A 1992 survey by the Wildlife Management Institute showed that hunters provide almost 75 percent, on average, of the wildlife program funding of state wildlife agencies nationwide. Funds from hunters currently provide an average of 45 percent of the funding for management of nonhunted wildlife in those states.

Everyone agrees that habitat is the consistent need for wildlife, but land protection itself can take some amazing turns. Since the advent of the National Wildlife Refuge System, duck stamp funding and the international wetland protection programs of Ducks Unlimited, the largest scale land-protection effort involving the widest array of people is occurring through the North American Waterfowl Management Plan. Joint ventures from coast to coast, and from Canada to Mexico are pooling resources of federal, state and private interests to protect wetlands that are benefitting all wildlife, not just hunted species. Yet, in seeking support for appropriations for either implementation of the plan or full funding of the North American Wetland Conservation Act, conservationists are finding themselves forced to justify the need for funds and support for this program based on benefits to everything except the resource that has generated the most interest. The waterfowl people, with an interest in hunting, as well as overall conservation of North America's waterfowl, have provided the planning, visibility, energy and most of the funding to date. Yet, in recent budget cycles, support from many organizations, some agencies and the Congress is qualified in terms of benefits for things other than ducks.

What does this tell us? I interpret it to mean a loss of a common foresight and a loss of common resolve to benefit resources on a grand scale. We need mutual recognition of compatibility between diverse goals—such as ducks and a much wider array of species. Even Congress has been reluctant to supply full support based on the very principles identified in the Wetlands Act itself to implement the waterfowl plan. The scoring system for proposals to the Act gives 75 percent of the weight to "nonduck" values. Never mind that examples can be provided from all around North America—from Quill Lakes in Saskatchewan, Cheyenne Bottoms in Kansas, the Central Valley in California, Cache River in Illinois, the ACE River Basin in South Carolina and projects in Delaware Bay, just to name a few—that are demonstrably helping wildlife resources through habitat protection on a truly ecosystem scale. Never mind that federal funds are matched 2:1 with nonfederal funds. Only a view of the future that has lost its perspective of the past and its touch with reality can reject these actions as supportable, necessary, primary efforts toward preserving important aspects of the biological diversity that was North America before Columbus.

Perhaps it is time to review what it is we all are striving for in North America. I want to harness the energy of traditional supporters of wildlife programs and add to that strong efforts to bring in songbirds and cooperate toward ecosystem-scale protection for wildlife—all of this in addition to maintaining existing programs. That is why we provide for this dialogue each year at this Conference. The way to success is to blend efforts—not for one set of interests to proclaim the superiority of their thinking and question the motives of those who got us where we are.

Many challenges face us in the short-term. The President and the Administration provided clear leadership in supporting the North American Wetlands Conservation Act in 1989. The professionals at this gathering are awaiting to see leadership from the Administration on implementation of reasonable wetland-protection procedures to achieve no-net-loss as a goal. Resource professionals here are waiting for leadership from the current Administration in the area of old-growth timber management, as well as conservation of the spotted owl. Conservationists everywhere are waiting for timely development and public release of proposed new directions for the national wildlife refuge system. These are but symbols of resource issues over which there is great polarization, on the one hand between development and nondevelopment interests, but possibly even more destructively within the conservation movement itself. As organizations grow, broaden their vision, and decide to take on the world and all of its problems, they seem to choke on success. These days, conservation organizations seem to have their own agendas, and many have lost the common purpose fostered by the events of the 1930s that resulted in this Conference and the modern conservation movement.

Let me be clear that I am not making a case for hunting and hunters apart from broad needs in conservation. I am making a case for doing business on behalf of wildlife with a reasonable view toward the world in which we live. We need to modernize our thinking and application of traditional measures to land management, but we need to understand how we got where we are, and who continues to pay the freight. The least likely way to success is top down, heavy-handed regulatory approaches that try to force changes without regard to successful existing programs, and to where the support has consistently originated. The crossroads that conservation faces, as evidenced by the programs at this 57th North American Wildlife and Natural Resources Conference, really is how we decide to deal with some old problems in a new context, with more people on the landscape and still only a few of them directly supporting active conservation.

New Times, Old Questions, Tough Answers

Mike Hayden
Assistant Secretary
Fish Wildlife and Parks
U.S. Department of the Interior
Washington, D.C.

Thank you, Larry. I appreciate the warm welcome all of you have given me. Being relatively new to my assignment in Washington, coming down here to speak before such a distinguished and knowledgeable audience is not just a great honor, but also a bit of a daunting task—it is nice to see so many familiar faces out there, people I have known and worked with over the years.

From the moment I arrived here, I have felt among my peers. Around Washington, if you scratch a lot of politicians, you'll find lawyers underneath. Scratch me and you'll find a wildlife biologist—coming here is like coming home to my roots.

In fact, I remember back when I was in college, and my college advisor—a very contemplative and serious fellow—asked me what I wanted to do with my life. Back then, becoming a governor of a state or assistant secretary of Interior was about the furthest thing from my mind. I told him I wanted to be "Mark Trail."

He was not amused.

But I took my best shot at becoming "Mark Trail" anyhow. A few years later, I was a budding wildlife biologist slogging through a collection of water and knee-high muck called Cheyenne Bottoms.

Now, I know some of you are thinking that slogging through knee-high muck is great training for politics. But that certainly wasn't what I had in mind at the time.

In fact, the real reason I entered into politics was the same reason many of you are here today—I saw a need for action to conserve our natural resources, a need for a systematic, professional approach to wildlife management. There was a job to do and nobody was doing it.

I was a biology teacher back then, and I can remember teaching a class at 7 a.m., jumping into my car and driving 150 miles to campaign for the state legislature. I told the voters the problem was not that my opponent was doing wrong things when it came to conserving wildlife, he simply wasn't doing anything at all.

Things have come a long way since then, both in Kansas and nationally. Today, there is a much better understanding of the need to conserve natural resources and the need for professionalism in the ranks of wildlife managers. But I think we should all remember progress hasn't come without a fight.

Shortly after I was elected to the Kansas legislature, I co-sponsored legislation to establish a state Duck Stamp. People thought I was crazy.

At the time, we were losing nearly 500,000 acres of wetland a year nationally, but there were few people who understood why I wanted to raise money to preserve wetland habitat.

Looking back it seems hard to believe, but it wasn't until 1987, after I became governor, that I was able to push the state Duck Stamp through the Kansas legislature.

I remember another political dogfight that erupted when, as governor, I signed an executive order establishing the Kansas Department of Wildlife and Parks by combining the old state Parks and Resources Authority with the state Fish and Game Department.

The idea was to put more emphasis on wildlife management and establish higher standards of professionalism. One of the more controversial elements of that reorganization was a requirement that the head of the department be trained in the field of natural resource management. That sounds reasonable now, but believe me, there was plenty of opposition to the idea back then.

Another example is the strong role I played in the passage of the Kansas Hunter-Education Act in 1973. It passed by only a single vote after an intense political struggle. Today, it's hard to believe a vote on what has become such a mainstay of state hunting programs would have been so close—and that was less than 20 years ago.

My point in recalling all this is to show that we should not deceive ourselves into believing that progress has ever been easy. Things we take for granted now came about through hard struggle.

And the truth we all must recognize is that progress is just as hard and probably harder now than it was back then. Many of us who should be getting widespread public support for what we are doing are, instead, being battered in the public eye.

To no small degree, it's our fault.

It's our fault because we aren't getting our message across. Too many of us continue to live in a scientific nether-world and are not taking our message to real people and conveying it in real terms they understand.

If you think that dealing with the press and the public is dirty business and you would just as soon avoid it, you need to think again. All the science in the world isn't going to help you achieve your wildlife management goals if you can't tell average citizens why they should support you.

If we are going to continue to go forward rather than stand still or retreat, we are going to have to get out there and do some dealing. We are going to have to do a better job of educating people about wildlife, wildlife habitat and why they are important.

And we can start with what is on everybody's minds nowadays—the economy.

The fact is that supporting wildlife makes good economic sense.

Supporting wildlife means jobs.

Supporting wildlife means economic growth.

Supporting wildlife means a better life for every American.

The last time we surveyed the nation's 17 million hunters, we found they spend more than $10 billion a year on equipment, transportation, food and lodging, magazine subscriptions, and any number of other expenses related to hunting.

The nation's 47 million anglers plunk down more than $28 billion a year on fishing.

And birdwatchers, photographers and other non-consumptive users spend more than $14 billion a year.

Added together, the $55 billion total equals nearly 1.5 percent of total gross national product—an enormous amount for one area of recreational activity. But when you consider that more than 160 million Americans participate in wildlife-related activities, it is not really all that surprising.

Now, let's talk specifics:

Take, for example, the sharp decline of red drum off the coast of Texas in the

1970s. The state's fishing industry was dealt a severe blow. But in the mid-1980s, the state of Texas used a combination of federal, state and private money to begin stocking 20 million hatchery fingerlings a year in the Gulf. The estimated cost—$647,000 a year.

Since then, the red drum population has recovered dramatically. Using conservative estimates, the value to the Texas economy from recreational fishing for red drum alone is now $178 million a year. That means that for every dollar spent on the program, the state reaps $275 in economic activity.

I ask: Did the public gets its money's worth?

Consider the annual elk season in Colorado. Last year some 193,000 hunters spent an average of $1,166 apiece to hunt elk. That's $225 million being pumped into the state's economy.

Furthermore, some 50,000 elk were harvested last fall. I should note that at one point earlier in this century, there were only 50,000 elk left in all of North America. It was science-based wildlife management that brought them back. That approach has meant jobs and economic growth to the people of Colorado and other states.

Let me ask again, did the public gets it's money's worth?

Of course, it's not just the hunters and fishermen generating economic activity. Wildlife-associated recreation is big business, and getting bigger every day.

Consider the annual "Wings over the Platte" festival in Grand Island, Nebraska. The festival helps draw some 100,000 people to the area in the spring to view the 400,000 sandhill cranes that roost on the Platte River for four to six weeks before flying northward. At a bare minimum, these people need to be fed and lodged, giving the local economy an incredible boost.

And when the Rocky Mountain Arsenal in Denver held its third annual "Bald Eagle Day" in January, giving the public a chance to come and see the 30–40 eagles that winter there, it was almost too successful.

So many people showed up, in fact, there was a two-hour wait to get in. Two thousand people had to be turned away. It demonstrated that people, especially in urban areas, leap at a chance to view wildlife. Again, the local economy got a boost—at a minimum, all these people had to be transported and fed.

I ask, did the public gets its money's worth for conservation efforts for the sandhill crane and the bald eagle?

Consider what the remarkable recovery of the wild turkey has done for nearly every state. Right here in the Carolinas, for example, an average turkey hunter spends anywhere from $400 to more than $700 each year on hunting. Had professional management of the wild turkey not started years ago, that money would not be spent now.

Again, I ask you, did the public gets its money's worth? I think so.

I could go on and on with examples. But the point here is that we need to fight the erroneous idea that it's always "wildlife versus jobs" or "habitat conservation versus recreation" or "the survival of animals versus the economic survival of humans."

We need to show people that conservation and management of our wildlife resources is good business, makes economic sense and stimulates economic growth. It's a winner.

But I don't want to drift too far into economics; it is only part of the message.

We need to do some educating out there about wildlife and its value, and in particular, about the need to preserve habitat.

If anyone doubts the need for education and outreach, I can tell you from experience there are more old wives' tales in wildlife management than in any other field.

Whenever I go hunting in Kansas, I'm bound to hear some local tell me the reason for the decline in prairie chickens is the pheasants chased them out. That simply isn't true—the prairie chickens were in trouble long before the pheasants came along. The real reason there are so few prairie chickens left is habitat loss—pure and simple. As agriculture spread, there was less grassland left for prairie chickens. But you have a hard time selling that fact in Kansas.

Such misconceptions have their cost. I have long been convinced that the planet is being abused more through ignorance than out of malice.

It is up to us to combat that lack of public knowledge.

We've already shown what we can do with hunter-education programs. Not only have we saved lives but we also have given many of the nation's hunters a deeper appreciation of wildlife. Now we need to educate the public as a whole.

To be sure, there are many good educational programs already out there. For example, the biologists and other staff members of the Fish and Wildlife Service's Denver office volunteer their time to teach Denver school children about everything from endangered species to wetland conservation.

The program is called "Scientists in the Schools," and is a good example of how to reach out to young people. Each school "adopts" a Fish and Wildlife employee who meets with the school principal and teachers to work out a schedule of visits, presentations and field trips.

This kind of educational program does not require that much commitment of time and resources, but has tremendous, long-lasting benefits for our mission.

Common sense should tell us this outreach to the young is more and more critical as our population becomes more urban. Many people, especially youngsters, don't have the same connection to the land and wildlife that their parents and grandparents had. We need to educate them in what is out there and why it is so important to protect it. Then, and in many cases perhaps only then, will they support what we are doing.

Before I conclude my remarks, I would like to talk about one particular project that is a good example of creative thinking in wildlife resource management, the kind of projects we should be striving for.

In recent years, Cook County in Illinois has been planning to construct a 40- to 60-acre fishing lake in an urban area northwest of Chicago on land owned by the county. Fish and Wildlife Service biologists in Chicago spotted an opportunity to alter the project slightly to create an additional 60–80 acres of wetland habitat.

So they formed a partnership with the county, the Illinois Department of Conservation, the Illinois Department of Transportation, the Fish and Wildlife Foundation, other conservation organizations and corporations to raise more than $1 million for the project. We're hoping to have it completed by the end of the year.

What do I like about this project?

First of all, it's a partnership. Everybody is getting involved from the county to conservation groups to corporations to the U.S. Fish and Wildlife Service. With fiscal pressures and demands on our resources growing, that's the way we need to operate. None of us can go it alone. We need each other.

Besides, it's smart. Nobody knows better what is going on at the state or local level than state and local officials. I believe that the closer we at the federal level are to state and local officials, the better we do.

Second, the project bridges the gap between recreational use and habitat conservation. It shows that they need not be mutually exclusive goals. We're accomplishing both in one project.

Third, the project will produce jobs and will have many indirect benefits to the local economy. And two million people in the Chicago area will see that spending money on natural resource conservation directly benefits their lifestyle, not just in the ability to go fishing, but also in the natural beauty of their city.

Lastly, the project has incredible potential for educational outreach. Thousands of school children in the Chicago area, for example, will be able to visit the site. Many will, for the first time, discover the joy of fishing, and learn about ducks, geese and other wildlife—not in a zoo, but in their natural habitat.

This is the kind of project I hope to see more of in the future. I would encourage all of you to look around for creative ways to combine conservation, recreation and education. We at the federal level will support you.

In closing, I would like to reiterate that the American spirit has a special place for our natural heritage. We as a people have decided that the beauty of our land and our natural resources is a critical part of our standard of living.

Support is out there for what we as managers of natural resources are doing, but it must be cultivated. We must be willing to go beyond our scientific roots into the world where average Americans live—we need to reach out to them in their language.

Only then will we be able to fully accomplish our mission to protect and conserve our precious natural resources for our children and grandchildren.

U.S. Coastal Habitat Degradation and Fishery Declines

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The Problem

Coastal and riverine habitat degradation are adversely affecting populations of living marine resources, production of seafood for the nation and for export, enjoyment of sport fishing, coastal communities' charm and economic basis, and much of America's very quality of life. The most significant causes of habitat degradation include: freshwater flow alteration and diversion, wetland conversion and loss, toxic chemical releases, and nutrient over-enrichment.

Coastal economies have long operated under the presumption that inshore waters could continue to be used to: accept pollutant loads from land drainage and waste discharges; accommodate dam construction, navigation channel construction and port development; provide waters for agriculture, municipal, industrial and energy production; withstand logging, agriculture and other resource consumptive uses in adjoining watersheds; and provide more land for development through sacrifice of additional wetlands and shallow water bottom habitats. Because these varied demands can adversely affect the ability of natural systems to support aquatic life and maintain their ecological integrity, competition and conflict over the fate of inshore habitats have risen with the accommodation of increasing coastal and inland development.

Maintaining clean and productive coastal waters also has a significant effect on regional and national economic activities. The decline in coastal fisheries and loss of clean water for recreation, coupled with the increased demand for these resources, has increased the outflow of dollars to import foreign seafood (U.S. imports of seafood totaled $5.2 billion in 1990) or to take foreign vacations (e.g., in the Caribbean). Degraded coastal waters can inhibit or preclude any expansion of domestic seafood export or foreign tourist industries in our coastal areas. Many U.S. coastal communities, which formerly were important family recreation areas, have been abandoned by the public, often because of water quality issues or lack of quality recreational fishing, creating economically depressed areas. Improving water quality and expanding fishery populations in these areas could be the key to returning such communities to sustainable, productive entities, creating more jobs and tax revenue.

National Opinion

National opinion surveys consistently indicate that the public is both concerned about the loss in environmental quality and willing to pay to protect the environment. Broad public concern for the integrity of riverine, estuarine and coastal systems found expression in the U.S. Congress which has recognized the problem of inshore habitat degradation. In 1989, the House Committee on Merchant Marine and Fisheries (MMFC) issued a report entitled, "Coastal Waters in Jeopardy: Reversing the Decline and Protecting America's Coastal Resources,'' which states: ''The evidence of the decline in the environmental quality of our estuaries and coastal waters is accumulating steadily. The toll of nearly four centuries of human activity becomes more and more clear as our coastal productivity declines, as habitats disappear, and as our monitoring systems reveal other problems. . . . The continuing damage to coastal resources from pollution, development, and natural forces raises serious doubts about the ability of our estuaries, bays, and near coastal waters to survive these stresses. If we fail to act and if current trends continue unabated, what is now a serious, widespread collection of problems may coalesce into a national crisis by early in the next century.''

Administration is concern for the protection of aquatic habitats and coastal water quality has been stated in many forums, including its response to the recommendations of the National Wetland Forum (CF 1988). In 1989, the President declared a national goal over the short term of ''No Net Loss'' of wetlands, with the long-term objective being a ''Net Gain.'' The Domestic Policy Council has established interagency Working Groups to implement the President's policy and achieve his goal.

Human Demographic Patterns

The coastal areas experiencing the highest levels of stress are generally those most densely populated. Growth in coastal counties is averaging four times the national average (Culliton et al. 1990). Demographic trends indicate that, by the year 2010, an estimated 54 percent of the U.S. population will live within 50 miles of the coast (Edwards 1989). If the proposed development associated with this increased human population is not adequately considered, its approval and construction will result in increased degradation of valuable coastal, estuarine and riverine environments, and further losses of living resources. Accordingly, there is a clear need for increased protection of coastal environmental quality if the nation is to (1) retain aesthetic values that draw people to the coast, (2) protect coastal habitats and ecosystems, and (3) rebuild populations of living marine resources that enrich our lives.

Living Marine Resources

Approximately 75 percent of the total U.S. commercial landings of fish and shellfish, valued at $5.5 billion in 1985 (including value added in processing), are composed of species dependent on inshore ecosystems for their reproduction, growth, migration and survival (Chambers 1992). (Such species will be referred to as estuarine-dependent, yet they include migratory species, such as salmon, which spawn far inland and mature at sea.) By region, estuarine-dependency was estimated by the author as follows: Northeast (41 percent), Chesapeake (78 percent), Southeast (94 percent), Gulf of Mexico (98 percent), Southwest (18 percent), Northwest (52 percent), Alaska (76 percent), and Pacific Islands (1 percent). Coastal, estuarine and inshore waters are also essential for sustaining what is thought to be an even larger proportion of the catch of an estimated 17 million sport anglers, who generate economic activity of over $8.2 billion per year (Prosser et al. 1988) in pursuit of the nation's most popular outdoor recreational activity.

Populations of virtually all estuarine-dependent fish species off the Atlantic, Pacific and Gulf of Mexico coasts, which have been the target of both commercial and recreational fisheries, are now at or near historic low levels of abundance. Encouragingly, within the last several years, many appear to be recovering (National Marine Fisheries Service 1991). Presumably, this is occurring as a result of the combined effects of increased fishery management, habitat protection, pollution abatement, upgrading of sewage treatment plants, improved land-use management, agricultural improvements, and related efforts by all federal, state and private organizations involved. This is the time to redouble our efforts.

Causes of Marine Fishery Losses

The major cause for most fishery population declines is widely recognized to be overfishing (including wasteful fishery practices), which is beyond the intended scope of this document. Although the cause and effect relationship is difficult to prove in many cases involving multiple threats, we now have evidence that many estuarine-dependent populations also are being affected by cumulative habitat degradation and loss. Three regional examples illustrate both the seriousness and complexity of the problem.

Between the mid-1960s and mid-1980s, Chesapeake Bay landings of migratory species declined as follows: hickory shad (down 96 percent), alewife and blueback herring (down 92 percent), striped bass (down 70 percent), and American shad (down 66 percent) (Chesapeake Bay Program 1988). The Bay's oyster harvest has declined by more than 96 percent from levels of 100 years ago (Kennedy 1991), due largely to disease, over-exploitation, predators and habitat degradation. Half of the Bay's wetlands and 40 percent of its forested areas have been destroyed. Ninety percent of its seagrass meadows, the prime nursery habitat, have been lost. More oil washes down the watershed's storm drains each year than was spilled by the *Exxon Valdez*. Fishing pressure, habitat degradation, oxygen depletion and pollution add to the stress on the Bay's fish and shellfish populations, making them more susceptible to disease, predators and natural stress in a complex, hard-to-understand manner. Some 3 million people are expected to settle here by the year 2020.

Sabine Lake, a large estuarine area between Texas and Louisiana, produced abundant shrimp harvests until navigation channels were dredged up its length from the Gulf of Mexico and at its margins; many of its bordering wetlands were levied off and filled for industrial development; and two reservoirs were constructed upstream. As a result, this valuable fishery collapsed (Sheridan et al. 1989).

Columbia River Basin salmon and steelhead, which now number approximately 2.5 million fish, have declined an estimated 75–84 percent from estimated historic levels of 10–16 million fish (from Northwest Power Planning Council 1986). Approximately 70 percent of those which remain are produced in hatcheries as mitigation for the effects of dams. More than 55 percent of the Columbia River Basin, which was accessible to salmon and steelhead, has been blocked by dams (Thompson 1976). Extensive additional losses of salmon habitat have been caused by agricultural and logging practices. Many races have now been lost (Nehlsen et al. 1991). Snake River sockeye salmon are now listed as an endangered species. Protective measures required by listing will have major effects on the region's economy and way of life.

Freshwater Flow Alterations

Alteration of flows by means of dams or diversions, as well as by land-use practices (e.g., logging), can be the single most important factor influencing the health of many riverine and estuarine ecosystems. Upstream dams and flow diversions can eliminate populations of species dependent on such riverine systems for reproduction. For example, more than 90 percent of California's salmon spawning habitat has been lost due to extensive federal and state water projects throughout the Central Valley. Spawning has been eliminated by water projects on the San Joaquin River system, which drains the southern half of the Central Valley, and drastically reduced on the Sacramento River system, which drains its northern half (Kier 1992). Sacramento River winter run Chinook salmon have declined 99 percent in only the past 20 years (Fisher personal communication), and they are now listed as a "threatened" species. Most other races of salmon, steelhead, striped bass and other migratory species have declined dramatically throughout California (Moyle and Morford 1991). The survival of both striped bass and salmon has been shown to be directly correlated with freshwater flows experienced by the young (Rozengurt 1992).

Reducing flows to estuaries also decreases their productivity. In 1981, a national symposium on the effects of freshwater diversions concluded that, "based on world-wide experience, no more than 25–30 percent of the historical river flow to an estuary can be diverted without disastrous ecological consequences to the receiving estuary" (Clark and Benson 1981). Many U.S. estuaries have been affected. In Chesapeake Bay, tributary flows have been reduced by about 40 percent, whereas Texas estuaries have lost nearly 90 percent of their historic inflows due to upstream diversions. By 1980, more than 62 percent of the annual historic freshwater inflows to San Francisco Bay had been diverted. Planned diversions will increase the annual loss of freshwater to 71 percent by the year 2000 (Nichols et al. 1986). About 85 percent of the water diverted is used for agricultural irrigation, much of it to grow rice and cattle pasturage, both high consumption uses, in a desert environment.

Wetland Losses

Riverine, estuarine and coastal wetlands provide many valuable functions. They reduce flooding, provide protection from storm damage and erosion, maintain water quality, and provide critical habitat for fish and wildlife. However, wetlands, which are among the most productive habitats anywhere, are disappearing rapidly. Over half of the nation's original coastal wetlands have been lost (Tiner 1984, Dahl 1990). Many that remain are being degraded by a variety of causes, including both natural and human-induced. Ironically, among the most important wetlands to marine fish are those located at the headwaters of tributaries to coastal and estuarine areas. These forested wetlands are rapidly being lost to agriculture and municipal development, often through nationwide general permits (without resource agency review), eliminating prime nursery areas for many important species. Losses of coastal marsh have been most extensive in California, Texas, Louisiana, Florida and the Northeast (Dahl and Johnson 1991). Large areas of submerged aquatic vegetation have disappeared in many coastal areas, including Chesapeake Bay, Florida Bay and Tampa Bay.

The Southeast has more than 300 estuaries, containing an estimated 17.2 million acres of coastal marsh. Commercial fishery landings along the Southeast Atlantic and Gulf of Mexico coasts have decreased by 42 percent since 1982. At the same time, extensive regional losses of coastal habitats, resulting from thousands of federal and private activities, have been documented (Lindall and Thayer 1982, Mager 1990). For example, Louisiana's coastal wetland losses between 1974 and 1983 are estimated to be more than 30 square miles per year (Britsch and Kemp 1990). Galveston Bay lost an estimated 95 percent of its former seagrass meadows and 16 percent of its emergent marsh between 1959 and 1979 (Sheridan et al. 1989). By 1981, coastal development had eliminated an estimated 81 percent of Tampa Bay's extensive seagrass (Lewis et al. 1985), as well as 44 percent of its emergent marsh and mangrove habitats (Lewis and Lewis 1978).

Elsewhere, the situation is equally serious. Chesapeake Bay has now lost 90 percent of its submerged aquatic vegetation, with 65 percent of this occurring between 1971 and 1979 (Stevenson et al. 1979). Marsh loss around the Bay now totals 50 percent. More than 91 percent of California's coastal wetlands have been lost (Zedler personal communication). San Francisco Bay wetlands have declined by 85 percent (Dedrick 1989).

Contaminants

Toxic substances affect reproductive success, growth, and survival of fish and shellfish. They also cause lesions and disease. Cause and effect relationships between liver contaminants and lesions have been established by the National Marine Fisheries Service (NMFS) in both the laboratory (Schiewe et al. 1991) and field (Landahl et al. 1990). There is extensive evidence of contamination by toxic and long-lived materials, such as PCBs, DDT, metals, petroleum derivatives, and large numbers of chlorinated hydrocarbon compounds in sediments and benthic organisms in urbanized inshore areas (Varanasi et al. 1989, Zdanowicz et al. 1986, Hanson and Evans 1991, National Status and Trends Program, 1991), as well as downstream of major agricultural areas of the U.S. (Pait et al. 1989, Scott et al. 1990).

A high percentage of bottom-dwelling fish from the more degraded coastal sites show contaminant-induced health problems. Liver cancer, the most extreme lesion, has been found in 20 percent of English sole collected from two of the most contaminated areas of Puget Sound (Myers et al. 1987) and in 15 percent of winter flounder samples from similarly affected areas of Boston Harbor (Murchelano and Wolke 1991). Liver cancer and pre-cancerous liver lesions have been found in 33 percent and 93 percent, respectively, of the killfish collected from a highly contaminated site in the Elizabeth River, Virginia (Vogelbein et al. 1990). Moreover, virtually all of the adult grey trout collected from heavily polluted areas of that river have contaminant-induced eye cataracts (Huggett et al. 1987). Grey trout feed by sight. The Smithsonian Institution's Registry of Tumors (Harshbarger and Clark 1990) has documented that fish with serious contaminant-related abnormalities generally are found in those areas of the U.S. most affected by coastal pollution from about 1,900 major industrial and municipal dischargers (Office of Technology Assessment 1987).

Nutrient Over-enrichment, Pathogens and Marine Biotoxins

The addition of excessive nutrients from agricultural runoff, atmospheric deposition and sewage treatment threaten the health of coastal, estuarine and riverine systems.

Nutrient over-enrichment can stimulate nuisance and toxic growths of algae and deplete oxygen when these growths decay, frequently causing kills of fish and other resources. Nutrient over-enrichment is believed to have been responsible for the loss of Chesapeake Bay's native seagrasses, a primary habitat for many juvenile fish and shellfish. However, federal grants for upgrading municipal sewage treatment systems have improved water quality in many areas, compared to pre-Clean Water Act conditions.

Humans can contract a variety of diseases of bacterial and viral origin, such as gastroenteritis and hepatitis, if they become infected with pathogens associated with human sewage, through ingestion during water-based activities or through the consumption of contaminated fish or shellfish. Shellfish bed closures exist coast-wide. On any given day, one-third of the nation's 16 million acres of shellfish waters are closed. In the Gulf of Mexico, 74 percent are restricted (U.S. Department of Commerce 1985), due, in part, to water quality degradation caused by inadequate septic systems, sewage discharges and urban runoff.

Shellfish growing waters also may be affected by blooms of several species of diatoms and dinoflagellates that can cause a variety of human illnesses. For example, some of Maine's productive shellfish growing waters have been closed during most years since 1958 because of the presence of dinoflagellate blooms responsible for paralytic shellfish poisoning (NOAA 1991).

National Marine and Fisheries Service (NMFS) Role in Decision Making

The mandate of NMFS is to act as the federal steward for the nation's living marine resources (including both anadromous and inland commercial fishery resources and their supporting food webs). NMFS has the authority to participate in all federal and many state decisions on proposed development which may affect such resources. Secondly, it conducts research on the importance of habitats and the effects of human activities on living marine resources. Its stewardship authority stems from the Fish and Wildlife Act and Reorganization Plan No. 4, which created NOAA and NMFS by removing the Bureau of Commercial Fisheries (NMFS' predecessor) from the U.S. Fish and Wildlife Service (FWS). The Magnuson Fishery Conservation and Management Act provides broad authority for NMFS to conserve and manage fisheries cooperatively, in a complex arrangement with eight Regional Fishery Management Councils, within the U.S. Exclusive Economic Zone. The Marine Protection, Research, and Sanctuaries Act authorizes a comprehensive program of research on the long-range effects of pollution, overfishing and human-induced changes of ocean ecosystems.

Federal agencies, which intend to construct or authorize projects (through permit, lease or license), programs or policies affecting "waters of the U.S.," including their adjacent wetlands, are required by the Fish and Wildlife Coordination Act to consult first with the federal (NMFS and FWS) and state fish and game agencies on the effects of these activities. Fish and wildlife resources are to be "given equal consideration with other project purposes." NMFS is authorized to represent the interests of living marine resources in all federal agency decision-making potentially affecting them. This involves about 10,000 proposed projects and as much as 300,000 acres of habitat each year. Projects can range from small (a quarter-acre wetland fill) to very large (construction of a major dam), and can be decided in a matter of weeks or as much as decades from initiation of planning to construction, all of which involves NMFS' oversight. The primary limitation to NMFS' effectiveness in the decision-making arena stems from the very large number of development projects which are proposed, and the small number of professional staff (less than two per coastal state, on average) to conduct a thorough assessment of the effects of each.

Insufficient appreciation for environmental values and resource agencies' advice has contributed to the continuing deterioration of coastal environmental quality described above. However, without a legislatively authorized "veto" (which the Environmental Protection Agency and Canada's Department of Fisheries and Oceans both have), NMFS and FWS can only make recommendations to the federal or state "action" agency making the final decision (except in narrowly defined situations involving hydropower activities).

Conclusions

Demographic trends may have serious implications for the nation's living marine resources. This is particularly true for the Southeast Atlantic and Gulf of Mexico coasts where recreational and commercial species are almost completely dependent on estuarine and coastal habitats for their survival. Habitat degradation and loss can have long-term adverse effects on living marine resources, in addition to those losses attributable to commercial and recreational harvesting practices. The importance of living marine resources' habitat must be elevated in priority, both in decisions on projects by responsible federal and state agencies and in the level of support given to agencies responsible for stewardship of such resources. Only then will we be able to significantly reduce those losses which we are now beginning to see as a result of past development practices and policies. Providing a scientific understanding of the effects of such development in federal and state decision-making processes is the responsibility of NMFS' National Habitat Protection Program—the federal steward of the nation's living marine resources and their habitats.

References

Britsch, L. D. and E. B. Kemp, III. 1990. Land loss rates: Mississippi River deltaic plain. Tech. Rept. GL–90–2. U.S. Army Corps of Engineers, Waterways Exp. Sta., Vicksburg, MS. 25 pp.

Chambers, J. R. 1992. Coastal degradation and fish population losses. *In*: R.H. Stroud, ed., Stemming the tide of coastal fish habitat loss. Marine Recreational Fisheries Symposium 14:45–51. National Coalition for Marine Conservation, Savannah, GA.

Chesapeake Bay Program. 1988. Draft strategy for removing impediments to migratory fishes in the Chesapeake Bay watershed. Agreement Commitment Report. Chesapeake Bay Program. Environmental Protection Agency. Annapolis, MD.

Clark, J. and N. G. Benson. 1981. Symposium Summary and Recommendations. *In*: R. D. Cross and D. L. Williams, eds., Proceedings of the National Symposium on Freshwater Inflow to Estuaries, Vol. II:523–528. U.S. Dept. Interior, Washington, D.C.

Conservation Foundation. 1988. Protecting America's wetlands: An action agenda. The final report of the National Wetlands Policy Forum. Conservation Foundation, Washington, D.C. 69 pp.

Culliton, T. J., M. A. Warren, T. R. Goodspeed, D. G. Remer, C. M. Blackwell, and J. J. McDonough. 1990. 50 years of population change along the nation's coasts. Nat. Oceanic and Atmospheric Admin., Rockville, MD.

Dahl, T. E. 1990. Wetland losses in the United States 1780s to 1980s. U.S. Fish and Wild. Serv., Dept. Interior, Washington, D.C. 20 pp.

Dahl, T. E. and C. E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970's to mid-1980's. U.S. Fish and Wildl. Serv., Washington, D.C. 28 pp.
Dedrick, K. G. 1989. San Francisco Bay tidal marshland acreages: Recent and historic values. *In*: Coastal Zone '89. Proc. 6th Symp. on Coastal and Ocean Mgmt. 1:383–398. Amer. Soc. Civ. Eng., New York, NY.
Edwards, S. F. 1989. Estimates of future demographic changes in the coastal zone. Coastal Manage. 17:229–240.
Gronlund, W. D., S-L. Chan, B. B. McCain, R. C. Clark, Jr., M. S. Myers, P. D. Plesha, J. E. Stein, D. W. Brown, J. T. Landahl, M. M. Krahn, W. L. Reichert, and U. Varanasi. 1991. Multidisciplinary assessment of pollution in Long Island Sound. Estuaries 14:299–305.
Hanson, P. J. and D. W. Evans. 1991. Metal contaminant assessment for the Southeast Atlantic and Gulf of Mexico coasts: Results of the National Benthic Surveillance Project over the first four years 1984–1987. NOAA Tech. Memo. NMFS–SEFC–284. 22 pp.
Harshbarger, J. C. and J. B. Clark. 1990. Epizootiology of neoplasms in bony fish of North America. Sci. Total Env. 94:1–32.
Huggett, R. J., M. E. Bender, and M. A. Unger. 1987. Polynuclear aromatic hydrocarbons in the Elizabeth River, Virginia. Pages 327–341 *in*: K. L. Dickson, A. W. Maki, and W. Brungs, eds., Fate and effects of sediment bound chemicals in aquatic systems. Soc. of Environmental Toxicology and Chemistry, Special Publication, Vol. 2. Pergamon Press, Elmsford, NY.
Kennedy, V. S. 1991. Eastern oyster. Pages 3.1–3.20 *in*: S. L. Funderburk, et al., eds., Habitat requirements for Chesapeake Bay living resources. Second edition. Living Resources Subcommittee, Chesapeake Bay Program and Chesapeake Research Consortium, Inc. Solomons, MD.
Kier, W. M. 1992. In the nick of time—reforming the Federal Central Valley Project to save the San Francisco Bay Estuary. *In*: R. H. Stroud, ed., Stemming the tide of coastal fish habitat loss. Marine Recreational Fisheries Symposium 14:211–216. Nat. Coal. Marine Conserv., Savannah, GA.
Landahl, J. T., B. B. McCain, M. S. Myers, L. D. Rhodes, and D. W. Brown. 1990. Consistent associations between hepatic lesions (including neoplasms) in English sole (*Parophrys vetulus*) and polycyclic aromatic hydrocarbons in bottom sediment. Environ. Health Perspect. 89:195–203.
Lewis, R. R. and C. S. Lewis. 1978. Colonial bird use and plant succession on dredged material islands in Florida. Vol II. Patterns of vegetation succession. Environmental Effects Laboratory, U.S. Army Corps of Engineers, Waterways Exp. Sta., Vicksburg, MS. 196 pp.
Lewis, R. R., M. J. Durako, M. D. Moffler, and R. C. Phillips. 1985. Seagrass meadows of Tampa Bay: A review. Pages 210–246 *in*: S. F. Treat, J. L. Simon, R. R. Lewis III and R. L. Whitman, Jr., eds., Proc. Tampa Bay Area Scientific Information Symp. (May 1982). Burgess Publishing Co., Inc., Minneapolis, MN.
Lindall, W. N. and G. W. Thayer. 1982. Quantification of National Marine Fisheries Service habitat conservation efforts in the southeast region of the U.S. Marine Fish. Rev. 44(12):18–22.
Mager, A., Jr. 1990. National Marine Fishery Service habitat conservation efforts related to federal regulatory programs in the southeastern United States. NOAA Tech. Mem., NMFS–SEFC–260. 12 pp.
Committee on Merchant Marine and Fisheries. 1989. Coastal waters in jeopardy: Reversing the decline and protecting America's coastal resources. U.S. Congress, Washington, D.C.
Moyle, P. B. and M. D. Morford. 1991. Salmon, steelhead, smelt, and sturgeon in California: Endangered resources. A report for the Amer. Fish. Soc., Pacific Coast Fed. of Fishermen's Associations, United Anglers of California, Trout Unlimited of California, California Trout, and the Bay Institute. 19 pp.
Murchelano, R. A. and R. E. Wolke. 1991. Neoplasms and non-neoplastic liver lesions in winter flounder, *Pseudopleuronectes americanus*, from Boston Harbor, Massachusetts. Environ. Health Perspect. 90:17–26.
Myers, M. S., L. D. Rhodes, and B. B. McCain. 1987. Pathologic anatomy and patterns of occurrence of hepatic neoplasms, putative preneoplastic lesions, and other idiopathic hepatic conditions in English sole (*Parophrys vetulus*) from Puget Sound, Washington, U.S.A. J. Nat. Cancer Institute 78(2):333–363.
National Marine Fisheries Service. 1991. Our Living Oceans, the First Annual Report on the Status of U.S. Living Marine Resources. NOAA Tech. Mem., NMFS–SPO–1. NOAA, Nat. Mar. Fish. Serv., Silver Spring, MD. 123 pp.

National Oceanic and Atmospheric Administration (NOAA). 1991. The 1990 national shellfish register of classified estuarine waters. NOAA, Washington, D.C. 100 pp.
National Status and Trends Program. 1991. Second summary of data on chemical contaminants in sediments from the National Status and Trends Program. National Status and Trends Program, NOAA, Rockville, MD. NOAA Tech. Memo. NOS OMA-59. 29 pp.
Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries, Amer. Fish. Soc. 16(2):4–11.
Nichols, F. H., J. E. Cloern, S. N. Luoma, and D. H. Peterson. 1986. 1986. The modification of an estuary. Science. 231:567–573.
Northwest Power Planning Council. 1986. Council staff compilation of information on salmon and steelhead losses in the Columbia River Basin. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, OR.
Office of Technology Assessment. 1987. Wastes in Marine Environments, OTA–O–334 Office of Technology Assessment, U.S. Congress. U.S. Govt. Print. Off., Washington, D.C. 313 pp.
Pait, A. S., D. Farrow, J. A. Lowe, and P. A. Pacheco. 1989. Agricultural pesticide use in estuarine drainage areas. *In*: Coastal Zone '89. Proceedings of the 6th Symp. on Coastal and Ocean Manage. Amer. Soc. Civ. Eng., New York, NY. 1:452–466.
Prosser, N. S., G. C. Radonski, and D. B. Rockland. 1988. A review of state agencies' capabilities to manage marine recreational fisheries. 118th Ann. Mtg., Amer. Fish. Soc., Toronto, Canada. Sport Fishing Institute, Washington, D.C. 11 pp.
Rozengurt, M. A., M. J. Herz, and M. Josselyn. 1987. The impact of water diversions on the river-delta-estuary-sea ecosystems of San Francisco Bay and the Sea of Azov. Pages 35–62 *in*: D. L. Goodrich, ed., San Francisco Bay: Issues, resources, status, and management. NOAA Estuary-of-the-Month Seminar Series No. 6 NOAA, Washington, D.C.
Schiewe, M. H., D. D. Weber, M. S. Myers, F. J. Jacques, W. L. Reichert, C. A. Krone, D. C. Malins, B. B. McCain, S-L. Chan, and U. Varanasi. 1991. Induction of foci of cellular alteration and other hepatic lesions in English sole (*Parophrys vetulus*) exposed to an extract of an urban marine sediment. Can. J. Fish. Aquat. Sci. 48:1,750–1,760.
Scott, G. I., D. W. Moore, M. H. Fulton, T. W. Hampton, J. M. Marcus, G. T. Chandler, K. L. Jackson, D. Baughman, A. H. Trim, C. J. Louden, and E. R. Patterson. 1990. Agricultural insecticide runoff effects on estuarine organisms: correlating laboratory and field toxicity testing with ecotoxicological biomonitoring. Volumes I and II. Final Rept. U.S. EPA, Gulf Breeze Environ. Res. Lab., Gulf Breeze, FL.
Sheridan, P. F., R. D. Slack, S. M. Ray, L. W. McKinney, E. F. Klima, and T. R. Calnan. 1989. Biological components of Galveston Bay. Pages 23–51 *in*: Galveston Bay: Issues, Resources, Status, and Management. NOAA Estuary-of-the-Month Seminar. NOAA, Washington, D.C.
Stevenson, J. C., N. Confer, and C. B. Pieper. 1979. The decline of submerged aquatic plants in Chesapeake Bay. FWS/OBS–79/24. U.S. Fish and Wild. Serv., Washington, D.C. 12 pp.
Thompson, K. 1976. Columbia Basin fisheries, past, present, and future. Columbia River Fisheries Project Report. Pacific Northwest Reg. Commiss. Vancouver, WA. 41 pp.
Tiner, R. W., Jr. 1984. Wetlands of the United States: Current status and recent trends. U.S. Fish and Wild. Serv., Washington, D.C.
U.S. Department of Commerce. 1985. 1985 national shellfish register of classified estuarine waters, NOAA and Dept. of Health and Human Services, Food and Drug Admin. Washington, D.C. 19 pp.
Varanasi, U., S-L. Chan, B. B. McCain, J. T. Landahl, M. H. Schiewe, R. C. Clark, D. W. Brown, M. S. Myers, M. M. Krah, W. D. Gronlund, and W. D. McLeod. 1989. National benthic surveillance project: Pacific Coast. Part II, Technical Presentation of the Results for Cycles III (1984–86). NOAA Tech. Memo. NMFS NWC–170. 204 pp.
Vogelbein, W. K., J. W. Fournie, P. A. Van Veld, and R. J. Huggett. 1990. Hepatic neoplasms in the mummichog *Fundulus heteroclitus* from a creosote-contaminated site. Cancer Res. 50:5,978–5,986.
Zdanowicz, V. S., D. F. Gadbois, and M. W. Newman. 1986. Levels of organic contaminants in sediments and fish tissues and prevalences of pathological disorders in winter flounder from estuaries of the Northeast United States, 1984. Pages 578–585 *in*: Oceans '86 Conference Record, Vol. 2. Marine Technology Soc. and IEEE Ocean Engineering Soc., Washington, D.C.

The Challenge of Biological Diversity: Professional Responsibilities, Capabilities and Realities

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Background

Loss of biological diversity is the subject of growing concern in the United States and elsewhere (Wilson 1988, Tobin 1990, Ryan 1992). The objective of this newly focused interest is to avert the accelerated rate of species extinctions predicted in coming decades (Soulé and Wilcox 1980, Ehrlich and Ehrlich 1981, Soulé 1986, Wilson and Peter 1988, Ehrlich and Wilson 1991). Study groups and task forces have been called to chart strategies for the preservation of biological diversity (National Science Broad 1989, Keystone Policy Dialogue 1991). National legislation and an international convention on biological diversity are being drafted (U.S. Congress 1991, United Nations Environment Programme 1990). A National Commission on Biodiveristy also has been proposed to develop a National Biodiversity Policy for the United States (Reid 1992).

At the same time, governmental agencies, professional societies and conservation organizations have been reexamining programs and missions to determine their appropriate roles in the conservation of biological diversity (Salwasser 1991, Lubchenco et al. 1991, Chadwick 1990). Scientific symposia and meetings on the subject have been convened (Miller et al. 1985, Wilson and Peter 1988, Solbrig 1991). Textbooks and compilations of conference papers are doubtlessly being rushed into print. Opaque reports and naive assertions abound in the mass media. Most such discussions are not helpful and some are harmful because they assume a limited or even parochial understanding of biological diversity.

This overview and special sessions on the topic are attempts to develop an understanding of biological diversity for colleagues in the wildlife profession. These papers are meant to help those managers and administrators who must answer difficult questions of what should be done to conserve biological diversity. In the first part of this paper, we explain some of the challenges of biological diversity and how they relate to real-world actions. In the concluding section, we relate these challenges to professional responsibilities, capabilities, and realities.

The long preoccupation of the wildlife profession with harvested and endangered species has tended to distract attention from the conservation of the vast majority of wild organisms that are neither directly exploited nor endangered. In the United States, approximately 90 percent of the nearly 2,200 species of vertebrates are neither hunted nor listed as threatened or endangered; less than 2 percent of North American migratory bird species are listed under the Endangered Species Act (Banks et al. 1987).

The fact that only a small number of species are hunted or endangered has had a little-recognized consequence. This orientation has encouraged the profession to think of biological conservation on a species-by-species basis rather than to view the biota of an area as a collective, dynamic, adaptive and interacting community. As a result, an incredible amount of attention has been focused on a few ubiquitous abundant species, e.g., the mallard (*Anas platyrhynchos*), and nearly equal attention on species often so troubled that individual organisms must be saved one at a time, e.g., the California condor (*Gymnogyps californianus*).

Recently, concerns for biological diversity confronted the conservation community with a broader mission. One proposal is the conservation of biological diversity as a formal mission of federal agencies and the extension of this mission to federal lands, such as represented by the National Wildlife Refuge System (Keystone Policy Dialogue 1991). If the wildlife profession accepts the mission of conserving biological diversity, agreement on some basic premises is necessary. What, exactly, is biological diversity? What about it is desirable? How does one conserve it?

What is Biological Diversity?

A major problem in addressing issues relating to biological diversity is the lack of a precise definition. A complex subject that embraces "the full variety of life and it processes" tends to defy definition (U.S. Fish and Wildlife Service 1992). Contemporary definitions of biological diversity (and the current buzzword, biodiversity) are of little help (Table 1). One, for example, describes biodiversity as "the full range of variety and variability within and among living organisms and the ecological complexes in which they occur, including ecosystem or community diversity, species diversity, and genetic diversity" (U.S. Congress 1991). This definition is so inclusive that differing interpretations of what really constitutes "true biodiversity" is no surprise. Depending on interpretation, one might conclude that we are now doing little or nothing to conserve biological diversity, whereas another could conclude with equal justification that nearly everything we are doing serves the conservation of biological diversity. Both viewpoints have their advocates and antagonists.

Understanding of biological diversity is still in the developmental stage. The concept of biological diversity is more or less intuitively perceived by most biologists, but like most intuitions, it is difficult to communicate the concept convincingly enough to achieve universal agreement. Part of the problem derives from a recognition that diversity represents an abstract, qualitative idea, rather than a tangible, quantitative thing. Moreover, overall diversity is progressively greater at higher levels and in more complex systems. Lacking consensus on an operational definition of biological diversity, we may be able to understand it better if we consider the different kinds of biological diversity at different levels.

Genetic Diversity

This level of biological diversity concerns the spectrum of genetic material in different organisms. Each individual possesses a unique combination of genes. Ge-

Table 1. Definitions of biological diversity or biodiversity.

Definition	Source
"All life forms, with their manifold variety, that occur on earth."	Miller et al. (1985)
"The variety and variability among living organisms and the ecological complexes in which they occur."	Office of Technology and Assessment (1987)
"The variety of life and its processes."	U.S. Forest Service (1990)
"The variety of life and its processes in a given area."	Salwasser (1990)
"The degree of nature's variety, including both the number and frequency of ecosystems, species, and genes in a given assemblage."	McNeely et al. (1990)
"The variety of life and its processes. It includes the variety of living organisms, the genetic differences among them, and the communities and ecosystems in which they occur."	Keystone Policy Dialogue (1991)
"The variety of and variability among living organisms and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."	United Nations Environment Programme (1991)
"The full range of variety and variability within and among living organisms and the ecological complexes in which they occur; encompasses ecosystems or community diversity, species diversity and genetic diversity."	U.S. Congress (1991)
"The variety of life in an area, including genetics composition, richness of species, distribution and abundance of ecosystems and communities, and the processes by which all living things interact with one another and with their environment."	U.S. Fish and Wildlife Service (1992)
"The total variety of life on earth."	Ryan (1992)

netic diversity can also apply to species, races, or populations, in which a greater variety of genetic material may result in increased variation among individuals and increased potential for variation between individuals and increased potential for variation and adaptation within populations. At the species level, we know that low genetic diversity may result in harmful expression of recessive traits, leading to poor reproductive success or maladaptation and lower survival of adults. On the whole, organisms seem to devote far more energy to the prevention of outbreeding than to the reinvigoration of genetic material, and too much genetic diversity can destroy the integrity of taxa. Therefore, we have a good idea of how much genetic diversity is too little and an equal notion of what is too much, but almost no knowledge of levels that are optimal. Populations need to be large enough to provide sufficient genetic diversity to allow species to survive. Genetic diversity also can be considered from a global perspective. The genetic material of each species, race, population or even each individual organism contributes to the pool of living material that underlies life on the planet. Like documents in an archive, each should be valued for its information content. Emphasis may be on variety and uniqueness or on the relative magnitude of the contribution of the individuals to the larger system.

Species Diversity

This level is what most wildlife biologists call to mind when thinking of biological diversity. Species diversity consists of the interaction between the variety and relative abundance of flora and fauna occurring together in biological communities. Diversity is lowest when few species inhabit and dominate an area, and highest when many species occur together and dominance by one or few is minimal. Although several accepted ways of measuring species diversity exist, most sooner or later prove counterintuitive. Measuring species diversity is difficult, especially in animal communities, and species richness, i.e., the total number of species, is often used as a crude approximation. Most species of plants and animals have relatively small populations within a specific habitat. Much of our knowledge is based on what should exist in a given area from generalized or historic species distributions rather than on contemporary field data on species occurrence and abundance.

Ecosystem Diversity

Biological diversity at this level encompasses populations of plants and animals in biotic communities and their complex interactions with the abiotic environment. The types of communities occurring naturally are determined not only by the availability and ability of organisms to populate them, but also by climate, geology, soils, and the dynamic changes in these factors, as well as human activities, occurring through time. Communities of plants and animals are always changing in response to environmental factors and stresses. Ecosystems are often described by combinations of all four determining factors; for example, one might recognize a mature tropical lowland rain forest ecosystem. In biological terms, the form of the dominant vegetation is most often used to characterize ecosystems, but there are exceptions, such as coral reefs. One or more ecosystems form landscapes. Diversity at landscape levels influences the ability of organisms to move among communities and to respond to climate changes over time. In terms of conservation, the goal of maintaining landscape, ecosystem and community diversity is to perpetuate the variety of organisms that would occur naturally over large areas, for example, by preventing the wholesale conversion of wetlands to agriculture or the extreme fragmentation of forest. The great majority of species broadly overlap different ecosystems, and only in rare instances are species restricted to a single ecosystem type. Consequently, conservation of ecosystem diversity may converse species diversity, but the converse is not necessarily true.

How Can We Manage for Biological Diversity?

When we manage for biological diversity, we need to consider the dimensions of area, from niches to landscapes, and time, from days to decades. Management strategies for conservation of biological diversity also must consider the problems of scale, quality and values inherent in this concept. To illustrate some of the issues related to these problems, we offer the following hypothetical examples.

The Problem of Scale

Suppose we had a 100-hectare forested island and wished to increase its biological diversity. The simplest way to increase diversity might be to clear the forest from one-half the land and maintain the cleared area as a grassland. If the island were close to a mainland, plants and animals adapted to grasslands could invade the managed area and overall biological diversity on the 100 hectares would increase significantly. Diversity might also be enhanced by establishing a broad transition zone suitable for plants and animals adapted to such situations rather than having an abrupt edge between grassland and forest. Scooping out a depression and developing a 10-hectare pond would permit the invasion of aquatic species and further increase the biological diversity on our island. Other manipulations could, likewise, add more biological diversity.

But our efforts to increase biological diversity would not have taken us wholly forward. Our grassland probably would not support as diverse biota as our forest, so we would have replaced 50 hectares of a more diverse with a less diverse system. And, although our artificial pond would have added species, it would probably be much less diverse than comparable natural wetlands. As a result of limiting the sizes of our managed habitats, we would have reduced the biological diversity within them. Our forest, now less than 50 hectares, might no longer support forest-dwelling animals that require more area in which to survive. Similarly, our grassland, pond, and edge habitats might so small that species potentially occurring in such habitats could not survive there. So we did something more complex than we first realized. We increased overall biological diversity on our island reserve, but we did it at the expense of degrading our original, relatively diverse forest and we replaced much of it with three comparatively impoverished systems.

Perhaps we could do better with a 1,000-hectare island. Then we could have 300 hectares each devoted to forest, grassland and a broad transition zone, and we could create a 100-hectare lake suitable for a variety of aquatic and wetland species. Biological diversity would be increased substantially on the larger island compared to the smaller island. But we probably still could not accommodate large animals; our grassland surely would not support large herds of bison (*Bison bison*) and our forest would not support a pack of wolves (*Canis lupus*). In fact, we know there may not be enough grassland in North America to support large herds of wild bison, and very few areas of forest that can accommodate packs of wolves.

On the continental and global scales, biological diversity is increased by the accretion of low-diversity systems as it is in our island examples. Deserts and arctic tundra tend to be relatively low in biological diversity, but the uniquely adapted biota that inhabit them contribute importantly to global biological diversity. Even a few animals in zoos could be seen as contributing to global biological diversity, although few wildlife professionals would agree that zoological collections are a reasonable strategy for conserving biological diversity.

We need to take the effect of scale into account if we are to understand fully the concept of biological diversity. Otherwise, our management efforts may be at cross purposes with those of others or even with our own, because increasing diversity on a smaller scale may decrease it on a larger one. We will do different sorts of things if we are trying to conserve the biological diversity of the United States than if we are trying to increase biological diversity on a wildlife refuge.

What is the appropriate scale at which to examine biological diversity? The question cannot be answered unequivocally because vast differences in scale have biological as well as human dimensions. Among vertebrates, differences range from a green salamander (*Aneides aeneus*), whose world consists of a square meter, to a white-tailed deer (*Odocoilieus virginianus*) confined by nature to a few kilometers, to a bobolink (*Dolichonyx oryzivorus*) annually covering untold thousands of square kilometers. Scale must be defined before meaningful goals for biological diversity can be established and appropriate management strategies can be implemented.

The Problem of Quality

Another complication concerns some of our ideas of quality and the role of endemism. Let us focus on an area of desert that, owing to its harsh conditions, has a low diversity of species. Plants and animals occurring there are adapted to life in arid regions, and some may be found nowhere else (Knopf 1992). Suppose a city is built in this desert and the planting of trees, irrigation of lawns, construction of reservoirs, and similar activities make the city little different as a habitat than most other cities. The composition of the plant and animal species, particularly highly mobile ones, may come to resemble that of other cities and suburbs much more than it does the biota of the surrounding desert. The invasion of urban species may increase the biological diversity of the area, but the diversity added is of very low quality. Unique desert species may be replaced, or at least supplemented by dandelions (*Taraxacum officinale*), starlings (*Sturnus vulgaris*) and houseflies (*Musca domestica*). On the island that we are trying to manage for biological diversity, we could add caged birds and a tropical greenhouse as a quick-and-dirty way to increase biological diversity, but neither would result in an increase in the quality of the biological system.

There is an aspect of quality in genetic diversity that is little recognized except by biologists. It involves the magnitude of differences, or the "biological distance" represented by organisms. A so-called living fossil, such as an American crocodile (*Crocodylus acutus*), might be seen as making a higher quality contribution to global biological diversity than would a local variant of the wide-ranging June beetle (*Phyllophaga fervida*). There are few species of surviving crocodilians, no close relatives, and the planet is far better supplied with beetle genes than with crocodilian genes. A recent paper by Mares (1992) expanded on the rationale for this idea, essentially arguing that taxa contribute to global biological diversity only by the increments that their genotypes differ from one another.

The Problem of Values

Related to the more or less intellectual consideration of quality is the much less objective matter of values. Certain types of biological diversity are valued by people more than others. Birds tend to be valued more than insects. Waterfowl are valued more than blackbirds. Butterflies are valued more than fleas. These values not only get us into a non-scientific, judgmental realm, but they also are related to two ways in which our scientific activities may be biased. First, when we endeavor to measure biological diversity, we discover that we cannot measure everything. Consequently, what we choose to measure may influence the outcome of our measurements. Conditions producing the greatest diversity of lizards may differ greatly from conditions that result in the greatest diversity of fungi and, if we measure one or the other, we may come back with far different ideas of what kinds of systems are high in biological diversity. Second, if we use existing data bases, we are much more likely to find information on highly valued biota than on less valued groups. It would almost certainly be far easier to get a list of bird species occurring in a particular park than to get a list of all insects occurring there, even though the contribution of insects to overall biological diversity would dwarf that of the birds (Table 2). So, even before we make the choice of what kind of biological diversity is worth conserving, we are faced with the problem that our supposedly objective scientific information is likely to be value loaded.

What Kind of Biological Diversity Do We Want?

Critical decisions must be made before we begin managing for biological diversity, and these decisions are related to the problems of scale, quality and values. Ultimately they also have to do with perceptions. The scientists who first alerted us to the problems of loss of biological diversity primarily were thinking on a global scale, had a strong sense of quality in favoring natural assemblages of species over managed systems and broadly valued all existing genetic material, for both its contribution to overall diversity and its evolutionary potential (Soulé and Wilcox 1980, Ehrlich and Ehrlich 1981).

At the other end of the scale, much of the public may have a far narrower view of biological diversity, with attendant perceptions and misperceptions of implied goals and objectives. People think locally rather than globally, with concerns about decreasing opportunities to observe song birds in the Washington, D.C. area, for example, probably outweighing global concerns. The concept of quality is likely to relate more directly to the nature of a viewing experience than to whether the assemblages observed represent natural biotic communities. Finally, there may be a strong intrusion of societal values that spring from the range of individual preferences; birds may be regarded as simply more important than worms but an exotic tree may be as acceptable as a native tree, i.e., any tree will do!

The typical resource manager is expected to be both a scientist and a public servant, and it is in the realm of resource management that conflicts resulting from different perceptions must be reconciled. Should we develop a wetland, thereby increasing the diversity of wetland species in an area that has none? Should we do it at the expense of a bottomland forest which itself contributes to biological diversity seen on a broader scale? Should we try to find formulas that will best serve biological

Table 2. Biological diversity of Plummers Island, Maryland.[a]

Flora	Species	Fauna	Species
Blue-green algae	32	Rotifers	200
Fungi	221	Mollusks	50
Lichens	91	Spiders	250
Mosses	70	Insects	3,679
Hepatics	18	Fishes	57
Ferns and scouring rushes	18	Amphibians	21
Trees, shrubs and vines	103	Reptiles	30
Other flowering plants	673	Birds	203
Total	1,216	Mammals	42
		Total	4,532

[a]Source: Washington Biologists' Field Club (1984).

diversity on the greatest number of possible scales? Or should we restrict our management activities to protecting remnants of undisturbed biotic assemblages? Should we seek to maintain existing biological diversity, attempt to restore that presumed to have existed before human influences, or to enhance it where possible?

Several factors relate to these questions and may influence how we answer them.

- We cannot ignore and, to a large extent, cannot undo the influence of human development on wildlife habitat. Fifty percent of the wetlands formerly occurring in the conterminous United States have been destroyed—in California, 90 percent have been lost (Dahl 1990). There is no foreseeable chance that all will be reclaimed. Losses continue, and maintaining even the present diminished diversity of wetland biota requires active measures. New wetlands must be created, if only to replace those still being lost to development, and existing wetlands must be actively managed to maintain their ability to support populations dependant on them. Moreover, mature forests have been cut, have regenerated, and are being cut again. Change has been a constant, at least since the time that retreating glaciers were followed closely by invasions of pre-Columbian peoples. Resolving to re-create the lost biological diversity of some past period would result in insurmountable difficulty, uncertain goals, prohibitive costs and little prospect for success; not to mention a complete lack of professional agreement on any of these points.
- People have caused the most recent threats to biological diversity and people will be essential for its preservation. The movement to restore depleted wildlife populations that began early in this century was fueled largely by the interests of hunters and anglers and directed primarily toward species that were formerly abundant and exploitable for sport. In the course of conserving these harvested species, many additional species were benefitted and much bilogical diversity was protected or enhanced. Likewise, recovery programs for endangered species can be viewed as desperate attempts to preserve national and global biological diversity that exists because of strong public support for the idea that species should not be permitted to disappear from the planet. To effectively stem the disappearance of species and to preserve biological diversity in the broader sense, it will be necessary to mobilize public support for conservation of the great majority of species that are neither abundant nor rare and precarious. An important part of the support necessary to conserve biological diversity on all levels will come from people who learn to appreciate biological diversity by experiencing it on a local level.
- The roles of federal, state and other agencies and the lands they manage for biotic resources need to be understood and, where necessary, clarified. Management of lands to promote conservation of local, regional, national, or global biological diversity involves an array of strategies and actions, and if goals are discordant or poorly understood, unintended consequences may result. Among federal lands, the national wildlife refuges constitute the only system managed primarily for wild animals, mostly continental populations of migratory birds and endangered species. Management of this system can be seen as being directed toward maintaining biological diversity at the national or higher levels. Lands devoted to endangered species preservation help to conserve genetic diversity, and those established for migratory bird conservation help to maintain the diversity of these animals on a continental basis, despite significant loss an deg-

radation of habitats elsewhere. The U.S. Fish and Wildlife Service has been criticized for managing refuges for single species, albeit the Mississippi sandhill crane (*Grus candensis pulla*), salt marsh harvest mouse (*Reithodontomys naviventris*), elk (*Cervus elaphus*), bison (*Bison, bison*) or the canvasback (*Aythya valisineria*). Such criticisms often ignore the essential role of preserving genetic and species diversity on the national level and have imbedded in them advocacy by special interest of a more restricted vision of biological diversity.

- An integrated, multispecies model, would be required to optimize conservation of biological diversity at all levels. Application of such an important resource management tool could evaluate effects of the following scenarios. Preserving a 5-hectare patch of mature forest that may enhance biological diversity on a local level but might not significantly influence it on regional or higher levels. Creating a 5-hectare addition to an existing wetland system might decrease biological diversity locally, but contribute significantly to regional or continental diversity. Presently, no such general model exists for wildlife habitat relations (Van Horne and Wiens, 1991), but even if it did, insufficient data on species biology and ecology exist to ensure reliable simulations or useful results at any level. Current understanding of ecosystem structure and function does not permit a critical evaluation of possible consequences of such experiments, and well-designed applied research, together with enhanced data management capabilities, is essential to identify optimal strategies.

Professional Responsibilities, Capabilities and Realities

Responsibilities

Biological diversity is an emergent concept, with different levels and kinds of diversity appearing as biological systems become progressively more complex. Depending on geographic scales, ideas of quality and differences in values, reasonable people may develop concepts of biological diversity that differ greatly from one another. A practical consequence of these differences is that the goal of conserving biological diversity can potentially be invoked to support or to condemn nearly any management action. This derives from current policy on biological diversity based on three differing and competing goals: managing harvests, saving endangered species and preserving habitats (Westman 1990). What is needed is a common goal for biological diversity around which resource managers can rally, as advocated by Salwasser (1990).

In the absence of policy consensus, Berryman (1991) implored wildlife professionals to apply a century of experience in applied ecology and to lead the current groundswell of enthusiasm, not follow it. He further stated that we have a responsibility to view proposals with hard-nosed realism and to act upon a vision of biological diversity that has the fullest scientific support. Among other things, this means that actions to conserve biological diversity should be taken only when scientific information indicates that such actions will not only have the desired proximal effects, but will not produce ultimal undesired effects. Also, the temptation to invoke conservation of biological diversity in attempts to promote various parochial causes must be overcome in order to maintain professional credibility in an arena rife with political advocacy in all quarters. Some biologists in North America have enthusiastically jumped on the ''biodiversity bandwagon'' and have parlayed concerns generated about the loss of biological diversity in the tropics into media coverage, budget initiatives, and new programs. Mares (1992) warned that the public could perceive biologists as alarmists if mass extinctions fail to occur or if species disappear at rates below what has been suggested.

Wildlife biologists and other applied ecologists have been criticized for regularly using vague, abstract words; we have a history of sloppy terminology according to Murphy and Noon (1991). Biodiversity is such a term. We must avoid neoscientific buzzwords like ''biodiversity'' and pseudoscientific jargon like ''sustainable'' that create an illusion of understanding and capability far beyond that supported by reliable scientific knowledge. To many, ''biodiversity'' promises more than can be delivered.

''Biodiversity'' may be a useful word for politics or publicity, but this term has little meaning for the resource manager or wildlife biologist. Communication is not helped by inclusive or vague terminology and jargon. Precise communication is critical to establish and maintain professional and scientific credibility. Wildlife biologists can maintain credibility by saying what they mean and meaning what they say. ''Conservation of biological diversity'' must not be used as camouflage for ''business as usual'' or as a way to either placate protectionist interests or entice new constituents.

Likewise the word ''conservation'' has taken an entirely new connotation among some conservation biologists. Traditional definitions of conservation encompassed the concept of wise use; some contemporary uses of conservation in programs and titles imply everything but use of any kind, i.e., ''preservation.'' But the reality is that human activities and developments are part of the landscape and people continue to use resources, produces wastes, and otherwise displace biota. Wildlife managers also continue to manipulate habitats for game and nongame species in accordance with agency missions (Franklin 1991).

We also must ask ourselves if whether embracing the concept of biological diversity truly represents a broader concern for the biota or merely provides a means to make traditional programs and activities more acceptable to the changing values of a more enlightened and sophisticated public. Have you ever thought that our profession might be accused of invoking dire concerns about biodiversity when the real motive was to enhance public image, to increase appropriation of funds, to improve competitiveness for grants, to disguise program objectives, to appear contemporary, or to be politically correct? Wildlife programs should stand on their own merits and not need to be wrapped in the cloak of biodiversity to gain public support. Slick brochures and chic words may be useful in promoting a biopolitical movement, but these public relations props do not make a conservation program for biological diversity. As Berryman (1991) observed, ''there is a vast difference between the slogan, bumper sticker phrase, and the reality of implementation.''

Capabilities

Ryan (1992) stated that biological diversity was complex beyond understanding and valuable beyond measure. From a global perspective, Wolf (1987) observed that ''the extent of our ignorance of biological diversity is imposing.'' Because scientific and technical knowledge concerning biological diversity is surprisingly deficient (Miller et al. 1985), wildlife professionals face sobering responsibilities to develop credible ecosystem management programs to contribute realistically to biological diversity. Whereas previous management regimes employed by conservation agencies and organizations have preserved much biological diversity, this result was achieved largely by default rather than design.

Management designed to benefit biological diversity on all possible levels should be the ultimate goal, but present capabilities permit management for no more than one level at a time, often with inevitable or unintended effects at other levels. Furthermore, management for biological diversity may not be feasible on every acre of public land. Salwasser (1990) observed that "the complexity of life is beyond comprehension, certainly beyond the technical capabilities of scientists and resource planners to address in much detail, even at the relatively small scale of a national forest or national park." Therefore, managers should be mindful that biological diversity on local scales may be adversely disrupted as a result of well-intended restoration management. Land acquisition and habitat management policies need to be critically evaluated for their effects on biological diversity at all levels. Furthermore, research is needed to develop a set of principles based on scientific knowledge in order to provide the necessary context in which prediction of consequences of proposed actions is possible.

A conservation strategy to preserve representative, sustainable ecosystems (provisionally defined as those that do not require active management), like sustainable development or sustainable agriculture, are laudable goals, but the prospects for achieving long-term sustainability are unknown. Sustainable ecosystems possessing diverse biological representation require different habitat management strategies than are currently employed on many wildlife management areas (Franklin 1991). Precious little research, baseline data or field experience is available to guide us. Moreover, the goal of sustainability may, in some cases, be obviated by practically irrevocable changes, e.g., wetland ecosystems in California's Central Valley can probably never be sustainable as long as water remains a scarce, valued and regulated commodity.

Wildlife biologists should view biological diversity as a useful measure of environmental health. The diversity of organisms affects the ability of ecosystems to withstand perturbations either natural, such as fire or weather, or human, such as harvest or pollution, without losing long-term productivity or stability. If the number of species and abundance of each species is high, a disturbance or harvest can be tolerated by the ecosystem. Simplified ecosystems often are less productive and less resistent to natural or human-induced stresses. Consequently, mankind's use or pollution of resources reduces the structure, function and resilience of ecosystems. Gain or loss of biological diversity provides a measure of society's success or failure to maintain sustainable systems.

Perceptions of human impacts on biological diversity have expanded from identifying local, visible abuses, e.g., water pollution, wetland drainage, forest fragmentation, to recognizing subtle, enigmatic global influences, e.g., acid precipitation, ozone depletion, climate change. Unfortunately, recognition of human-induced environmental stresses, as measured by political action, lags far behind the process of awareness. In terms of conserving biological diversity and testing political will, preventing the drainage of prairie wetlands or limiting the harvest of old-growth forests represent challenges at one level; filling the hole in the ozone layer or dewarming the planet constitute larger challenges.

Realities

While the global crisis in biological diversity is primarily in the tropics where rapid human population growth and escalating economic development are wrecking havoc with biota inhabiting tropical rain forests, wildlife biologists in North America face different opportunities and challenges. In reality, wildlife is but a small part of biological diversity in terms of biomass, numbers of species, numbers of individuals and many other measures. If wildlife professionals accept the larger goal of conservation of biological diversity, they must first ask themselves whether it can be accomplished, to what degree and at what cost? Furthermore, what are the implications of the new responsibilities for existing programs and agency resources?

The complexity of biological diversity is such that no single organization or entity has more than a partial role in its conservation. The roles of federal agencies are primarily at the national level, and this dictates that certain of their activities favor the maintenance of national or global biological diversity over diversity on the local or regional levels, with the result that areas or projects will continue to be devoted to single species. On the other hand, management for local or regional biological diversity is an appropriate role for state and local organizations, and is to be encouraged to the extent that it does not have significant negative effects on broader geographic scales. Maintenance of local biological diversity can have significant positive effects, including the development of appreciation for biota among citizens. Nevertheless, long-term maintenance of biological diversity may require a management strategy that places regional objectives over local concerns (Noss 1983).

Although environmental education will certainly have an important role to play, biotic conservation must become more than public information campaigns to increase awareness or promote action. Professional efforts to conserve biological diversity should also go beyond promoting revamped agendas of agencies, hiring coordinators, collecting new specimens for museums, placing endangered animals in zoos, mapping discontinuities in public lands, and other activities in the name of biodiversity. Management for biological diversity is not manipulation of habitats to favor both nongame and game species and it will not be achieved by preserving unique examples of ecosystems.

Effective programs for biological diversity require significantly enhanced and redirected efforts as well as substantial increases in personnel representing a new spectrum of disciplines in addition to those traditionally employed by natural resources agencies. University curricula in biology need innovative overhaul to better prepare and train students for new challenges and responsibilities. Over the past two decades, the cellular and molecular focus of most academic biology programs has substantially weakened basic ''ology'' disciplines that will be required to mount effective efforts for biological diversity in the future. A new cardre of professionals must be recruited and oriented to initiate and integrate new transdisciplinary management and interdisciplinary research programs for conservation of biological diversity into ongoing agency missions.

Conservation of biological diversity requires a new management paradigm. To preserve biological diversity, inordinate current emphasis has been placed on large and attractive species that elicit public support (Tobin 1990). Credible programs for biological diversity must go beyond favored species of charismatic birds and mammals that are rare or sporting to encompass plants, insects, invertebrates, bacteria, algae, fungi, and the entire range of other life forms. Such programs present substantial scientific and operational challenges because the taxonomy and systematics of many of these life forms are poorly understood, and the distribution and abundance of most species are poorly documented. Futhermore, some key ecological assumptions are no longer consistent with current scientific understanding (Westman 1990).

Clearly, hard work lies ahead. Most disturbing to wildlife managers and biodiversity activists are the realities that baseline data are insufficient to fill critical informational gaps largely because inventories of flora and fauna are nonexistent or obsolete, investigations of species habitat requirements are lacking or incomplete, studies of biological and ecological limiting factors are short-term or flawed, and the identities and relationships of many species are unknown or controversial. And the requisite information and understanding are not forthcoming serendipitously by applying old data to a new hypotheses. Theoretical issues on biological diversity have been explored in detail (Solbrig 1991, Lubchenco et al. 1991, Soulé and Kohm 1989), but little research has been proposed that relates to immediate management needs.

Although there is widespread belief that ecosystem approaches to conservation of biological diversity are more cost-effective than programs designed to save one species at a time, there is a profound lack of scientific information to support and guide such efforts. Lack of knowledge also hampers enlightened management to maintain or enhance the biological diversity and ecological integrity of those natural areas already preserved or protected. Lacking adequate knowledge on all species of flora and fauna comprising biological diversity, the concept of "keystone" species has come into vogue. "Keystone" is another buzzword for the old concept of indicator or dominant species. The idea is that certain species in an ecosystem are representative or determinative of the whole biotic assemblage. Although biologists have long been enamored with this concept, where is the scientific validation? Critical thinkers may question the logic of this concept, and a paucity of scientific information is available to support it.

Pimm and Gittleman (1992) concluded that "we clearly know too little about where the diversity is, why it is there, and what it will become." We do know that biological diversity is not stable. Populations of plants and animals are always changing. Any environmental stress, whether natural or human caused, will differently affect various species. The reality is that some loss of biological diversity is inevitable.

Despite increased awareness and commitment by public resource agencies and private conservation organizations, initiatives to conserve or manage biological diversity are highly fragmented and lack focus. Consequently, such programs are ineffectively implemented and results are inefficiently achieved. Much management, albeit well intended and sincerely motivated, is being done on an ad hoc, trial-and-error basis with less than optimum or even desirable results. The upshot is that more harm than good may often have been done in the name of conservation and biological diversity. Precious resources of organizations and agencies may also have been wasted. Without sound data and critical analysis, conservation strategies may be seriously misguided and conceptually flawed (Mares 1992).

Looming over these daunting gaps in our knowledge of biological diversity are some serious questions. Thoughtful professionals ask how much do we need to know to base credible management programs while others question whether we will ever know enough or we will have time enough. How far do we need to go in order to fill these informational gaps? How far can we go? How far should we go? How far are we willing to go? Do we need to know everything before we do anything? When will we know enough? How much will it cost? Our sense is that professional consensus on these issues is prerequisite to credible, meaningful progress toward conservation of biological diversity—a view that is also shared by others (Soulé 1991, Erwin 1991, Ehrlich and Wilson 1991). The spectre of the national economy and budget deficit as well as the reality of competing social priorities and political agendas may force us to make some difficult choices and to face some hard decisions.

During recent years, proposals have been advanced unsuccessfully to conduct a National Biological Inventory which would delineate areas of high biological diversity and to establish National Biodiversity Reserves designed to preserve diverse flora and fauna and to perpetuate ecological and evolutionary processes. Creation of a National Biodiversity Trust Fund organized to provide grants and incentives to private individuals and organizations as well as to state and local governments for protection of areas high in biological diversity has also failed to garner a groundswell of support.

Therefore, what recommendations can we offer to natural resource managers who share the sense of urgency that we must act now or forever lose the opportunity to conserve the last remnants of our biotic heritage? There are not many answers, but we propose the following;

1. First, do no harm. Do not knowingly take actions that will be inimical to any native organisms without fully considering the consequences. As Leopold (1953) instructed, the first rule of intelligent tinkering is to save all the parts.
2. Adopt a holistic viewpoint. Look at all native plants and animals under your management as parts of larger biotic communities for which you are responsible (Franklin 1991). The best way to preserve biological diversity is to maintain native species in natural landscapes.
3. Be open to a wide range of management options and ask lots of questions. When considering how management actions might affect biological diversity, use the best biological judgement to evaluate schemes and programs advanced by others to conserve biological diversity. Weigh the possible risks of doing the wrong thing against the consequences of doing nothing.
4. Be conservative in management policy and practice. Avoid getting caught in irreversible processes with irretrievable consequences. As Soulé (1986) warned, "dithering and endangering are often linked."
5. Invest in additional research to advance knowledge and understanding (Soulé and Kohm 1989, Lubchenco et al. 1991, Solbrig 1991). Public policy in the conservation of biological diversity should rest firmly on sound scientific information even though temptations and pressures to act now rather than prudently wait may be overwhelming. Research administrators recognize that it is a matter of pay us now or pay us later, and deferred costs are likely to be much greater.

Wildlife biologists should heartily welcome new supporters, investigators, and practitioners to the cause of biological conservation. Unfortunately, many newcomers to the field are preoccupied with symptoms rather than root causes. Although increased interest and effort will be essential in the next few years, hard fought efforts to conserve biological diversity may be too little and too late in the face of overwhelming increases in human population and escalating pressures for economic development and resource exploitation nearly everywhere around the world. Habitats are being degraded and destroyed and species are declining and disappearing on an unprecedented scale (Ryan, 1992). To ignore the problem of human population, whether for political, ideological or theological reasons, establishes a policy that inevitably leads to habitat loss and species depletion according to Morowitz (1991), who warned that "no discussion of managing global habitats and preserving species can avoid the population imperative." Professionals in natural resources fields have a responsibility to bring the pervasive reality of this spectre to public attention at every opportunity.

Conclusion

Conservation of biological diversity is a pressing problem of global dimensions and concern. The concept of biological diversity is poorly understood and represents a challenge to natural resource professionals. There is no clear and universally accepted definition or goal for biological diversity, although the principle has been recognized and valued by conservationists for decades. Biological diversity is an inclusive, abstract term that has an emergent quality. As currently used, it refers to the variety of life that becomes progressively more complex at genetic, species and ecosystem levels, and at local, regional, national, continental and global scales. Professionals in natural resource management should be cognizant of the extent and limits of scientific and technical information when shaping public policy on biological diversity. They should be careful to maintain professional integrity and credibility concerning the nature, potential, scope, impact and limitation of projects and programs in order to foster public understanding and enhance political support. The wildlife profession has important responsibilities and capabilities to contribute toward the conservation of biological diversity, but no single organization or agency has more that a partial role. Conservation of biological diversity is a transdisciplinary, interdisciplinary endeavor that will require innovative approaches and partnerships in professional cooperation and scientific coordination.

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References

Banks, R. C., R. W. McDiarmid,and A. L. Gardner. 1987. Checklist of vertebrates of the United States, and U.S. Territories, and Canada. U.S. Fish and Wildl. Serv., Washington, D.C. Resources Publication 166. 79 pp.

Berryman, J. H. 1991. Biodiversity: . . . and a word of caution. Presentation 45th Ann. Meet. Southeastern Assoc. Fish and Wildl. Agencies, 5 pp.

Chadwick, D. H. 1990. The biodiversity challenge. Defenders of Wildlife. Washington, D.C. 16 pp.

Dahl, T. E. 1990. Wetland losses in the United States 1780's to 1980's. U.S. Fish and Wildl. Serv. Washington, D.C. 21 pp.

Ehrlich, P. R. and A. H. Ehrlich. 1981. Extinction: The causes and consequences of the disappearance of species. Random House. NY. 305 pp.

Ehrlich, P. R. and E. O. Wilson. 1991. Biodiversity studies: Science and policy. Science 253:758–762.
Erwin, T. L. 1991. An evolutionary basis for conservation strategies. Science 253:750–752.
Franklin, T. M. 1991. Biological diversity and wildlife management. Presented at the Spring Meeting of the Maryland-Delaware Chapter of The Wildlife Society. 3 pp.
Keystone Policy Dialogue. 1991. Final consensus report of the Keystone Policy Dialogue on biological diversity on federal lands. The Keystone Center, Keystone, CO. 96 pp.
Knopf, F. L. 1992. Faunal mixing, faunal integrity, and the biological template. Trans. N. Am. Wildl. and Nat. Resour. Conf. 57:current volume.
Leopold, A. 1953. Round river. Oxford University Press. New York, NY. 173 pp.
Lubchenco, J., A. M. Olson, L. B. Brubaker, S. R. Carpenter, M. M. Holland, S. P. Hubbell, S. A. Levin, J. A. MacMahon, P. A. Matson, J. M. Melillo, H. A. Mooney, C. H. Peterson, H. R. Pullium, L. A. Real, P. J. Regal, P. G. Risser. 1991. The sustainable biosphere initiative: An ecological agenda. Ecology 72(2):371–412.
Mares, M. A. 1992. Neotropical mammals and the myth of Amazonian biodiversity. Science 255:976–979.
McNeely, J. A., K. R. Miller, W. V. Reid, R. A. Mittermeier, and T. B. Werner. 1990. Conserving the world's biological diversity. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland; World Resources Institute, Conservation International, World Wildlife Fund-US, and the World Bank, Washington, D.C. 193 pp.
Miller, K. R., J. Furtado, C. DeKlemm, J. A. McNeely, N. Myers, M. E. Soulé, and M. C. Trexler. 1985. Issues on the preservation of biological diversity. Pages 337–362 *in* R. Repetto, ed., The global possible: Resources, development, and the new century. Yale Univ. Press, New Haven, CT. 538 pp.
Murphy, D. D. and B. D. Noon. 1991. Coping with uncertainty in wildlife biology. J. Wildl. Manage. 55(4):773–782.
Morowitz, H. T. 1991. Balancing species preservation and economic considerations. Science 253:752–754.
National Science Board. 1989. Loss of biological diversity: A global crisis requiring international solutions. Committee on International Science's Task Force on Global Biodiversity. National Science Foundation. Washington, D.C. 19 pp.
Noss, R. R. 1983. A regional landscape approach to maintain diversity. BioScience 33:700–706.
Office of Technology Assessment. 1987. Technologies to maintain biological diversity. OTA–F–330. U.S. Govt. Print. Off., Washington, D.C. 334 pp.
Pimm, S. L. and J. L. Gittleman. 1992. Biological diversity: Where is it? Science 255:940.
Reid, W. V. 1992. The United States needs a national biological diversity policy. World Resources Institute Issues and Ideas. Washington, D.C. 12 pp.
Ryan, J. C. 1992. Conserving biological diversity. Pages 9–26 *in* L. R. Brown, C. Flavin, S. Postel, and L. Starke, eds., State of the World 1992. W. W. Norton and Company. New York, NY. 256 pp.
Salwasser, H. 1990. Conserving biological diversity: A perspective on scope and approaches. Forest Ecology and Management 35(1):75–90.
———. 1991. New perspectives for sustaining diversity in the U.S. national forest ecosystems. Conservation Biology 5(4):567–569.
Solbrig, O., ed. 1991. From genes to ecosystems: A research agenda for biodiversity. International Union of Biological Sciences. Paris, France. 124 pp.
Soulé, M. E. 1986. Conservation biology and the real world. Pages 1–12 in M. E. Soulé, ed., Conservation biology—the science of scarcity and diversity. Sinauer Associates, Sunderland, MA. 584 pp.
———. 1991. Conservation: Tactics for a constant crisis. Science 253:744–750.
Soulé, M. E. and M. A. Kohm. 1989. Research priorities for conservation biology. Island Press, Washington, D.C. 97 pp.
Soulé, M. E. and B. A. Wilcox, eds. 1980. Conservation biology—an evolutionary-ecological perspective. Sinauer Associates, Sunderland, MA. 395 pp.
Tobin, R. 1990. The expendable future: U.S. politics and the protection of biological diversity. Duke University Press, Durham, NC. 325 pp.
United Nations Environment Programme. 1991. Fourth revised draft convention on biological diversity. 48 pp.

U.S. Congress. 1991. National Biological Diversity Conservation and Environmental Research Act (S. 58/H.R. 585). 102nd Congress, 1st Session.
U.S. Fish and Wildlife Service. 1992. Conserving biological diversity—a strategy to maintain biodiversity and ecosystem function in the Northeast. Region 5. Newton Corner, MA. 6 pp.
U.S. Forest Service. 1990. Conserving our heritage—America's biodiversity. U.S. For. Serv., Washington, D.C. 12 pp.
Van Horne, B. and J. A. Wiens. 1991. Forest bird habitat suitability models and the development of general habitat models. U.S. Fish and Wildl. Serv., Fish and Wildl. Res. 8. 31 pp.
Washington Biologists' Field Club. 1984. The members and history of the Washington Biologists' Field Club. Rev. ed. Washington Biologists' Field Club. Washington, D.C. 80 pp.
Westman, W. E. 1990. Managing for biodiversity. BioScience 40(1):26–33.
Wilson, E. O. 1988. The current state of biological diversity. Pages 3–18 *in* E. O. Wilson and F. M. Peter, eds., Biodiversity. National Academy Press, Washington, D.C. 521 pp.
Wilson, E. O. and F. M. Peter, eds. 1988. Biodiversity. National Academy Press. Washington, D.C. 521 pp.
Wolf, E. C. 1987. On the rink of extinction: Conserving the diversity of life. Worldwatch Paper 78:1–53.

A Bridge to the Future: The Fish and Wildlife Diversity Funding Initiative

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On February 3, 1936, the inaugural North American Wildlife Conference was held in Washington, D.C. Interest in wildlife at that time centered almost exclusively on game species and the conference poster, now a collectors item, pictured thirty-four species of mammals and birds, and two species of fish. Only one was not sought after for its sporting qualities by hunters and anglers and that one, the Coopers Hawk, undoubtedly was the target of shooters who, with the support of early game managers, played out their role in the control of predators.

Who can deny the excitement of the hunt that brought many of us to the profession of wildlife management and continues to make its mark in the minds of men and women who enjoy the shooting sports. And similarly, who would belittle the importance of the art of flyfishing or the tug of a bullhead on a cane pole that peeked the interest and instilled the fever of fisheries management among aquatic biologists.

These same interests and the desire for greater game abundance caused hunters and anglers to organize and work with managers to secure the financial resources necessary for increasing knowledge through research that would guide scientific fish and game management through the years. It was the strength of this constituent base that led to passage of the Pittman-Robertson (P-R) Act in 1938 and enabled implementation of the Federal Aid in Wildlife Restoration Program. It was similar support that led Congress, in 1950, to establish the Dingell-Johnson (D-J) Act that provided funding for the Federal Aid in Sport Fish Restoration Program. These two Acts gave recognition to the importance of cooperative management of fish and game, and through creation of excise taxes on equipment used by the constituents, provided hundreds of millions of dollars to the states for research and management projects.

The sporting constituency has continued to advocate the user pays concept over the years with its support for Duck Stamp fees, enhanced revenues for the Pittman-Robertson program and expanded fisheries management funded from revenues provided by the Wallop-Breaux Act of 1984. In the states as well, hunters and anglers have supported licensing of their sport and the periodic increases in fees necessary to maintain and enhance management programs.

The evolution of environmental awareness that intensified in the 1960s gave recognition to the active but less visible interest in fish and wildlife that is shared by a large and growing segment of our society.

Dr. C. H. D. Clarke, in his 1970 report to a special New York Commission on the Future of the Adirondacks, described wildlife as the "hallmark of quality." Much earlier, Aldo Leopold was instrumental in advancing the philosophy of the land ethic by sharing his perceptions of the relationships between the land and its wild inhabitants. John James Audubon and Roger Torry Peterson made nature real through their artistic talents, and John Burrows and Henry Thoreau have thrilled millions with their writings about the natural world.

Recent surveys have revealed that a larger and larger portion of the American public enjoy the out of doors and identify fish and wildlife as a primary allure. People gravitate to the wild animal exhibits at fairs and visit zoological parks in increasing numbers. They have supported an environmental movement that has used, as a standard-bearer, the health of fish and wildlife as indicators of environmental quality.

Yet, even with this overwhelming interest that people have shown in wild creatures and their habitats, it was necessary for Congress to enact the Endangered Species Act in an atmosphere of crisis to identify, protect and restore those species of fish and wildlife whose numbers and occurrence indicate a risk of extinction. Rachael Carson's *Silent Spring* awoke people to the realities of the consequences of pollution and environmental degradation, and conference after conference called for a return to the conservation ethic and appealed to government to take an active role in protecting and fostering responsible management of our natural resources.

The time was right in the late 1970s for Congress, with tenacious urging from a broad base of conservation and environmental groups, to address the need for comprehensive planning for fish and wildlife resources that would recognize the importance of all species. Then, in 1980, Congress enacted the Fish and Wildlife Conservation Act, also known as the Nongame Act, that encouraged the states to conserve nongame species through preparation of comprehensive plans and implement those plans through the projects that have been identified. This measure was designed to close the funding gap between management of game and conservation of non-game species. Unfortunately, the executive branch has not requested appropriations and the program has never been funded.

In the meantime, the states have been active in their search for new sources of revenue to support non-game programs. Thirty-six states, following Colorado's 1978 initiative, have generated $30 million through voluntary contributions using tax check-offs. These revenues have been declining recently as a result of increased numbers of completing check-off options and the troubled economy. Only one state, Missouri, has been successful in gaining sustaining tax-base support for comprehensive resource management.

The 1980 Act included a provision that directed the U.S. Fish and Wildlife Service to "conduct a comprehensive study to determine the most equitable and effective mechanism for funding state conservation plans and actions—and report to the Committee on Merchant Marine and Fisheries of the House of Representatives the results of such study." The study was completed on schedule and advanced without recommendation.

In 1986, and again in 1990, the Fish and Wildlife Conservation Act of 1980 was reauthorized and, despite the strong urging of organizations like the International Association of Fish and Wildlife Agencies, Wildlife Management Institute, Defenders of Wildlife and National Wildlife Federation, there continues to be no funding provided.

The frustrations from more than ten years of unsuccessful efforts to secure non-game funding peaked in 1990 when the International Association of Fish and Wildlife Agencies established, as one of its top priorities, the establishment of an adequate and sustaining source of money for non-game fish and wildlife projects. Then, President William Molini appointed an ad hoc committee charged with assessing the non-game funding situation and devising a strategy for achieving federal legislation to fund the Fish and Wildlife Conservation Act. He expressed a desire to create a system that would parallel the Pittman-Robertson and Dingle-Johnson/Wallop-Breaux programs.

The Committee presented a series of recommendations to the International Association, at its business meeting in September 1990, that included the following:

1. *The Committee recommended* that programs funded with new sources of revenue be based on ecosystem management recognizing that species management, habitat management, uses and natural occurrences and monitoring form a matrix that constitutes the dynamics designed to achieve diversity objectives. Further, that program thrusts include a combination of preventive and corrective actions that will lead to adaptive management of fish and wildlife resources at early stages of ecosystem development.
2. *The Committee recommended* that the proposed program orient to major plant communities and that the principal thrust be toward those communities with a concern for plants as they are associated with management of fish and wildlife resources. It was further recommended that in recognition of the interest in fish and wildlife expressed by people participating in peripheral recreational activities, such as hiking and backpacking, the funding base for programs supported by revenues remain broad, but that expenditures be focused on fish and wildlife resource needs.
3. *The Committee recommended* that the Fish and Wildlife Conservation Act be used as the vehicle to establish necessary legislative authorization and specific funding mechanisms and that the 1992 reauthorization be targeted as the effective date for accomplishment.

The International Association approved the recommendations and directed its staff to implement them on a priority basis on, what is now called, the Fish and Wildlife Diversity Initiative.

As a first step, a Steering Committee was created to give guidance and direction to the initiative. Conservation organizations were invited to become members that represent a broad base of fish and wildlife interests, while retaining a small group that could efficiently formulate proposals and advance them within the constituencies and with Congress. The Committee includes the Wildlife Society, American Fisheries Society, Defenders of Wildlife, Wildlife Management Institute, National Wildlife Federation and World Wildlife Fund. The International Association provides the chairperson. The Committee had its initial meeting on December 3, 1990.

As the organizational structure for developing the Fish and Wildlife Diversity Funding Initiative was involving, an inventory of priority needs for managing non-game species was well underway. Each state was asked to identify priority programs that would be undertaken if new funding were to be made available. These needs were organized to clearly demonstrate the diverse nature of projects that would be funded and characterize the programs that would be implemented to enhance non-game resources. This information was presented in a publication, complete with illustrations, entitled "A Bridge to the Future."

Making provision for participation by conservation organizations and others interested in and concerned about the future of fish and wildlife resources also is being considered by the Steering Committee. It is recognized that dedicating a source of revenue to non-game programs will be no easy task during these difficult economic times. It is intended, then, to demonstrate the depth and breadth of public support by forming a coalition that will be the active advocacy for Congressional action. Invitations to join the coalition will be mailed in the near future, and expressions of interest tò join the coalition will be welcome.

The International Association of Fish and Wildlife Agencies is creating a national network for information exchange to sensitize people throughout the country to the need for non-game fish and wildlife funding. Each state agency is being asked to be the conduit through which information on the Initiative will flow and the catalyst to energize state organizations and individuals into action when the proposal is presented for Congressional action. A groundswell of support will be necessary if the funding initiative is to receive priority attention.

During the past year, the Steering Committee has been developing the elements of the legislative proposal. It has been agreed that the fish and wildlife diversity program will have two principal thrusts:

1. actions necessary to ensure sustainable fish and wildlife populations, and thereby prevent scarcity and risk of species loss; and
2. projects that will lead to continuing and enhanced enjoyment of the resource by the public.

To carry out the program, sources of revenue need to be adequate and sustaining. The needs inventory clearly indicates a minimum of $100 million will be required to put the program on a sound fiscal footing. Sources of revenue also must be reliably available each year so that program continuity can be assured. To accomplish this, the precedent set by the Pittman-Robertson and Dingell-Johnson Acts will be used as a model. It also is desirable that the administrative structure, already established in the Pittman-Robertson Act, be used for implementation of the new program. Fish and Wildlife Diversity program funds must remain discreet from existing wildlife restoration revenues, however, to assure maintenance of the desired program focus.

It is being proposed that the diversity program be cost shared at 75 percent federal and 25 percent state, as the P-R and D-J programs are. The qualifying formula for distribution of funds, however, would change, using human population and land area in each state as the factors for determining the individual state share. As in the previous acts, no state would receive less than 0.5 percent nor more than 5 percent of the total funds available.

In a departure from P-R and D-J, up to 10 percent of the total revenues would be authorized as administrative funds. Priority on use of these funds would be given to:

1. projects for monitoring and predicting national and continental trends in fish and wildlife occurrence and abundance;
2. meeting special fish and wildlife habitat and management needs in specific states and territories to prevent populations from becoming threatened or endangered; and
3. regional projects that involve or effect groups of states.

Preference would be given to providing at least 2 percent of the total annual administrative funds for projects in categories 1 and 2 above, to the extent that significant needs are identified. Similarly, emphasis in state programs would favor meeting critical needs identified in the national context. This orientation is proposed in recognition of the importance of extensive analysis and management efforts that will be required in the conservation of neotropical birds. It also is proposed that the U.S. Fish and Wildlife Service be required, after consultation with the states and territories, to periodically report to Congress and the public on the status of fish and wildlife populations.

Criteria for use of diversity funds by the states also would be developed. They would include programs to:

1. enhance enjoyment of all fish and wildlife species;
2. preserve and enhance fish and wildlife habitats;
3. implement comprehensive fish and wildlife planning;
4. survey and monitor the status of species;
5. support fish and wildlife education and interpretation;
6. restore rare, threatened or endangered species; and
7. undertake conservation law enforcement using up to 10 percent of a state's allocation where enforcement activities include protection of fish and wildlife values consistent with the purposes of the Act.

The principal goal of the Act would be to provide funding for management of fish and wildlife species and their habitats where taking of animals and reducing them to personal possession or commercialization is not the primary purpose. Recognition would be given, however, to the acceptability of secondary benefits that will accrue to all species as a result of habitat management.

The Steering Committee is in the final stages of proposal development and hopes to present Congress a complete product within a month or two. The only outstanding matters that remain are finalization of the funding mechanisms. It is important and may even be essential that funds be derived from sources that will cause a minimum of opposition. Users of fish and game resources have a long history of paying their fair share of the costs for management of those resources. The industries that provide the funds through excise taxes also are supportive. There is every reason to believe that users of non-game resources will come forward to support their interests with the same zeal in the future, as sportsmen and sportswomen have in the past.

The time has come when people who thrill to the flute-like song of the wood thrush or the visit of a cardinal to a backyard feeder must step forward to assure that these same experiences will be available for their children and grandchildren. We can no longer leave for tomorrow those actions that are necessary to assure the perpetuation of fish and wildlife values.

We have done much as scientists, administrators, organization leaders and private citizens to assure that fish and wildlife are a continuing part of our natural heritage. It is time, once again, to work together to put in place that final piece of the jigsaw puzzle that will complete the funding picture for fish and wildlife conservation to assure, once and for all, *The Bridge to the Future*.

Presentation of the 1992 Guy Bradley Award

Whitney Tilt
Project Director
National Fish and Wildlife Foundation
Washington, D.C.

In 1988, the National Fish and Wildlife Foundation established an award to recognize excellence in wildlife law enforcement. This award is established in recognition of the vital role law enforcement plays in fish and wildlife conservation. As North America's human population grows, pressures on our natural resources increase as demand for the use and access to these resources rises exponentially. Together with the biologists, habitat managers, and host of other state and federal land management professions, law enforcement represents a "thin green line" dedicated to conserving this Nation's fish, wildlife and plant resources for future generations.

The Guy Bradley Award was established by the Foundation in 1988 to recognize the contribution of the law enforcement community to conservation. The award is to be given annually to that person, or persons, whose dedication and service to the protection of the country's natural resources provide outstanding leadership, extended excellence and lifetime commitment to the field of wildlife law enforcement, and whose actions advance the cause of wildlife conservation. The award is given in the spirit of Guy Bradley, an Audubon game warden killed in the line of duty in July 1905, while preserving a Florida rookery from plume hunters. Guy Bradley is believed to have been the first warden to give his life in the line of wildlife law enforcement.

In the past, the Foundation has recognized state and federal law conservation officers. This year, the Foundation is honored to present the 1992 Guy Bradley Award to Ronald D. Lahners, United States Attorney in Omaha, Nebraska in recognition of the vital role the Department of Justice and state and federal judicial systems play in successful law enforcement. For law enforcement to be an effective deterrent in the field, there must be dedicated support from the judicial system, and the Foundation is pleased to honor one of their own.

Picked from a field of outstanding nominees, Lahners more than meets the award's qualifications. He was selected by a volunteer panel of judges comprised of representatives from federal and state wildlife agencies and conservation organizations.

Ronald D. Lahners, United States Attorney, Omaha, Nebraska

Ronald Lahners' dedication to wildlife law enforcement and other wildlife concerns has not been short lived. As a career prosecutor, he has prosecuted numerous violations of both state and federal wildlife laws. During his ten years as United States Attorney, he has made wildlife cases one of his top priorities.

Mr. Lahners is both the chief law enforcement officer for the District of Nebraska and the primary litigation attorney for the U.S. Fish and Wildlife Service. His track record demonstrates a commitment to seek judgements in both civil and criminal cases that directly benefit fish and wildlife, often in ways that break new ground. Lahners' strong leadership over the last 10 years, fast action and personal involvement are directly responsible for the saving of countless thousands of birds, including some that are on the endangered species list, such as whooping cranes, piping plovers, least terns and bald eagles.

A sampling of his conservation achievements as U.S. Attorney include: (1) negotiating an agreement between the Service and power company officials to install marker balls on power lines, cutting crane mortalities by over 80 percent; (2) helping to develop a raptor electrocution seminar leading to the reduction of eagle mortality—to date, hundreds of miles and problem power lines have been modified to prevent raptor electrocution; and (3) orchestrating a pilot program to prevent migratory bird mortality to oil sludge pits through cooperation of the Nebraska Game and Park Commission, Nebraska Oil and Gas Commission and the U.S. Fish and Wildlife Service.

The hard work of dedicated field agents would mean nothing if United States Attorneys were not willing to devote limited resources to prosecuting violations of wildlife laws. Lahners has embraced this responsibility. Moreover, Lahners has gone above and beyond the call of duty to ensure that his cases are resolved in a manner that directly benefits wildlife concerns. He is truly deserving of this award.

The Award

In recognition of Ronald's efforts on behalf of wildlife conservation, the National Fish and Wildlife Foundation is pleased to present him with the Foundation's 1991 Conservation Print and commemorative plaque, together with a check for $1,000.

The Foundation recognizes that Ronald is only one of the hundreds of dedicated individuals in the larger law enforcement community who also deserve this recognition. The Foundation would like to thank John Doggett, Terry Crawforth, Gary Myers, Ken Goddard, Terry Grosz, Rollie Sparrowe and Max Peterson for their willingness to serve as Guy Bradley Award judges. Finally,our thanks to the Wildlife Management Institute for its help in this presentation.

Special Session 1. *Wildlife Damage Management*

Chair
JOHN P. WEIGAND
Research and Technical Services Bureau
Montana Department of Fish, Wildlife and Parks
Bozeman, Montana

Cochair
JAMES E. MILLER
Extension Service
U.S. Department of Agriculture
Washington, D.C.

Bridging Traditional Barriers and Achieving Balances

John P. Weigand
Research and Technical Services Bureau
Montana Department of Fish, Wildlife and Parks
Bozeman

America's wildlife profession, with the support of hunters and trappers, can take rightful pride in restoring the nation's wildlife resources, depleted during four and a half centuries of settlement following Columbus' landing. Much of our public relates readily to early descriptions of the cornucopia of wildlife available to early settlers. Many also are aware of the recorded dearth of wildlife by the passing of the 19th century.

Too few people, however, are aware that conscionable individuals who harvested wildlife not only sounded the alarm about declining wildlife numbers, but they organized and they pressured for enactment of legislation to protect wildlife. Wildlife harvesters went one step further: they volunteered to replenish low populations through wildlife surveys, research, trapping and transplanting, habitat acquisition and development and, at the same time, limited their own harvests of wildlife. Harvesters even taxed themselves to provide the funds for these efforts. The restoration of wildlife across America as a direct result of these efforts is a classic success story (Kallman et al. 1987).

Concurrent with this success, we overlooked persistent and seemingly paradoxical concerns for over-abundance of wildlife. Our intense dedication to recovering low wildlife numbers has seriously overshadowed these concerns for too much wildlife, or wildlife taking residence in unwanted situations. The wildlife profession has been unholistic in managing ecosystems for wildlife diversity, and perhaps thereby preventing the need for some wildlife control operations.

Even today, more than 50 years after collective scientific efforts to recover wildlife populations, most wildlife management curricula in America's colleges and universities continue to emphasize identifying the factors that limit wildlife numbers and means to neutralize those factors. That emphasis remains justified because nonharvesters have joined the harvesters in demanding more wildlife; they also want that wildlife to be accessible for viewing, photographing and so on.

However, in responding to those demands, we unfortunately continue to de-emphasize prevention and control of problem wildlife. As we meet here today, wildlife recovery plans are being disrupted by continued human population growth and conversion of wildlife habitat to human habitat, increasing loss of human ties to the land and its products, and encouragement by some entertainers, other publics, and the popular media to escape from reality through animation and anthropomorphism.

Wildlife managers have been thrust "back to the future." They must again dig deep into their basic training and share the same knowledge about wildlife dynamics and habitat requirements with today's nonharvesters that they previously shared with harvesters. They must educate the new public in how we perpetuate wildlife populations, even when it means sacrificing individual or groups of animals. It means educating the public in achieving balances between the needs of humans and those of wildlife. It means periodic harvest of some species on a widespread basis if overall public demands and individual tolerances are to be balanced.

Columbus and his crew were successful in locating North America because they persisted in navigational and sailing skills. No doubt some of them challenged their leadership and even questioned the existence of this new continent. I am confident that the wildlife profession is based solidly in laws, principles, theories, and concepts in the biological and physical sciences. It can develop and apply whatever technology is needed to achieve holistic management of wildlife resources in a society of changing and ofttimes emotional demands.

The manner in which controlling wildlife that damages domestic crops and animals also has been a long-lived concern. It was addressed during the American Game Conference in 1934 when "Objections to Poison as a Method of Rabbit-Control" was discussed by Wallace Grange. Wildlife damage management has had technical session status at North American Wildlife and Natural Resources Conferences in 1949, 1960 and 1974. Development of preventative and control methodology since 1974 has been communicated mostly through regional conferences, workshops and symposia. Participants at these meetings tend to be the practitioners. It is therefore to the credit of The Wildlife Society and the Wildlife Management Institute that we are revisiting this issue to update our present administrators and the new public on progress in this technology.

Presentations today were selected for their ability to relay state of the art damage management philosophies, procedures and assessments. They are intended to be provocative as well as educational. Each presenter has 15 minutes to stimulate your thinking; they will then accommodate your questions for up to 5 more minutes. We encourage your review of the details of each presentation in the forthcoming transactions of this conference.

At this time, I will turn the session over to our Co-chairman, Jim Miller, the National Program Leader for Fish and Wildlife Management in the U.S. Department of Agriculture's Extension Service.

Reference

Kallman, H., C. P. Agee, W. R. Goforth, and J. P. Linduska, eds. 1987. Restoring America's wildlife, 1937–1987. U.S. Fish and Wildl. Serv., U.S. Govt. Print. Off., Washington, D.C. 394 pp.

The Complexities of Implementing Wildlife Damage Management

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Wildlife damage management is one of the most complex aspects of wildlife management. ". . . twas ever thus." And, harkening back to the theme of the Conference—"500 years after Columbus"—if you visit Jamestown on Virginia's Eastern Shore, and the site of the first settlement, you will find a Powatan Village and, in the center, a curious platform. It was for a villager to frighten away the blackbirds to protect the Indian crops. And, if, while in the old Commonwealth, you visit the Custis Lee House Museum at Arlington National Cemetery, you will find an exhibit with a message from George Custis, urging the Colonies to establish a domestic independent wool industry. He probably was not aware of the problem that coyotes would pose. And we are not too far from the home of our first wines, their grape arbors and the related bird problems.

From pre-settlement and colonization, through the westward expansion and the establishment of agriculture, there have been various problems with damage caused by wildlife—from Indian corn fields to protection of the Kennedy Space Center; from wolves on prairies to moles in suburbia.

And with the increasing population, diversification of interests and the sophistications of resource management, the problems of managing wildlife damage have grown increasingly complex.

There are many factors that contribute to the complexity of implementing wildlife damage management programs: the number of agencies having some responsibility and their legislative mandates; the various kinds of wildlife damage involved and the affected publics; the various methods of control or management; and, of course, the public perception and attitude.

I would like to discuss a number of the complexities, and one in particular—the divergent views within the professional wildlife community. As a member of the Secretary of Agriculture's Advisory Committee on Animal Damage Control, I have a number of opportunities to meet with or speak to those with some responsibility for wildlife damage management. This panel, however, provides a platform to speak to a wider spectrum of professional interests and to explore a much needed common understanding.

But first, let us examine some of the other complexities.

The complications begin with the responsibilities of a host of agencies. It is superficial to say that animal damage control responsibilities were transferred from the U.S. Fish and Wildlife Service in the Department of Interior to APHIS in Agriculture in 1986. That really is only the beginning, but that is the way the subject is usually dismissed, consciously and subconsciously by many professionals, as well as the lay public. That is only a part of the story. Indeed, the federal responsibility is vested with APHIS. Additionally, however, the states have control elements, usually within the fish and wildlife agency. But, the public perception of responsibility is unclear—a perception that needs correction.

Although my topic is about the complexities, one of which is agency responsibilities, let us pause to look more broadly at some other areas where responsibilities are exercised.

It begins with the legislative process. Several state legislatures have acted to ban, restrict or regulate the use of traps and/or toxicants. Similar actions have been proposed at the federal level.

The Congress and most state legislatures have established and assigned responsibilities to agencies which directly affect control activities. Examples are environmental protection, animal welfare, endangered species and others.

Legislative mandates have directly affected control methods and costs. For example, amendments to the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) have resulted in the Environmental Protection Agency requiring costly reregistration of virtually all chemicals used in control work. Some state legislatures have taken other regulatory actions.

And, legislation has resulted in confused agency responsibilities. In a number of states, the responsibilities for some animals are vested with the state agriculture agencies and, for other species, with the fish and wildlife agency. At the federal level, authority for migratory birds is vested with the Department of Interior, while responsibility for control of depredations is vested in the Department of Agriculture.

On occasion, the executive branch injects itself at the highest levels. An Executive Order of 1972 prohibited most chemicals used in predator control.

Counties and cities also have adopted measures which affect control.

This brief listing is cited simply to illustrate the complexity or maze of actions that those involved with animal damage management must be aware of even before attempting to coordinate with and enlist the support of cooperating agencies.

For purposes of this discussion, the cooperating agencies may be considered in two categories: those that regulate methods; and those that need some form of control to carry out their mission. Examples of the latter include airport authorities, urban and suburban instrumentalities, fish and wildlife and land managing agencies.

I would like to concentrate on the latter—the agencies that require wildlife control in pursuit of their objectives.

As examples:

- Airport authorities are responsible for aircraft safety. If they determine that bird strikes present a problem, they turn to the state or federal control agency.
- Public health officials are responsible for public health. If they determine that plague, rabies or histoplasmosis are a threat and that wild animal numbers need to be reduced, they turn to the control agency.
- Fish and wildlife agencies are responsible for the well being of fish and wildlife resources, including endangered species. If they determine that predation is a problem, perhaps in the restoration of an endangered species; if waterfowl are causing unacceptable crop damage; or if cormorant are taking Atlantic salmon smolts—they call on the appropriate control agency.
- Land managing agencies are responsible for administering legislatively mandated multiple uses, including grazing. That includes practices essential to grazing management, such as fencing, water development, rotation of flocks, road de-

velopment and maintenance. If predation is a problem in the successful management of grazing, they turn to the control agency.

This all may seem an elaboration of the obvious. It is not.

It is important to bear in mind that the state or federal wildlife damage control elements or agencies operate no airports, have no public health problems, no salmon smolts, and no land or livestock to manage. What they do have is the capability and expertise to recommend or apply control measures to assist other agencies in achieving their objectives. They can suggest the combination of measures needed to implement a responsible integrated management system, including the application of lethal means, if appropriate. There is a vast difference.

Wildlife damage management personnel, state and federal, have a service to render in a responsible manner. The requesting agency, however, should identify the need, develop the documentation and justification—and, there is a moral obligation to publicly support the program.

Too often, however, this has not been the case. For example, APHIS, and the U.S. Fish and Wildlife Service before it, found themselves in the position of justifying the funding, documenting the need, defending—and accepting the criticism—even of asking approval of the requesting agency. And, the requesting agencies have found this to be a splendid arrangement—they did not need to do the control or take the criticism.

Added to the complexity of dealing with so many agencies is the reality of the public attitude which is often anti-control.

A very important component of the public attitude is the professional viewpoint which contributes to the public view and contributes to agency and organization positions.

I think it is important to point out that the public as a whole does not always distinguish between various agencies or agency responsibilities—state or federal. They all relate to wildlife, its problems and achievements. We are all "tarred with the same brush." It therefore behooves us to arrive at our conclusions very carefully.

Clearly, professional wildlifers view wildlife damage management from different perspectives—from solid support to antagonistic opposition. Why is this so? I think some of it probably stems from a perpetuated hangover from long ago; some from a lack of understanding of the wide variety and extent of damages caused by so many different species under a host of circumstances—the popular perception of coyotes and blackbirds falls way short of the mark. Some wildlifers are simply not aware of the kinds of knowledge needed to practice damage management—the laws, the publics, the animals, the toxicology and rules governing the use of chemicals. Some stems from a lack of understanding of the progress and sophistication that has occurred in research, methodology and program direction. Unfortunately, some professional wildlifers look down their noses at practitioners of damage management.

I think we need to distinguish between the personal views of the individual professional and the views of the profession as a whole. The perceptions of the wildlifer are conditioned or shaped by his or her academic training which, generally, has been shifting away from an emphasis on management. The orientation received from academia influences the wildlifers' understanding and perceptions.

As an aside, how many universities or colleges offering courses in wildlife can you think of that offer course work in wildlife damage management? I am very pleased that the last paper will be dealing with professionalism. I hope Dr. Schmidt will explain the very progressive cooperative initiative of Utah State University and APHIS to develop a curriculum in wildlife damage management.

I believe that most of the difficulty or misunderstanding—or differing viewpoints—have their genesis in a failure on the part of professionals to accept or recognize that wildlife damage management is an essential and integral component of wildlife management. There has, however, been some encouraging progress. The Wildlife Society recognizes wildlife damage control as ". . . an essential and responsible part of wildlife management. . ." And, the Society's new position on the "Responsible Human Uses of Wildlife," approved by Council October 1990, embraces the same recognition. And let me urge your attention to the fine paper on "Wildlife Damage Management: Policy and Professional Considerations," delivered by Harry Hodgdon at the Fifth Eastern Wildlife Damage Control Conference last October. Among other things, he said, "The Wildlife Society recognizes that it is appropriate to manage wildlife to sustain and enhance populations, species, habitats, and ecosystems for human benefits, while responsibly protecting property and other resources and preventing health and safety hazards. Let me say right up front that ecologically sound wildlife damage management is an important and integral part of wildlife management and the wildlife profession. It is necessary and increasingly important due to expanding human populations and their associated impacts on wildlife habitats."

As wildlifers, no matter what specialty, I think we must recognize that successful wildlife management includes not only research, protection, habitat manipulation and other positive measures—but the management of damage when and where that same wildlife causes some kind of unacceptable damage. In fact, our ability to gain the goodwill of landowners and their willingness to accept and manage wildlife often depends on our willingness to assist with damage problems.

As the human population grows and the competition for space and other resources increases, there will be more, not less, need for managing the damage caused by wildlife. And, I do not mean just control of numbers, but the application of a wide variety of management, sociological and economic tools to assure that wildlife resources remain an acceptable component of our national fabric.

I believe that conceptual understanding and support for wildlife damage management among professionals is essential to a healthy and successful program of wildlife management. For, as I stated before, the professionals influence agency and organization positions, which, in turn, influence the success or failure of successful wildlife management.

In conclusion, wildlife damage management is extremely complex because of the responsibilities of the various state and federal agencies involved. Clearly, coordination among the agencies is imperative. The complexity is compounded by the public attitude, increasingly sensitive to animal damage control. All of the complexities can be reduced by acceptance by all professionals of the concept that we all must share and defend; damage management is a necessary part of wildlife management.

Decision Making for Wildlife Damage Management

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Introduction

Wildlife damage management is an integral and responsible part of the wildlife management profession (The Wildlife Society 1990). "It is a broad subject, cutting across the entire field of wildlife ecology and management" (Berryman 1972). Specifically, this aspect of wildlife management focuses on reducing conflicts between humans and wildlife that occur when wildlife negatively impact any of a wide variety of agricultural resources, properties, natural resources, and public health and safety.

Unfortunately, wildlife damage management decisions are too often misunderstood by the general public, as well as by some members of the wildlife profession. Many perceive wildlife damage management solely as coyote (*Canis latrans*) control to protect livestock. In fact, it encompasses a broad range of management activities directed not only at wildlife but at affected resources as well. In order that responsible management of wildlife damage may be conducted, it is imperative that the basic tenets of wildlife damage management decision making be understood.

Many state and federal agencies have legislated mandates, special interest, or involvement in wildlife damage management. Private organizations, institutions, pest control firms and individuals are also actively involved in this specialized field. Frequently, the formulation, implementation and success of a control strategy is contingent on highly coordinated and cooperative efforts among many parties. Those responsible for wildlife damage management decisions are routinely challenged with unique and often complex problems. No single method or combination of methods is applicable to all damage situations (Berryman 1972, Salmon and Lickliter 1983), nor are there simplistic rules of thumb. In fact, truly effective decision making can only be achieved through interdisciplinary consideration of the specific biologic, physical, economic, sociocultural and other environmental circumstances associated with each wildlife damage problem.

In this paper we present a compartmentalized decision model (Figure 1) and discuss the key factors requiring consideration in formulating responsible and effective strategies to address specific wildlife damage problems. Our objective is to increase the awareness of this decision making process among wildlife managers to better enable them to explain the variables and complexities of the process to all of our publics.

Decision Model

Wildlife damage decision models can be useful management tools (Schmidt et al. 1985). They can serve as meaningful communication instruments as well. The fol-

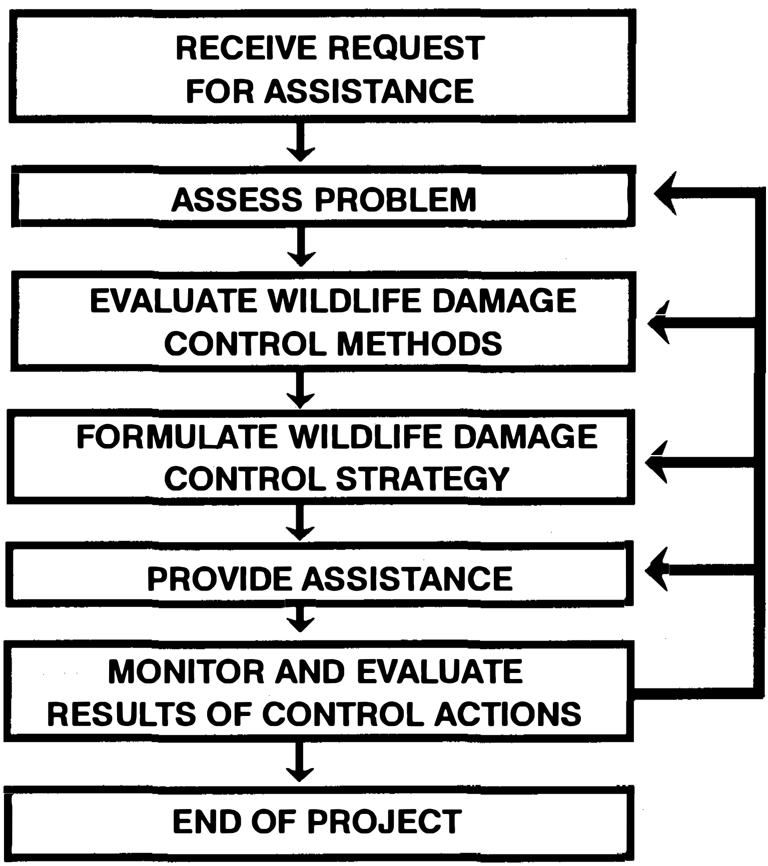

Figure 1. Wildlife damage management decision model.

lowing model is well suited to serve as both a useful management and communication tool; however, it necessarily depicts thought processes as being more linear than they actually are. In our experience, this model includes the major considerations to responsibly address specific wildlife damage management decisions.

The following discussion is represented by compartments in the decision model as shown in Figure 1.

Receive Request For Assistance

Wildlife damage management services are provided in response to requests for assistance. Such requests may encompass a broad range of wildlife conflicts from nuisance wildlife in urban structures to more intricate problems, such as wildlife hazards to public safety, wildlife predation on livestock or protection of endangered species.

Assess Problem

Those engaged in wildlife damage management are subject to limitations on the scope and diversity of their activities. These limits are established by legislative direction, legal mandates, MOUs, cooperative agreements and other constraints. Therefore, a brief initial assessment of each request is necessary for a purview determination. Those requests determined to be within the responsibility and authority of the receiving agency, organization, firm or individual should then be subjected to a more detailed assessment of the damage.

In assessing the damage, immediate attention should be given to confirming that damage was caused by vertebrate animals, the species responsible for damage and the type of damage (e.g., bird hazard at an airport, loss of livestock, flooded crops). This commonly requires an on-site inspection, depending on the type and complexity of the problem. The extent and magnitude of damage is also important in assessing current and potential economic losses in the absence of control. The resource manager or affected party is usually the source of this information. Pertinent aspects of the damage history also are relevant to the assessment. For example, is this a recurring problem, or is it the first episode of this type? What control actions, if any, have been attempted by the resource manager or affected party? What were the results? If no further control action is taken, is damage likely to continue or recur? All of these factors are considered in deciding which management options are potentially applicable to the problem.

Evaluate Wildlife Damage Control Methods

Once the problem assessment is completed, potentially available methods are evaluated for their practicality in reducing damage. Conceptually, this component of the decision model consists of a series of legal, administrative and environmental screens for each potential method (Figure 2). The output from this compartment is a list of methods deemed practical for further consideration in the formulation of the wildlife damage control strategy.

To facilitate a better understanding of the availability of control methods and who generally applies them, methods are organized under three action approaches to managing wildlife damage problems (Table 1). For the purposes of this paper, Table 1 is limited to methods potentially available to prevent or control damage caused by blackbirds (*Icterinae sp.*), beaver (*Castor canadensis*) and coyote.

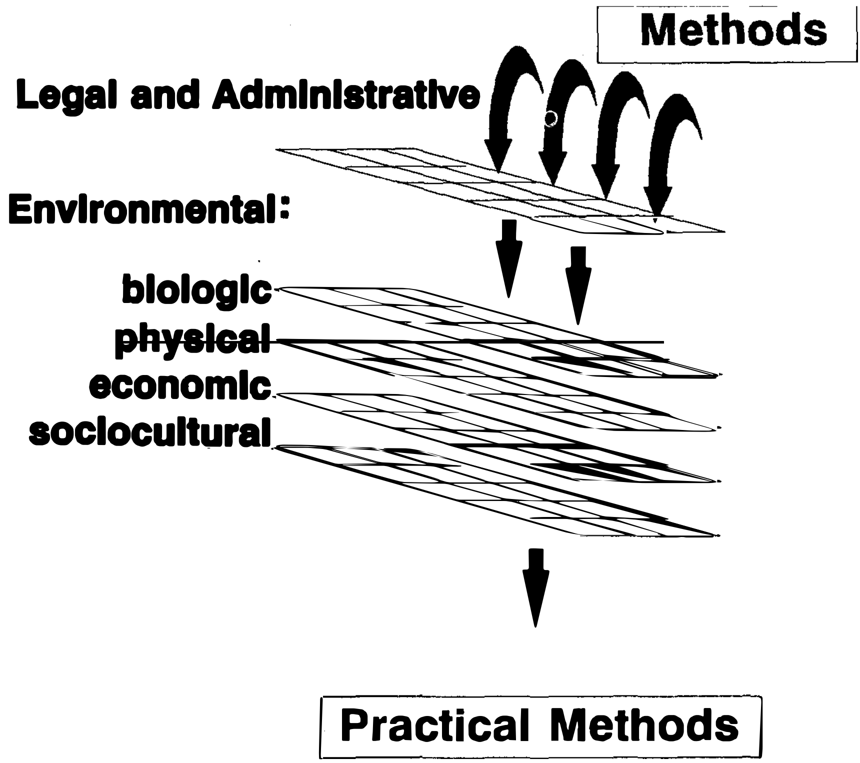

Figure 2. Methods evaluation screens.

One action approach is management of the resource damaged or negatively affected by wildlife. It includes those activities designed to improve or modify ongoing resource management practices, such as husbandry and cultural practices, as well as modification of human behavior. Application of these methods is typically the responsibility of the resource manager or affected party. However, wildlife managers make technical assistance recommendations concerning these methods.

A second action approach is placement of physical barriers to separate the resource that has sustained or is susceptible to damage from specific wildlife species. Fences, nets and wire grids are examples of physical barrier methods. Like resource management methods, these are usually applied by the resource manager or affected party. Wildlife managers often make technical assistance recommendations concerning the installation of physical barriers to reduce wildlife damage. State and federal programs may also loan materials or demonstrate fencing or other physical exclusion methods.

A third approach, management of wildlife, includes habitat management, modification of wildlife behavior and wildlife population management to reduce damage. Habitat management includes activities such as thinning trees from bird roosts or manipulating water level through removal of beaver dams. Habitat management is

Table 1. Wildlife damage methods by action approach.

Control methods	Beaver	Blackbirds	Coyote
RESOURCE MANAGEMENT			
Animal husbandry			
Night penning			x
Shed lambing			x
Time of breeding			x
Move livestock			x
Change class of livestock			x
Herding			x
Guarding animals			x
Removal of dead livestock			x
Crop selection and planting schedules			
Time of harvest		x	x
Time of planting		x	x
Damage resistent varieties		x	
Change crop		x	x
Habitat management architectural design			
Modify human behavior			
Stop wildlife feeding			
Stop wildlife handling			
Alter aircraft flights		x	
PHYSICAL BARRIERS			
Fencing			x
Sheathing (hardware cloth, solid metal, chain link)			
Tree protectors	x		
Entrance barricades			x
Netting		x	
Roost exclusion		x	
Wire grid			
Other			
Close storage containers			
WILDLIFE MANAGEMENT			
Habitat management			
Modify vegetation		x	
Eliminate standing water		x	
Roost thinning/removal		x	
Close garbage dump		x	
Manipulate water level	o		
Dam removal (beaver)	o		
Lure crops/alternate foods			
Food planting—hold birds		x	
Crop sacrificed—to birds		x	
Grain piles—attract birds		x	
Sacrifice goats—protect sheep			x

Table 1. Continued.

Control methods	Beaver	Blackbirds	Coyote
Frightening devices			
Electronic distress sounds		o	
Propane exploders		o	x
Pyrotechnics		o	
Lights			x
Water spray devices		o	
Harassment (boats, planes, autos, atvs)		o	x
Other soaring devices			
Strobe—siren			o
Eye-spot balloons		o	
Effigies		x	x
Chemical repellents			
Odor	x		
Tactile, etc.		x	
Frightening agents		o	
Kill or relocation methods			
Leghold traps	o		o
Cage traps	o	o	
Snares			
Neck/body	o		o
Foot/Leg			o
Catch-pole			o
Quick-kill traps	o		
Denning			o
Shooting			
Aerial hunting			o
Calling and shooting			o
Spotlighting and shooting	o		o
Shooting on sight	o	o	o
Hunting dogs/shooting			
Tracking/trailing dogs			o
Decoy dogs			o
Egg and nest destruction			
Remove hatchlings			
Chemical toxicants			
Aluminum phosphide			
Zinc phosphide			
Strychnine			
Sodium cyanide			o
Livestock protection collar			o
Gas cartridges			o
DRC-1339		*	
Starlicide		o	
PA-14		*	

Methods Primarily Used by:
* - Wildlife Damage Specialists
x - Resource Manager or affected party
o - Wildlife Damage Specialist and Resource Manager or affected party

usually implemented by the resource manager or affected party. Modification of wildlife behavior includes the use of frightening devices, repellents or lure crops. Population management includes translocation or lethal removal of wildlife from local populations. Behavior and population management methods may be conducted by either the resource manager or wildlife managers, depending on legal and administrative considerations in each state, county or municipality.

Legal and administrative considerations. Wildlife damage control methods are subject to legal and administrative authorities. For example, a method may be legal in one state and not another. Or, a method may be legal only in portions of a state (e.g., not allowed in areas heavily populated by humans). The status of the target species (state or federally listed as threatened or endangered), or the presence of listed species in the general area where control activities are proposed may preclude the use of a method. Also, wildlife damage control programs may restrict the use of specific methods by policy or agreement with other agencies or parties. The important questions that should be answered for each method during this phase of the assessment include:

1. Is it legal and administratively permissible to use this method on this species within the state where the request for assistance has been received?
2. Is it legal and administratively permissible to use this method to address this specific type of damage?
3. If so, is it legal and administratively permissible to use this method at the specific site for the request for assistance, or are there restrictions because of land class, other land use patterns or the presence of listed species near the damage site?

All of the methods that pass these legal and administrative screens are deemed available for further consideration in the decision process. It should be noted, however, that there are additional legal considerations with regard to who may apply methods. These are considered under the "Formulate Wildlife Damage Control Strategy" compartment.

Environmental considerations. During this phase of the assessment, each legally and administratively available method is evaluated with regard to pertinent aspects of the biologic, physical, sociocultural and economic environments. In effect, the methods evaluation is an environmental cost-effectiveness analysis (Owens and Slate 1991). Consideration is given to the impacts each method would have on each of the four environments and vice versa. A general question to be considered is: what are the positive or negative, short- or long-term, direct, indirect or cumulative environmental effects of implementing or not implementing control action with each method under evaluation on each of the environments? Other important questions that should be considered in making decisions about each method are discussed for each of the four respective environments.

Important questions to be addressed for the biologic environment include:

1. What is the population status of the target species—endangered, threatened, or is it relatively abundant nationally, statewide and locally?
2. Are there any threatened or endangered or other potential nontarget species in the area that could be directly or indirectly impacted either positively or negatively by using this method?

3. Are there any special behavioral traits of the target species, such as daily or seasonal movement patterns, that require consideration relative to method application?
4. Could the use of this method potentially affect species diversity?

Important questions to be addressed for the physical environment include:

1. What effect would local weather or climatic patterns have on the use of this method?
2. What effect would soil, water, air, elevation or other physical habitat features have on the use of this method?
3. What health and safety risks would this method pose to the applicator and the public?
4. What health and safety risks would be posed to the public by not conducting control using this method?

Important questions to be addressed for the economic environment include:

1. Would the use of this method in this situation be likely to reduce damage?
2. Does the magnitude of damage warrant the cost of applying this method?

Evaluating methods in the sociocultural environment frequently presents the greatest challenge because of differences in human attitudes toward wildlife species (Kellert 1976, Decker and Goff 1987), wildlife damage management methods (Stuby et al. 1979, Arthur 1981) and the resources damaged by wildlife (Connolly 1982). In spite of the difficulties associated with evaluating methods in the sociocultural environment, societal values are important in decision making and they deserve similar consideration in methods evaluation as the other environmental factors. Some important sociocultural issues to consider in evaluating wildlife damage control methods include:

1. What are the perceptions regarding the humaneness of the methods?
2. How acceptable would the risks of this method to nontarget animals be to the resource manager or affected party and the general public?
3. How acceptable is the effect of each method on the target animals—no effect, frighten, exclude, modify habitat, translocate or kill—to the resource manager or affected party and the general public?

The methods evaluation should result in one or more practical methods available for further consideration in formulating a control strategy. However, as a function of this evaluation it is possible to determine that there are no practical methods available. This results in no action being recommended or taken.

Additionally, it should be noted that monetary compensation for wildlife damage is sometimes legislatively mandated. Compensation, however, does not address the damage problem and is not considered as a method in the three action approaches in Table 1.

Formulate Wildlife Damage Control Strategy

At this decision step, those control methods determined to be practical from the previous evaluation are formulated into a control strategy based on considerations of available expertise, legal constraints on methods users, costs and relative effectiveness of methods. In determining the sequence or combination of methods to be applied and who will apply them, preference should be given to practical nonlethal methods.

Available expertise. As previously discussed, resource management and physical barrier methods are usually applied by the resource manager or affected party. Some wildlife management methods also may be applied by the resource manager or affected party; however, effective application of many of these methods often requires personnel with special expertise in wildlife damage management.

The availability of expertise to address each specific request may influence the balance of direct, hands-on management provided by the resource manager or affected party and wildlife damage specialists. Relatively simple damage problems may be adequately addressed through technical assistance. However, effective solutions to many damage problems require an integration of those methods used by the resource manager with direct control services provided by wildlife damage specialists.

Legal constraints on method users. Screening was previously performed (*see* "Legal and administrative considerations") to determine which methods were legally and administratively permissible for the problem. Here it is necessary to consider any additional legal constraints that define who may apply each method. For example, restricted use pesticides cannot be used by persons who are not certified applicators. Also, EPA label restrictions on specific pesticides may limit their use to specific groups. The avicide DRC 1339, for example, can be used only by USDA personnel trained in bird damage control or persons under their direct supervision.

Costs. Cost-effectiveness is an obvious goal in wildlife damage management. However, the costs of implementing wildlife damage management should not be considered independently from the damage problem, probable environmental impacts and other strategy considerations.

The costs of methods and their application should be weighed against the severity of damage. Even in cases involving serious damage, lack of funds may constrain the resource manager or affected party from hiring special expertise adequate to solve the problem.

Off-site or indirect benefits have to be considered as well. For example, the costs associated with the suppression of an offending coyote population at one location may be relatively high. But when costs are considered in the context of avoided or continuing loss of sheep in neighboring areas, the costs of implementing the control strategy may be low.

Overriding social concerns often preclude the use of the most cost-effective methods. The use of pyrotechnic frightening devices in and around developed areas to reduce damage caused by birds may not be recommended or used because of noise, aesthetic or other social concerns. Safe and effective lethal methods may not be used in a variety of circumstances primarily because of social considerations.

Short-term versus long-term costs and benefits of wildlife damage management strategies also are important. Methods such as the propane cannon have substantially higher initial costs in comparison to pyrotechnics, yet may be less expensive when labor is factored into the strategy budget. Compared to pyrotechnics, propane cannons may be as socially acceptable and efficacious in reducing wildlife damage for some damage problems.

Relative effectiveness of methods. Subject to other constraints and considerations, as previously discussed, wildlife managers should recommend or use the most effective method or combination of methods to resolve problems. Method effectiveness must take into account many of the variables previously discussed, such as legal and administrative availability, and practicality from a comprehensive environmental perspective. Effectiveness of a method or combination of methods is also determined by their costs, negative environmental impacts and ability to reduce damage. Ideally, a method or combination of methods should be selected that produces maximum damage resolution with minimal negative environmental impacts (Owens and Slate 1991).

Provide Assistance

Wildlife damage management service may be provided to the public by two basic means: technical assistance and direct control. Technical assistance is the provision of advice, recommendations, information or materials for use in managing wildlife damage problems. Its emphasis is on helping others help themselves. Technical assistance may require substantial effort by wildlife damage specialists in the decision-making process, but the actual control activities are the responsibility of the resource manager or affected party. Direct control is the implementation of control activities by wildlife damage specialists. Direct control may be provided when funding is available and if the control efforts of the resource manager or affected party are ineffective and technical assistance alone is inadequate. Direct control should be employed when actions may affect sensitive species or sensitive areas of the public domain, or involve certain hazardous materials (Berryman 1972).

Monitor and Evaluate Results of Control Actions

If wildlife damage management services have been provided, it is usually necessary to monitor control actions to determine if they are achieving the desired results. Return site visits or telephone contacts to the resource manager or affected party represent the common forms of monitoring activities. Site visits or phone contacts also are required to monitor equipment placed in the field to assess if it is functioning properly, or with capture methods such as traps and snares, to determine if any animals have been captured.

Monitoring control actions is an important step in determining if further assistance is required to address the problem. Monitoring also allows the wildlife damage specialist to know when to discontinue control activities, thus reducing unnecessary environmental impacts and expenditures.

The need for additional assistance is usually identified through routine monitoring and evaluation of control actions. If the recommended strategy is having an effect but damage has not abated, continuation of the strategy may be in order. In our model (Figure 1) this is represented by a feedback to "Provide Assistance." When monitoring reveals that further assistance is needed, additional feedback from problem reassessment, methods reevaluation or control strategy reformulation may be necessary to determine if more assistance is feasible.

End of Project

For many projects that are addressed through technical assistance alone, the project ends with recommendations or advice being provided to those making the request. Some direct control projects such as the removal of a single family of beaver and the associated dams responsible for flooding a road or dispersing blackbirds from an urban roost have well defined end points. Other projects such as chronic predation on livestock or at aquaculture facilities may require ongoing attention at various times of the year and have no well-defined end point.

Summary

The resolution of human-wildlife conflicts is a dynamic and complex process. Each damage situation has to be addressed in relation to the unique set of environmental circumstances associated with the problem. To effectively address wildlife damage problems, it has been stressed that managers need access to accurate information (Kendrick 1978, Schmidt et al. 1985) and effective management tools and options (Berryman 1972, Salmon and Lickliter 1983), as well as the ability to adapt each management strategy to local environmental conditions (Salmon and Schmidt 1986).

The model presented in this paper emphasizes that decision making should be based on a complex of factors including a comprehensive assessment of the damage and an evaluation of methods in the context of biologic, physical, economic, sociocultural, and other environmental and legal circumstances. Methods identified as practical are then formulated into a wildlife damage management strategy based on the availability of expertise, legal constraints on methods users, costs and the relative effectiveness of methods. Preference should be given to practical, nonlethal methods when formulating each strategy. However, this must not be misinterpreted as a recommendation that nonlethal methods always be applied as a first response to each damage problem. Commonly, the most appropriate response is the integration of nonlethal and lethal methods, and there will be many instances where the application of lethal methods alone is the responsible approach. In fact, there may be more than one appropriate strategy for each damage problem.

We feel that the process discussed in this paper is generally applicable to decision making across the broad range of wildlife damage problems. It is important that those in the wildlife profession understand and communicate the many variables and complexity associated with wildlife damage management decision making. Wildlife managers should emphasize sound decision making as the key to balancing human interests and wildlife needs.

References

Arthur, L. M. 1981. Measuring public attitudes toward natural resource issues: Coyote control. Tech. Bull. No. 1657, Nat. Research Econ. Div., Economic Research Service, USDA, Washington, D.C. 67 pp.

Berryman, J. H. 1972. The principles of predator control. J. Wildl. Manage. 36(4):395–400.

Connolly, G. 1982. On cost effectiveness of coyote control to protect livestock. Pages 279–294 *in* J. M. Peek and P. D. Dalke, eds., Wildlife-livestock relationships symposium: Proceedings 10. Univ. Idaho, Forest, Wildl. and Range Exp. Sta., Moscow, ID.

Decker, D. J. and G. R. Goff, eds. 1987. Valuing wildlife: Economic and social perspectives. Westview Press, Boulder, CO. 424 pp.

Kellert, S. R. 1976. Perceptions of animals in American society. Trans. N. Am. Wildl. Res. Conf., Washington, D.C. 41:533–546.

Kendrick, J. B., Jr. 1978. Agriculture's most important battle. Calif. Agric. 32:3.

Owens, R. D. and D. Slate. 1991. Economics and effectiveness of control methods: Fact and fiction. Proc. 5th Eastern Wildl. Damage Control Conf. In press.

Salmon, T. P. and R. E. Lickliter. 1983. Comparisons between vertebrate pest control materials: Essential considerations. Pages 5–19 *in* D. E. Kaukeinen, ed., Vertebrate pest control materials: Fourth symposium, ASTM STP 817. Am. Soc. Testing and Materials, Philadelphia, PA.

Salmon, T. P., R. E. Lickliter, and R. H. Schmidt. 1986. California ground squirrel management systems: Complexity, uncertainty, and surprise. Trans. West. Sect. Wildl. Soc. 22:71–74.

Schmidt, R. H., T. P. Salmon, and D. C. Stroud. 1985. Decision-making variables in California ground squirrel management. Cal-Neva Wildl. Trans. 21:31–36.

Stuby, R. G., E. H. Carpenter, and L. M. Arthur. 1979. Public attitudes towards coyote control. Economics, Statistics, and Coop. Serv. Rept. No. 54, USDA, Washington, D.C. 11 pp.

The Wildlife Society. 1990. Conservation Policies of The Wildlife Society. The Wildlife Society, Bethesda, MD. 20 pp.

Risk Management Concepts for Improving Wildlife Population Decisions and Public Communication Strategies

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When making decisions about desirable wildlife population objectives, wildlife managers often must balance the economic and recreational benefits of wildlife with the social and economic problems they may cause. For wildlife management agencies, balancing the detrimental and beneficial impacts of a wildlife population is a challenge that is becoming more frequent and complex, especially in states in which wildlife have adapted successfully to a variety of human-occupied environments.

Wildlife populations provide a range of social and economic benefits (Decker and Goff 1987). These include direct benefits related to consumptive and nonconsumptive use (e.g., wildlife-related recreation, observation, harvest, sale), indirect benefits derived from vicarious wildlife-related experiences (e.g., reading, television viewing), and the personal enjoyment of knowing wildlife exists and contributes to the stability of natural ecosystems (e.g., ecological, existence, bequest values) (Bishop 1987).

The same wildlife populations that are enjoyed by many, however, also create conflict with a number of land uses. Some examples will illustrate the problems. Landowners incur financial losses from white-tailed deer (*Odocoileus virginianus*) damage to agricultural (Brown et al. 1978) and forest crops. Electrical utilities experience losses from a variety of wildlife that cause damage to transmission lines and electrical substations (Enck and Brown 1989). Flooding associated with beaver (*Castor canadensis*) activity results in considerable expense for road and drainage-culvert repair (Purdy 1987, Enck et al. 1988). Homeowners experience property damage from many species of birds and mammals (Spencer 1983, Curtis and Decker 1990), including white-tailed deer that browse on ornamental plants (Sayre and Decker 1990) and gardens. Wildlife-transmitted diseases, such as rabies and Lyme disease, can cause loss of human life. Additionally, motor vehicle or airplane collisions with wildlife can result in property damage, human injury or loss of human life (Walker and Bennett 1983, Decker and Loconti 1989, Decker et al. 1990, Dolbeer et al. 1989).

When wildlife agencies lack knowledge about people's experiences and perceptions regarding wildlife damage, a significant discrepancy may arise between an agency's wildlife population objectives and the population preferences of stakeholders. The result can be the development of a divisive, disruptive wildlife management issue (Peyton 1984). Consequently, accurate information about the perceptions and preferences of key stakeholders (i.e., those most affected by wildlife population management) is essential in setting wildlife population levels and minimizing management problems. Understanding the interests, preferences and behaviors of key stakeholders enables managers to develop socially-responsive management programs.

In recent years, decision-makers dealing with a variety of environmental risk issues (e.g., nuclear power production, hazardous waste disposal, chemical manufacturing) have developed a risk management approach to decision making that integrates the physical/chemical and sociological dimensions of environmental hazard management, while considering both risks and benefits. The risk management framework can be combined with a comprehensive wildlife management approach and applied by wildlife managers. The combined framework allows managers to integrate biological and sociological dimensions of wildlife management with risks and benefits such that alternative wildlife management objectives and actions can be evaluated in terms of socioeconomic and ecological consequences. In the context of this combined framework, decisions about setting wildlife population objectives are based on stakeholders' perceived and actual risks compared to the perceived and actual benefits from wildlife. Risks may include a variety of potential injuries or losses to humans, such as property damage, negative human health impacts or loss of personal safety. Managers assess public perceptions and opinions about the various risks and benefits associated with wildlife, and compare those with public behavior and actual incidence of problems caused by wildlife. The framework also provides a means for identifying an array of biological, social and technical management actions to respond both to stakeholders' perceived risk from wildlife interactions and the actual incidence of negative human/wildlife interactions.

During the past 15 years, the Human Dimensions Research Unit (HDRU) at Cornell University has assessed New York State residents' interactions with white-tailed deer, including risks such as property damage (e.g., browsing on agricultural field crops and ornamental plantings), nuisance problems (e.g., damage to noncommercial gardens), and human health and safety concerns (e.g., vehicle collisions, Lyme disease). Here we draw on nine HDRU studies to demonstrate the applicability of risk management concepts for guiding wildlife population decisions by identifying alternative management actions that consider both risks and benefits associated with human/deer interactions. We first review a wildlife management framework that helps integrate the biological and social dimensions of wildlife management conceptually, then we discuss the major issues considered important in risk management. The next section synthesizes previous HDRU deer management studies in the context of wildlife risk management. We conclude with a discussion of the implications of these concepts for managing the risks associated with white-tailed deer.

A Framework for Management

Wildlife management decisions can be characterized in several ways, two of which are particularly useful for considering human interactions with white-tailed deer. First, deer management decisions can be viewed as part of a comprehensive system of natural resource management, in which managers focus on the organismal, environmental, social and institutional dimensions of management. Second, the consideration of both risks and benefits associated with deer corresponds to general risk management concepts used in other aspects of environmental management. These two approaches are discussed separately below, then considered in tandem for specific application to white-tailed deer management.

Dimensions of Deer Management

Whole-system perspectives of wildlife management incorporate the organisms of interest (e.g., white-tailed deer), the habitats in which the organisms occur, the human communities or social systems interacting with the organisms or habitats, and the institutional context in which management is conducted (Knuth and Nielsen 1989). Comprehensive wildlife management considers the four individual dimensions, as well as interactions among them (Figure 1).

The organismal dimension of deer management focuses on the quantity, quality and distribution of deer populations throughout a particular region. Organismal objectives of deer management are directed toward changing or maintaining an existing deer population. Management actions may include conducting deer population research, implanting fertility control agents in deer, regulated hunting or removing specific damage-causing deer.

The environmental dimension of deer management includes the quantity, quality and distribution of deer habitat. Environmental objectives of deer management focus on maintaining or changing specific habitat characteristics and may involve management actions such as assessing habitat use and optimal habitat structure, constructing deer exclosures or fences at specific sites, establishing food plots, or manipulating natural vegetation to increase or maintain deer browse.

The social dimension of deer management considers the range of attitudes, values and behaviors exhibited by humans interacting with deer or deer habitat, and includes an assessment of the numbers and characteristics of people affected. Deer management objectives focused on the social dimension may include maintaining or changing the numbers of people who hold positive attitudes toward deer or interact with deer in some way, or increasing the economic benefits associated with deer-related recreation in a region. Socially oriented management actions may include implementing communication programs to increase human knowledge about the deer resource or to stimulate behavioral change among people interacting with deer. They also may include regulating development activities on potential deer wintering areas, providing incentives to landowners who allow deer hunters access on their property, or providing regulated deer hunting opportunities.

Dimensions of Deer Management

	Organismal (Deer and Other Wildlife Populations)	Environmental (Habitat)	Social (People's Attitudes and Behavior)	Institutional (Management Agency)
Benefits Derived from Deer - Perceived - Actual	e.g., high quality populations and communities	e.g., ecosystem functioning	e.g., educational values; recreation opportunities	e.g., license sale revenues
Risks Posed by Deer - Perceived - Actual	e.g., low quality populations and communities	e.g., habitat destruction for other species	e.g., health and safety problems; property damage	e.g., damage compensation payments; drain on staff time

Figure 1. A risk/benefit framework for managing white-tailed deer, with examples of each management dimension.

The institutional dimension of management focuses on the administrative and political aspects of management. Institutional objectives target such management components as agency operating budgets, staff availability and qualifications, morale, cooperative relationships with other agencies, and statutory constraints. Management actions focus on assessing, modifying or maintaining any of these components.

Interactions among the four management dimensions are not always apparent and, therefore, not always considered when management decisions are made. Interactions between the environmental and organismal dimensions of deer management include the following examples: modifying habitat with controlled burns to increase food availability so a larger population can be sustained; limiting habitat availability on a small scale with exclosures to reduce access by a local deer population and, thus, reduce property damage experienced by people. The latter example illustrates the interaction of social and institutional dimensions of management with the organismal and environmental dimensions. Other examples include: development regulations that limit human activity to protect critical deer habitat and thus influence the long-term sustainability of the deer population; hunter access and associated harvest on private lands that influence the size of the regional deer population; and institutional ability to measure deer harvest accurately that influences decisions made about harvest levels and ultimately affects the deer population size and future hunting opportunities.

In addition to interactions among the four deer management dimensions, elements within each management dimension interact. For example, if managers change the incentives provided to landowners who allow deer hunter access, deer hunting activity may change, with modified levels of economic benefits returning to the community. Comprehensive deer management considers interactions within and among the four management dimensions. Combining this framework with concepts of risk management suggests that as benefits or risks are produced within one wildlife management dimension, managers should predict the associated benefits and risks caused in other management dimensions. This prediction can be used to guide other management decisions. While this application of the combined framework has utility as indicated, it may be most valuable as a tool for proactive management planning because it encourages evaluation of proposed actions, i.e., what are the consequences on the other three management dimensions that will be caused by actions carried out in the domain of one dimension?

Components of Risk Management

Risk management concepts developed for a variety of environmental risks provide wildlife managers with a framework for evaluating the desirability of alternative wildlife management activities. Risk management is generally defined as the array of judgments and analysis used to interpret scientific data and other information about environmental hazards and the people potentially affected by them to make decisions about appropriate objectives and actions for a management program (e.g., *see* U.S. Environmental Protection Agency [EPA] 1984).

Several factors are typically considered in risk management. When available, information about the actual incidence of a particular hazard in society is considered (e.g., frequency of deer/car collisions within a region). Incidence may be expressed in terms of how many people are affected, what geographic scale is affected or what types of people are affected. Perceived (i.e., beliefs about actual) incidence also is an important factor in risk management decisions, and may be expressed in measurable units similar to actual incidence. Perceptions are particularly important at the stage of deciding on appropriate risk management actions. For example, if actual incidence of some hazard is high, but people perceive the incidence to be low, a risk management program focused on changing people's behavior to reduce future incidence may be unsuccessful if people are not first convinced through an information program of the need for changing their behavior (Stedman et al. 1991). Lack of public response to the real dangers associated with radon (Brenner 1989) is a classic example of the importance of both perceived and actual risks in environmental risk management.

Cost, another factor typically considered in risk management, may include the costs created by the hazard (e.g., dollar damage from deer/car collisions), costs of controlling the hazard (e.g., fencing for orchards, deer-crossing road signs, time and equipment used in removing individual damage-causing deer), and lost or relinquished benefits that may be caused through hazard-control activities (e.g., lost hunting opportunities from a reduced deer population).

Similarly, benefits provided by the same wildlife population that is considered a hazard are an important component of risk management deliberations. Benefits may include aesthetic deer observation opportunities, deer hunting activities, expenditures and multiplying effects from purchases related to deer recreation, and psychological well-being from knowledge about or interactions with deer.

Finally, overall management agency goals and philosophy guide risk management decisions. Although not always stated explicitly, mandates and goals indicate the hazards for which an agency has responsibility and what types of management concerns should be balanced in decision-making.

Overall management agency philosophy influences how those mandates and goals are interpreted and acted upon. In New York State, for example, the New York State Department of Environmental Conservation (NYSDEC) Division of Fish and Wildlife is charged with "the efficient management of the fish and wildlife resources of the state . . . to promote natural propagation and maintenance of desirable species in ecological balance . . . [considering] ecological factors . . . the compatibility of production and harvesting of fish and wildlife crops with other necessary or desirable land uses, . . . [and] requirements for public safety . . ." (Environmental Conservation Law of New York State 1992).

NYSDEC Bureau of Wildlife (BOW), therefore, has responsibility for maintaining deer (assuming deer is a desirable species) in combination with other desirable land uses, while providing for human health and safety. A risk management framework can aid wildlife managers by making more explicit the considerations that enter into decisions about the desirability of deer and of providing for various land uses, balanced with the associated perceived and actual human safety concerns.

Combining Deer Management and Risk Management Concepts

Adding risk considerations to deer management decisions encourages wildlife managers to assess public perceptions and opinions about the various risks associated with deer, and compare those perceptions with public behavior and actual incidence of deer problems. Each of the important wildlife management dimensions is considered regarding perceived and actual risks and benefits, including organismal, environmental, social and institutional dimensions (Figure 1). As wildlife managers set deer population objectives in this framework, they are expected to be informed about the opinions and behaviors of various stakeholders, and can identify an array of biologically and socially oriented management actions to respond both to the perceived risk from wildlife/human interactions and the actual incidence of negative kinds of such interactions.

If perceived risks differ greatly from actual incidence, more emphasis may be placed on management options in the social dimension (Table 1). Management or research objectives may include understanding more completely why perceived risks differ from actual incidence, modifying perceived risks to correspond more closely to actual incidence or decreasing actual incidence by modifying human behavior. Several factors may affect risk perception (Merkhofer 1987), including the perceived incidence of a hazard (e.g., deer/car collisions), prior experience with the hazard, ability to tolerate the hazard (e.g., acceptance of deer-caused crop damage) and perceived benefits associated with the hazard (e.g., ecological values) (Stedman et al. 1991). When factors influencing perceived risks are understood, wildlife managers can decide to focus management actions on modifying actual and/or perceived incidence of deer-related problems, or perceptions associated with personal and/or societal benefits derived from deer. Risk communication programs are designed specifically to influence the social dimension of natural resource management problems through modifying human attitudes and behavior (e.g., Knuth 1990).

Management actions targeted at modifying actual incidence of deer-related problems may involve any of the four management dimensions (Table 1). Organismal actions might target reductions in the deer population through reproduction controls. Environmental actions might target reductions in crop damage by modifying the habitat with deer exclosures or chemical repellents. Social actions might target human behavior, informing people about safer driving habits that could reduce deer/car

Table 1. Example risk management options for white-tailed deer.

Management dimension	Management option examples
	Modify or maintain actual or perceived incidence of risks and benefits by:
Organismal	Modifying or maintaining deer population size (e.g., conduct population research, implant fertility controls, harvest antlerless deer)
Environmental	Modifying or maintaining habitat availability or quality (e.g., assess habitat use, construct deer exclosures, establish food plots)
Social	Modifying or maintaining people's attitudes and behaviors (e.g., assess perceived incidence and other factors associated with overall risk perception, provide landowner incentives to allow hunter access, implement education programs to communicate protective measures individuals can take to reduce their chances of exposure to disease, communicate benefits deer provide)
Institutional	Modifying or maintaining administrative and political components (e.g., lessen statutory constraints on management, institute cooperative relationships with other agencies, allocate staff time and money for compensation payment, evaluate current deer management procedures)

collisions. Institutional actions might target management agency capabilities by increasing the staff or other resources devoted to addressing deer-related problems.

In the following section, we review nine studies conducted by the Human Dimensions Research Unit in the Department of Natural Resources at Cornell University. These studies assessed New York State residents' perceptions of risk from interactions with white-tailed deer. Risks included property damage (e.g., browsing on agricultural field crops and ornamental plantings), nuisance problems (e.g., damage to noncommercial gardens), and human health and safety concerns (e.g., vehicle collisions, Lyme disease).

Lessons from White-tailed Deer Research

Property Damage

Decker et al. (1982) examined the relationship between number of deer and farmers' tolerance of deer through a comparison of deer damage studies conducted in New York over a five-year time period. Types of farming included tree fruits, small fruits, grapes, green vegetables, corn, wheat, hay, forest plantations, woodlands and other farm crops. The study evaluated the effect of actual incidence of deer damage and perceived changes in the deer population size on farmers' perceptions and tolerance of deer damage and attitudes about deer.

In the Decker et al. (1982) study, the majority of farmers reported no deer damage. Some farmers perceived the size of the deer population to be increasing, reflecting accurately actual deer population trends over the five years. Farmers who reported deer damage were more likely to perceive that the deer population was increasing than those who had not experienced damage. Damage reports at the end of the five years indicated more damage than in earlier years. More farmers worried about deer damage at the end of the period, although most considered deer aesthetically valuable. By the end of the five years, fewer farmers preferred an increase in the deer population and more preferred a decrease than in earlier years. The authors concluded that three considerations are important when developing deer population management objectives in relation to farmers: relative tolerance (or intolerance) of deer numbers; relative tolerance (or intolerance) of monetary loss from damage; and percent of tolerance change attributable to deer damage. Farmers' monetary losses from deer damage were not related directly to attitudes about or tolerance for deer.

Results from Decker et al. (1982) indicate a disparity between the actual change in the deer population size and the change farmers perceive. A higher deer population size was not perceived until the farmer experienced damage, highlighting the need to consider both actual and perceived risks. The importance of tolerance of deer population size and of monetary losses in contributing to attitudes about deer population management confirm the importance of the social dimension of deer risk management.

In another study of property damage, Decker and Brown (1982) analyzed the relationship between deer damage incurred by full-time fruit growers and other types of farmers, and preferences for deer population size. Fruit growers reported more financial losses than other farmers, although their percent of total crop loss was comparable to or less than that of other farmers. Fruit growers, however, were twice as likely as other farmers to describe their damage as "substantial" or "severe," consider their damage "unreasonable," "worry about crop damage," and prefer a decrease in deer population size. Fruit growers without damage were more worried about deer than other farmers without damage, but did not differ in their deer population preference. Conversely, significantly more fruit growers with damage than other farmers with damage preferred a decrease in the deer population.

Decker and Brown (1982) concluded that a deer population desired by non-fruit farmers could be maintained satisfactorily if damage to commercial fruits could be mitigated through damage control assistance or reparation for damage incurred. Without such mitigation or compensation, deer population size would have to be lower to protect fruit crops. The authors also suggested that if deer population size was increased for recreational opportunities, then mitigation for damage to other crops might be needed as well. This study confirms the need to consider the perceptions of various stakeholders regarding risks and benefits associated with deer and the impacts (negative and positive) each will experience from different population levels.

Purdy et al. (1989) focused on deer damage incurred by fruit growers, and attitudes toward deer and deer damage held by adjacent landowners and deer hunters. Most fruit growers reported deer damage to their crops, and a majority believed the deer population was too high. A majority of growers believed that deer congregated on adjacent, posted lands and that part of their deer damage was attributable to deer from these adjacent, nonhunted lands.

Purdy et al. (1989) found that some adjacent landowners experienced damage to fruit trees, gardens and ornamental plantings, but the majority described the damage as light. About half of the landowners were satisfied with the deer population size, and more than one third desired a higher deer population size. Half of the landowners recognized that fruit growers were experiencing deer damage, but most believed growers should accept "moderate" amounts of damage. Very few landowners realized that their denial of hunting access could create refugia for deer and exacerbate deer damage to nearby fruit production.

Nearly all deer hunters in the Purdy et al. (1989) study recognized that fruit growers were experiencing deer damage. Hunters believed posting of private land was the key factor associated with deer damage to orchards, and almost half of the hunters indicated they would be willing to pay for access to private land. Only a slight majority of hunters had applied for a permit to harvest anterless deer.

The Purdy et al. (1989) study demonstrated that landowners adjacent to orchards and deer hunters shared, to some extent, a recognition that fruit growers were experiencing deer damage. However, the behaviors of landowners and hunters did not indicate an awareness of their ability (or perhaps a willingness) to assist growers in potentially reducing the levels of damage experienced. Risk communication programs that foster an understanding of the links between personal behavior (e.g., allowing free or fee access, hunting anterless deer) and deer damage impacts experienced by growers may help change hunter and landowner behaviors and contribute to reduced deer damage. Communication programs could focus on the interactions among the management dimensions, highlighting how human behavior (social dimension) and regulations (institutional dimension) influence the deer population size (organismal dimension), and thus, deer damage experienced (environmental and social dimensions).

A final property damage study (Sayre and Decker 1990) compared the deer damage experiences and perceptions of the three audiences (nursery producers, landscape contractors and residential property owners) in two geographic regions of New York State. Regional differences in deer damage acceptance indicated past experience may have a strong influence on risk perception. People living or working in areas in which deer damage had existed longer were more likely to label a certain level of damage "slight" compared to people where deer damage was more recent, who would label a similar level of damage as "severe." Risk communication programs can help people put the risk they are experiencing in perspective, and can help foster an understanding of the various factors managers must consider when making deer population management decisions. Differences in importance citizens place on deer-related risks may be considered by managers as one factor in setting priorities and allocating management resources for modifying deer populations in various geographic regions.

Nuisance Problems

We separated nuisance problems from property damage according to the potential impact of the damage on a person's economic livelihood (i.e., nuisances are less costly than property damage). Nuisance deer studies reported here focus on homeowner attitudes toward deer and experiences with deer damage.

Decker and Gavin (1987) studied homeowners living adjacent to a National Wildlife Refuge (Seatuck, Suffolk County, New York). About one quarter of the residents experienced plant damage, but most described it as moderate to slight. Residents were far more concerned about human health and safety concerns (e.g., Lyme disease, deer/car collisions) than about plant damage. Even those who experienced plant damage were more concerned about Lyme disease. Deer were generally considered an asset to the community, although almost one third of the residents enjoyed deer but worried about the problems they could cause. One-fifth of those experiencing damage considered deer a nuisance. The authors concluded that managers should measure the costs involved with deer populations, and realize that a broad constituency may have widely varying perceptions and preferences about appropriate deer population management objectives. This study also demonstrated that negative perceptions about deer are likely linked to the type of risk posed. Nuisance and minor property damage may be inherently less worrisome risks than human health and safety concerns.

Connelly et al. (1987) also examined residents' perceptions about deer damage and attitudes toward deer in a suburban environment. Although almost half of the residents reported plant damage, more people were concerned about Lyme disease and deer/car collisions than plant damage. A majority of residents enjoyed deer but worried about problems they might cause. Deer population size preferences varied according to the primary concern residents held about deer. Among residents whose greatest concern was deer/car collisions, 34 percent desired a deer population decrease. If Lyme disease was the primary concern, 46 percent desired a population decrease. If plant damage was the primary concern, 82 percent of residents desired a deer population decrease.

To put these population preferences in context, managers also would want to understand the actual incidence of each of these deer problems, but these data are not available from this study. Actual incidence may help managers understand why one type of deer risk is more strongly associated with desires for a reduced deer population size than other risks. Incidence, however, may not be the only factor influencing deer population preferences. Other factors, such as personal control over the problem and benefits associated with deer, may influence perceived risk and, thus, deer population preferences (Stedman et al. 1991). Connelly et al. (1987) noted that residents expressed concerns not only about problems caused by deer, but also about one method of deer population control, hunting. Especially in suburban situations, wildlife managers may face a decision between neglecting the public desire for deer population control and reduced deer damage, or neglecting public concern about hunting if alternative management options cannot be identified. Assessments of human attitudes and values may be an appropriate management option to improve future deer population management decisions. Managers may have to make tradeoffs between the perceived risks posed by a deer population and the perceived risks associated with hunting.

Human Health and Safety Concerns

Two HDRU studies focused on risks related to deer/car collisions. Decker et al. (1990) estimated the actual number of deer-related vehicle accidents (including collisions) in Tompkins County, New York. Nearly one-third of county residents had experienced a deer-related accident, with an average damage claim paid by insurance companies of $1,415. The authors estimated deer-related accidents cost approximately $1.5 million in the county in one year.

Stedman et al. (1991) conducted a followup to the Decker et al. (1990) study, focusing on the perceived risks associated with deer-related accidents. A majority of residents knew someone who had been involved in such an accident, but a majority also believed their personal chance of being in a deer-related accident was low. A large majority of residents (90 percent) enjoyed deer, but 60 percent also worried about problems they could cause. The two primary concerns expressed were deer/car accidents and Lyme disease, although Lyme disease had never been contracted within the county at the time of the study.

The perceived costs associated with deer contributed to preferences for fewer deer (Stedman et al. 1991). Considering the status quo regarding deer/car accidents, 37 percent of residents desired a decreased deer population. However, if accidents could be eliminated, only 17 percent would still desire a deer population reduction. The authors demonstrated the importance of several factors on deer population preference, including past involvement with deer/car accidents, perceived chance of being in an accident, acceptance of deer-related problems and importance to the individual of deer-related benefits, such as ecological, educational, existence and environmental quality values. This study confirmed the importance of considering both benefits and risks associated with deer in deer management decisions, and indicated that a combination of organismal (deer population control) and social (attitude and behavior change) management strategies may be desirable for managing deer-related risks.

Knuth and Siemer (unpublished data) focused on people's concerns toward Lyme disease, and their associated attitudes toward wildlife. Two locations were studied, one with a relatively long history of human Lyme disease cases, the other with a relatively recent exposure to Lyme disease. In both locations, a majority of people wanted the deer population to remain the same or decrease in size; they believed that controlling human health risks should be a top priority in making deer management decisions. People residing in the location having a longer history of Lyme disease were much more likely to have had some personal experience with the disease, either through family or friends. They also demonstrated greater knowledge about the disease than those in the location with a shorter history of Lyme disease. Overall risk perception was associated with several variables, including the perceived likelihood and control over contracting Lyme disease, and perceived seriousness of the disease. Results indicated that the length of time exposed to a deer problem is important in modifying people's attitudes toward Lyme disease and associated wildlife and land-management concerns. Decker et al. (1982) also reported that exposure time had an effect on attitudes associated with property damage. The first experience with deer damage (even if relatively minor) greatly affected attitudes toward deer. If time is important to the social dimension of risk management associated with deer, managers can adopt a ''wait-it-out'' strategy and wait for people to become more tolerant of deer problems, or may develop education strategies designed to accelerate the process of gaining familiarity with deer problems by becoming aware of such problems experienced by others. However, Decker and Brown (1982) offered evidence that awareness of deer damage problems without actually experiencing them could lead to anxiety associated with anticipation of problems occurring. Education programs would have to be designed carefully to limit anxiety, while producing desirable attitude and behavior change.

Implications for Managing Risks Associated with White-tailed Deer

These studies demonstrate the applicability of risk management concepts for guiding wildlife population decisions, as well as identifying alternative management actions that seek a balance between positive and negative outcomes associated with human/deer interactions. Perceived risks may not correspond to actual incidence, yet perceived incidence of problems may be an important contributor to an overall preference for deer population size. Deer population preferences also may be affected by perceived benefits from deer, knowledge of other stakeholders' concerns, and perceived severity or importance of a particular deer-related problem.

Wildlife managers must decide when it is appropriate to modify institutional management dimensions (e.g., reallocate staff time), organismal dimensions (e.g., reduce deer population size), environmental dimensions (e.g., provide deer exclosures) and/or social dimensions (e.g., increase public tolerance of deer damage) to address deer risk problems. An explicit consideration of perceived and actual risks and benefits in each of the four management dimensions should aid this decision process. We believe the risk management framework can be a useful conceptual tool for integrating the human and biological dimensions, and risks and benefits of wildlife management.

References

Bishop, R. C. 1987. Economic values defined. Pages 24–33 *in* D. J. Decker and G. R. Goff, eds., Valuing wildlife: Economic and social perspectives. Westview Press, Boulder, CO. 424 pp.

Brenner, D. J. 1989. Radon: Risk and remedy. W. H. Freeman, New York, NY. 225 pp.

Brown, T. L., D. J. Decker and C. P. Dawson. 1978. Willingness of New York farmers to incur white-tailed deer damage. Wildl. Soc. Bull. 6(4):235–239.

Connelly, N. A., D. J. Decker, and S. Wear. 1987. White-tailed deer in Westchester County, New York: Public perceptions and preferences. HDRU Series Rep. 87–5. Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. 80 pp.

Curtis, P. D. and D. J. Decker. 1990. Wildlife damage management needs in New York State: Perceptions of Cornell Cooperative Extension: Cornell Coop. Ext., Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. 29 pp.

Decker, D. J. and T. L. Brown. 1982. Deer management in New York's Hudson Valley Region: An assessment of the interests and opinions of three key constituencies. Wildl. Soc. Bull. 13:228–233.

Decker, D. J. and T. A. Gavin. 1987. Public attitudes towards a suburban deer herd. Wildl. Soc. Bull. 15:173–180.

Decker, D. J. and G. R. Goff, eds. 1987. Valuing wildlife: Economic and social perspectives. Westview Special Studies in Natural Resources and Energy Management. Westview Press, Boulder, CO. 424 pp.

Decker, D. J. and K. M. Loconti. 1989. When two worlds collide: A look at deer/car accidents in New York. The Conservationist 44(3):44–47.

Decker, D. J., K. M. Loconti Lee, and N. A. Connelly. 1990. Deer-related vehicular accidents in Tompkins County, New York: Incidence, costs, and implications for deer management. Trans. N.E. Sect. Wildl. Soc. 47:21–26.

Decker, D. J., N. Sanyal, R. A. Smolka, Jr., N. A. Connelly, and T. L. Brown. 1982. Reanalysis of farmer willingness to tolerate deer damage in western New York. Pages 37–45 *in* D. J. Decker, ed., Proc. 1st East. Wildl. Damage Control Conf., Coop Ext., Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. 379 pp.

Dolbeer, R., M. Chevalier, P. Woronecki, and E. Butler. 1989. Laughing gulls at JFK Airport: Safety hazard or wildlife resource. Pages 37–44 *in* S. R. Craven, ed., Proc. 4th East. Wildl. Damage Control Conf., Coop. Ext. Serv., Univ. Wisconsin, Madison. 258 pp.

Enck, J. W. and T. L. Brown. 1989. Animal deterrents for electrical substations. Empire State Electric Energy Corp., New York, NY. 97 pp.

Enck, J. W., K. G. Purdy, and D. J. Decker. 1989. Public acceptance of beavers and beaver damage in wildlife management unit 14 in DEC Region 4. HDRU Series Rept. 88–1. Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. 29 pp.

Knuth, B. A. 1990. Risk communication: A new dimensions in sport-fisheries management. North American J. Fisheries Manage. 10(4):374–381.

Knuth, B. A. and L. A. Nielsen. 1989. Social and institutional performance indicators for wildlife and fishery resource management systems. Soc. Nat. Resour. 4:351–366.

Merkhofer, M. W. 1987. Decision science and social risk management. D. Reidel Publ. Co., Boston, MA. 330 pp.

Peyton, R. B. 1984. A typology of natural resource issues with implications for resource management and education. Michigan Academician 17:49–58.

Purdy, K. G. 1987. Landowners' willingness to tolerate white-tailed deer damage in New York: An overview of research and management response. Pages 371–375 *in* D. J. Decker and G. R. Goff, eds., Valuing wildlife: Economic and social perspectives. Westview Press, Boulder, CO. 424 pp.

Purdy, K. G., T. L. Brown, D. J. Decker, and J. W. Enck. 1989. Deer management in New York's Hudson Valley Region: An assessment of the interests and opinions of three key constituencies. HDRU Series Rept. 89–1. Dept. Nat. Resour., New York State Coll. of Agric. and Life Sci., Cornell Univ., Ithaca. 34 pp.

Stedman, R. C., R. J. Stout, B. A. Knuth, and D. J. Decker. 1991. Risk perceptions and tolerance of deer-related vehicle accidents: A pilot study of residents in Tompkins County, New York. Abstract. Proc. 5th East. Wildl. Damage Control Conf., Coop. Ext., Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. In press.

Sayre, R. W. and D. J. Decker. 1990. Deer damage to the ornamental horticulture industry in suburban New York: Extent, nature, and economic impact. HDRU Series Rept. 90–1, Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. 75 pp.

Spencer, D. A. 1983. Animal damage control in the eastern United States. Pages 17–25 *in* D. J. Decker, ed., Proc. 1st East. Wildl. Damage Control Conf., Coop. Ext., Dept. Nat. Resour., New York State Coll. Agric. and Life Sci., Cornell Univ., Ithaca. 379 pp.

United States Environmental Protection Agency. 1984. Risk assessment and management: Framework for decision making. USEPA, Washington, D.C. 35 pp.

Walker, T. C. and C. W. Bennett. 1983. Apparent efficacy of bird aircraft strike hazard programs at four naval air stations. Pages 115–121 *in* P. T. Bromley, ed., Proc. 2nd East. Wildl. Damage Control Conf., Raleigh, NC. 281 pp.

Survey Use and Landowner Tolerance in Wildlife Damage Management

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Surveys have been used widely for data collection in many scientific, social and business applications, and are part of our everyday life. Wildlife managers frequently have turned to postal surveys as the information base for wildlife damage management programs (Pomerantz et al. 1986, Siemer and Decker 1991). This trend is understandable, given the magnitude and diversity of wildlife damage problems in the United States (USDA/APHIS, Draft EIS 1990) and the difficulty and expense involved in the collection of field data over extensive areas and time frames.

Surveys have been used to document the characteristics and magnitude of wildlife damage and stakeholders' tolerance levels, knowledge base, and wildlife management preferences (Pomerantz et al. 1986). Conover and Decker (1991) noted that, in the absence of such survey data, controversies may arise because stakeholder groups (such as farmers) feel that managers are unaware of damage or insensitive to problems. de Calesta and Schwendeman (1978) emphasized the importance of data on the characteristics of damage before practical and effective control methods could be implemented. Heinrich and Craven (1992) pointed out how a lack of data on farmer attitudes and goose damage hampered goose management in Wisconsin.

McDowell and Pillsbury (1959) conducted the first broad-scale survey of wildlife damage when they polled state agencies in 1957. Early surveys concentrated on the magnitude of wildlife damage and the species involved. In the 1960s, the concepts of social implications and tolerance were incorporated in surveys (McDowell and Benson 1960, McNeil 1962, Flyger and Thoerig 1962). The next surge of survey activity occurred in New York (Brown et al. 1978a, 1978b, 1979, 1980, Brown and Decker 1979). The New York research (Brown et al. 1978a) stimulated a wave of similar surveys in other states. Pomerantz et al. (1986) identified 23 studies of wildlife damage and stakeholder tolerance conducted between 1957 and 1985. State, federal and independent investigators continue to collect data and report on the magnitude and distribution of wildlife damage (Phillips and Blon 1988, Anonymous 1990a, Anonymous 1990b, Anonymous 1991, Hafer and Hygnstrom 1991, Hygnstrom and Craven 1991). Siemer and Decker (1991) updated the research summary of Pomerantz et al. (1986) and synthesized the management implications of the collective survey data base to date with an emphasis on stakeholder tolerance of wildlife damage.

Building on this base of survey experience, we discuss the practical use of survey data and the integration of such data into wildlife management programs. In many cases, recent surveys have utilized modified versions of the New York questionnaire (Brown and Decker 1979, Brown et al. 1978a) as their survey vehicle. Also, the majority of recent surveys (Siemer and Decker 1991) have focused on white-tailed deer (*Odocoileus virginianus*). Thus, responses, such as tolerance, and logistic parameters, such as response rates, can be generalized, and comparisons can be made among areas and over time. Generalizations may reduce the perceived need for managers to replicate extensive and expensive surveys. We also will alert managers and resource policy makers to potential abuse and misinterpretation of survey data.

Stakeholder Tolerance

As identified by numerous authors (Siemer and Decker 1991), tolerance is a key parameter measured by surveys. Tolerance, as such, may impose upper bounds on the population objective for wildlife populations. If this upper bound is below the population objective of other stakeholder groups for the same population, the wildlife management agency must strike a balance between the competing interests (Decker and Purdy 1988).

Tolerance has been evaluated in several ways, often within the same survey. For example, tolerance may be expressed as a percentage of survey respondents who rate damage as "unacceptable" or "intolerable." It also may be indexed by considering the proportion of respondents who desire a reduction in the population causing the damage. Most often, tolerance is measured by calculating the amount of monetary losses below which most survey respondents rate damage as low, acceptable or tolerable. Tolerance then becomes the threshold level of damage, above which stakeholders are likely to seek mitigation, compensation or a wildlife population management response.

Factors that Influence Tolerance of Wildlife Damage

Tolerance of wildlife damage varies with: type, amount and severity of damage; ability to withstand the economic consequences of damage; personal attitudes toward wildlife and the species involved; perceptions of population trends; and attitudes toward hunting. We will draw heavily on the work of Siemer and Decker (1991) to describe current understanding of the relationship between these factors and wildlife damage tolerance. Then, we will illustrate how wildlife managers have integrated and applied these findings to the process of developing a wildlife management program.

Amount of Damage

As would be expected, tolerance decreases as perceived amounts of damage or severity of damage increase (Brown et al. 1980, Decker and Brown 1982, Stoll and Mountz 1983, Decker et al. 1984b, Decker and Gavin 1985, Purdy and Decker 1985, Enck et al. 1988). But, the amount of damage that is defined as intolerable varies among stakeholder groups. For instance, New York suburban residents (Decker and Gavin 1985, Connelly et al. 1987) and rural farmers (Brown et al. 1980) reported that deer damage was intolerable when they suffered an average of $1,000 in damage to their shrubs and crops, respectively, over the course of a year. However, on average, Virginia Christmas tree growers did not describe deer damage as severe until it exceeded $5,700, and described anything below $1,000 as moderate (Jones 1984). Missouri farmers described damage as intolerable when it exceeded $465 per year (Porath et al. 1984). The average amount of beaver (*Castor canadensis*) damage considered intolerable by New York landowners was about $3,000 (Enck et al. 1988). Thus, people who experience similar levels of economic loss often express dissimilar levels of damage tolerance.

Farmers' and rural landowners' tolerance of deer is most strongly influenced by concerns about crop damage (Brown et al. 1977, 1978a, 1978b), whereas tolerance of deer among residents in suburban environments is more often influenced by perceptions of health and/or safety risks (Decker and Gavin 1985, Connelly et al. 1987, Decker et al. 1989). Landowners who derive a moderate to high proportion of their income from their land (e.g., orchardists, row-crop farmers, ornamental horticulturists, timber producers) are less tolerant of wildlife damage than other landowners (Brown et al. 1980, Decker et al. 1981, Decker and Brown 1982, Tanner and Dimmick 1984, Purdy and Decker 1985, Enck et al. 1988, Sayre and Decker 1990). Of the various types of agricultural producers, orchardists are least tolerant of deer damage. Landowners with cash crops or those who produce commercial timber are less tolerant of beaver damage than those who own the land primarily as homesites. Dependency on the economic productivity of the land is the strongest factor motivating these landowners to invest time and money in measures to control wildlife damage (Tatro 1986, Siemer et al. 1991).

Most landowners are willing to tolerate some deer damage because they enjoy the presence of deer on their property for aesthetic or recreational reasons (Brown et al. 1980, Stoll and Mountz 1983, Tanner and Dimmick 1984, Wisconsin Department of Agriculture and University of Wisconsin 1984, Decker and Gavin 1985, Connelly et al. 1987, Purdy et al. 1989). This is especially true for people who hold positive attitudes about the ecological, educational and appreciative values of wildlife (Purdy and Decker 1985, Enck et al. 1988, Decker et al. 1989). Damage tolerance attitudes are diminished, however, by other factors, such as economic dependency on the land being damaged. The aesthetic value of wildlife can be exceeded by the cost of damage to crops (Decker and Brown 1982, Purdy and Decker 1985, Purdy et al. 1989). Aesthetic appreciation for wildlife also is countered by concerns other than experience with damage. For example, in suburban environments of southern New York, concerns about the potential to contract Lyme disease or to have a deer/car collision cause people to worry about the presence of deer (Decker and Gavin 1985, Connelly et al. 1987, Decker et al. 1989).

An additional factor in tolerance determination may relate to awareness of a wildlife damage problem and peer pressure. Decker et al. (1984a) replicated Brown's (1978a) survey of New York farmers and detected a shift in the opinion of farmers who reported "no damage" caused by deer. In the second survey, the percentage of farmers "worried" about damage increased, but the percentage of farmers with losses did not. Hygnstrom and Craven (unpublished data) also noted a reduction in several measures of tolerance in a deer damage survey replicated over a four-year period (1981–84) in Wisconsin. In both cases, deer populations had increased, but in Wisconsin, and perhaps New York, there was a very aggressive media campaign to increase public awareness of deer damage. Monetary loss figures were touted as a serious problem to state farmers. We suggest that publicity and peer experience may play a significant role in tolerance determination.

As an example of this effect, the senior author was contacted by several farmers after he conducted a survey on wild turkey (*Maleagris gallopavo*) damage (Craven 1989). Turkeys were reintroduced into southwestern Wisconsin in 1976 and the population quickly expanded. With the growth in turkey numbers, there was an outbreak of farmer concern about turkey damage. Although wildlife managers were rarely able to document any crop loss caused by turkeys, perception ruled farmer opinion. In one case, a farmer visited at the senior author's office and expressed a desire to discuss turkey damage. The farmer was visibly upset and went on to relate his fears of the potential loss of his family farm because of severe turkey damage. When questioned about the number of turkeys involved, the farmer stated that he had yet to *see* a turkey on his farm but that he was convinced by friends and neighbors who had been "exposed" to turkeys that the potential for disaster existed. Such perceptions directly affect tolerance and cannot be ignored in wildlife management programs (Craven 1988). Surveys provide an excellent vehicle for managers to evaluate both perceptions and management programs.

Attitudes and Wildlife Damage Control

Little research has been directed at understanding the relationships between people's attitudes about damage and the likelihood that they will take action to reduce or minimize damage potential. The individual faced with a wildlife damage problem can take several courses of damage control action: accept or tolerate the damage; remove offending animals; eliminate or alter the habitat supporting the offending animals; or alter the situation in a way that reduces or minimizes the damage potential (Spencer 1983).

A study of fruit growers in New York (Siemer et al. 1991) suggests that people may not take damage control actions, even when they believe the damage they have incurred is "severe" or "intolerable." Also, people who may be motivated to prevent or control damage may encounter any number of social, economic or other barriers to prevent them from taking action. Three common barriers identified by Siemer et al. (1991) involve opportunity,skills and social desirability.

Opportunity

An array of potential control actions can be taken for some types of wildlife damage. But, even when people find control techniques that are acceptable, and have faith in their effectiveness, some will not actually use these potential tools due to perceived or real expense, availability, or legality.

Skills

When people find a particular damage control technique available and affordable, they may not believe they have the skills to use it effectively. For example, homeowners experiencing damage to garden plants may not believe they have the skills to use chemical repellents effectively. Orchardists experiencing deer damage may feel strongly that they should pursue legislation effecting lower deer populations in agricultural areas, but a perception of limited communication or political skills can impede personal involvement in legislative pursuits.

Social Desirability

Persons with the opportunity, skills and inclination to use a given wildlife damage control technique still may not do so if opposition from friends, family or community is great. For example, farmers incurring crop damage may not seek a special permit to destroy deer on their farms because utilizing such a permit would meet with disapproval by family members or friends. For some farmers, the negative social consequences of killing depredating deer may be more significant than the damage they wish to prevent. Thus, social desirability can be an important factor contributing to the use of potential damage management strategies.

Stakeholders and Wildlife Populations

Surveys generally contain questions about current wildlife populations, trends and future preferences for wildlife populations. If stakeholders are accurate in their assessment of population size and trends, then useful generalizations can be made between real population fluctuations and changes in tolerance, losses and other parameters of damage.

Dramatic changes in conspicuous species were readily detected. In Wisconsin, 86 percent of farmers correctly recognized a rapid population increase in wild turkeys (Craven 1988). Eighty-five percent of Nebraska sheep producers who were surveyed reported that the number of coyotes (*Canis latrans*) increased substantially from 1985 to 1990. This was consistent with reports that coyote populations had increased substantially in response to decreased hunting and trapping and increased cover available through the Conservation Reserve Program (C. S. Brown, USDA/APHIS/Nebraska Animal Damage Control and K. L. Johnson, Nebraska Game and Parks Comm. personal communications). However, with species that are generally more secretive or relatively less abundant, the ability to detect changes decreased. Decker et al. (1984b) reported that 35 percent of farmers in New York correctly recognized changes in deer population. Only 12 percent of New York landowners were able to detect changes in black bear (*Ursus americanus*) populations (Decker et al. 1985).

Decker et al. (1984b) concluded that farmers were not always able to detect changes in deer numbers, but they responded to their perceptions of change with changes in attitude and management preference. The magnitude of attitudinal change, however, was not clearly related to level of change in deer numbers. Farmers with a history of deer damage were less likely to correctly detect deer population changes than were farmers with no damage experience. Decker et al. (1984b) went on to state that such findings should be disappointing to wildlife managers because straightforward relationships do not exist and, therefore, general predictions of responses to deer population changes cannot be made with confidence.

Regardless of the true or perceived base population levels, surveys clearly indicate stakeholders' preferences for direction of change. In most random-sample surveys, the majority of respondents favored the status quo in population level (Pomerantz et al. 1986). However, as sustained damage levels increased, preferences tended toward a reduction in population size (Decker et al. 1984a, Kube 1983, Phillips 1980, Tanner and Dimmick 1984, Wisconsin Department of Agriculture and University of Wisconsin 1984, Purdy and Decker 1985). Regional variation in management preference detected by Pomerantz et al. (1986) was related more to perceived damage levels and tolerance than to any differences between geographic areas. Deer damage surveys conducted in the western United States reported levels of tolerance and preferred deer herd reduction comparable to studies in eastern states (Phillips 1980, Trindle and Menzel 1989).

Surveys also have been used to evaluate stakeholders' support for various management strategies directed at their desired change in population levels. Craven (1989) reported that, among several options to reduce wild turkey populations, farmers favored a fall hunting season even over financial compensation for damage.

Impacts of Survey Data on Management

Wildlife damage considerations, often generated by surveys, are becoming an important factor in management decisions. In 1987, 90 percent of wildlife agency representatives indicated that their agency manipulated hunting seasons and bag limits to alleviate damage. Agencies also offer an increased level of technical assistance to those who suffer wildlife damage when compared to services available 30 years ago (Conover and Decker 1991). In Wisconsin, farmer tolerance and damage levels are considered in setting over-winter population goals of deer management units.

Tolerance levels generated by surveys have been used to set "deductible" levels for wildlife damage compensation programs (Craven 1984, Heinrich and Craven 1988). Survey data on stakeholder tolerance and preferences have been incorporated into a concept analogous to biological carrying capacity for deer in New York (Decker and Purdy 1988, Siemer and Decker 1991) and coyotes in Oregon (de Calesta 1978). This Wildlife Acceptance Capacity (WAC) standardizes the management preferences of diverse stakeholders and therefore, allows managers to assess the relationship between a wildlife population objective and the preference of a range of stakeholders. Thus, management plans can strive for compromise in the development of population objectives and target specific groups for which techniques must be identified and applied to raise or lower the WAC.

In the absence of an approach, such as the WAC, when tolerance levels are exceeded, stakeholders may turn to external forces for relief. For example, a state legislature may respond to constituent concerns and mandate a change in wildlife management policy. Vocal farmers in Wisconsin achieved a reduction in wildlife damage claim deductible levels, changes in deer shooting permit allocation and additional funds for damage claim payments via legislative initiative. Such changes are not necessarily bad. However, with survey-generated data on tolerance levels or preferences, wildlife managers are in a position to be proactive. Legislative mandates may not consider wildlife populations, professional opinion and all stakeholders as evenly as they treat the proponents of the change.

Considering Stakeholder Concerns about Wildlife Damage in Management Programs

In most wildlife management agencies, program development follows the same basic planning cycle: a broad goal is established for management; managers gather information (e.g., biological, social and fiscal information) and set objectives; they plan, develop, prioritize and implement actions; then they evaluate outcomes and revise the program where necessary. Ongoing mechanisms of communication, including systematic surveys with stakeholder groups, provide vital feedback, completing a cycle of management that includes public input (Freeman 1984).

In Figure 1 we have highlighted some of the key considerations and interactions between wildlife managers and the public during a management planning cycle for any species that generates stakeholder concern about wildlife damage. As a general illustration, we describe key points in a typical beaver management scenario. The figure depicts how public input on wildlife damage concerns can be considered in management decisions and how management actions can, in turn, affect the public's perceptions, attitudes and behaviors with respect to wildlife damage.

For any given species, many publics have an interest or ''stake'' in management. Beaver management stakeholder groups include forest owners, highway superintendents, row-crop farmers, waterfowl hunters, trappers and many others. These stakeholders bring to the management process a range of beliefs, values, attitudes and interests (Figure 1–A). Among these is a demand for relief from damage that beaver may cause by flooding fields, forests and roads.

Based on their interests and experiences, each stakeholder forms specific attitudes and a specific level of tolerance for a particular species, such as beaver (Figure 1–B). Stakeholders may express their attitudes through any number of behaviors (Figure 1–D). For beaver, stakeholders' attitudes are expressed as damage control actions,

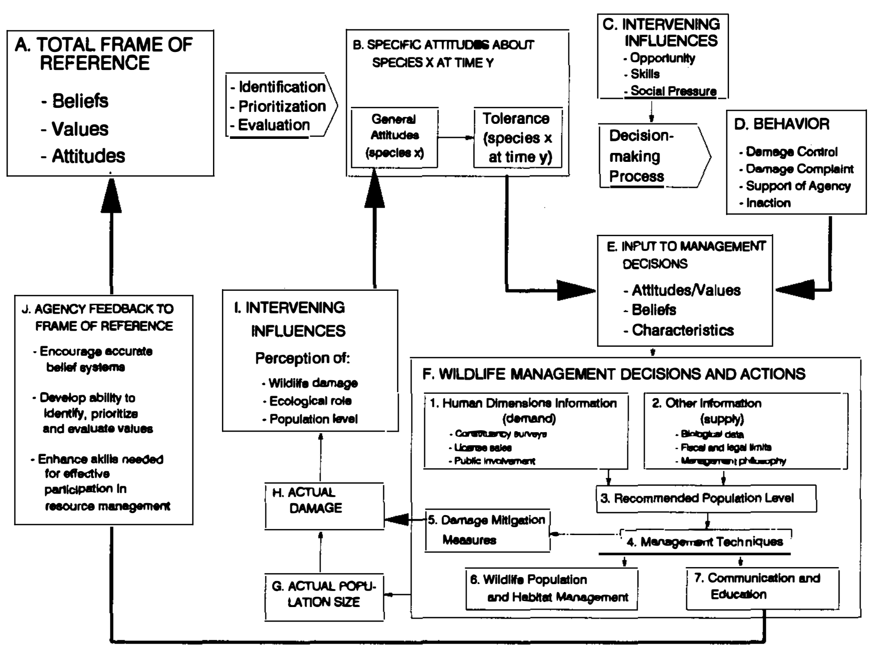

Figure 1. A conceptual model of the development of human beliefs, attitudes and preferences about wildlife damage, and their incorporation into wildlife management decisions.

complaints to the wildlife management agency, and support or opposition to existing beaver management policy. The relationship between attitudes and behavior can become complex, however, because an individual's behavior often may be influenced by a number of external factors and personal attitudes that may vary in strength and importance (Figure 1–C).

Wildlife managers can estimate the needs and preferences of management stakeholders by using surveys to monitor their beliefs, values, attitudes and behaviors (Figure 1–E). The WAC concept, discussed earlier, offers a conceptual tool to characterize the preferences key stakeholder groups have for wildlife population management. This would provide the managers with a reasonable view of the principal "demands" (i.e., damage relief, recreation, existence, etc.) that exist for a given species at that time. The information then could be combined with biological data, fiscal and legal constraints, and overall management philosophy, to determine the expected "supply" of benefits for that species (Figure 1–F2).

With a broad body of information on both the demands for a species and the level of benefits that could be supplied, managers could respond to stakeholder concerns and preferences by adjusting the population objectives of their wildlife programs (Figure 1–F3). They could then strive to meet those revised population objectives through some combination of management techniques that influence wildlife populations and human demands and activities (Figure 1–F4). When legislation permits, agencies may engage in mitigation measures (Figure 1–F5) to reduce actual damage or compensate for economic loss of damage incurred.

A variety of actions can be taken to address the objectives through changes in habitat management or harvest regulation (Figure 1–F6). To the degree that people perceive these population changes, they may form new attitudes about the species being managed (figure 1–K, L, M). The agency also can attempt to meet its objectives through efforts to inform and educate stakeholder groups. Communication and education strategies could be employed to inform stakeholders how their demands for a wildlife species are being considered in setting management objectives, and the degree to which those management objectives are being met (Figure 1–F7). These management techniques also can be used to inform publics about a given species and its management, providing information that dispels inaccurate beliefs or helps a particular public participate more fully and effectively in the management program development process (Figure 1–10). These activities may affect attitude change by stimulating a change in the WAC of a given stakeholder group.

Ongoing mechanisms of communication with stakeholder groups provide vital feedback, completing the cycle of agency/public interaction. As the species being managed undergoes changes in population, mechanisms of sustained agency/public interaction become a vital component of a management system that is socially responsive.

When successful, this basic approach to program planning: (1) allows managers to monitor and respond appropriately to public needs and preferences; (2) helps managers identify areas of potential conflict; (3) maximizes the wildlife benefits available to key stakeholders; and (4) can generate increased public acceptance of a management program. The challenge facing a wildlife manager is in developing the mechanisms of sustained stakeholder input (e.g., surveys, public hearings, citizen advisory groups) and feedback (communication and education programs) that are critical links in the planning cycle. The authors have been involved with citizen advisory groups in New York and Wisconsin, and are aware of such activity in other states.

Pitfalls for Resource Managers

Despite the major advantages and opportunities survey-generated data can provide for resource managers, there are several potential problems in survey execution and interpretation. A major area of concern has been the tendency of the media and stakeholder groups to focus attention on the "bottom line" generated by surveys (i.e., total monetary loss to a particular species generated by extrapolating survey responses to the total stakeholder population). In Wisconsin, an extensive survey of farmers (Wisconsin Department of Agriculture and University of Wisconsin 1984) resulted in an estimate of $36.7 million in annual crop losses caused by deer. Despite numerous "qualifiers" in the original report (e.g., tolerance levels, difficulties in assessing losses, perception versus reality) the total loss figure was widely used to publicize the deer problem and rally support for a reduction in the deer herd. The public was led to believe that such a loss figure was both absolute and a reasonable estimate of the cost to solve the deer damage problem, presumably via direct compensation.

Total loss calculations can serve as useful indices of damage and trends between replicated surveys (Wisconsin Department of Agriculture and University of Wisconsin 1984, Conover and Decker 1991, Heinrich and Craven 1991), but as time-specific estimates, they have severe limitations. First, most surveys identify a distribution of damage level estimates skewed toward farmers with minor to moderate losses, often at or below identified tolerance levels. Thus, a significant portion of a total loss figure consists of many small losses which farmers are willing to tolerate for a variety of reasons (Pomerantz et al. 1986). Second, wildlife damage can be a very emotionally charged issue. To some, the loss of personal property is such a sensitive matter that stakeholders perceive damage to be greater than the actual value. Others may intentionally bias surveys by reporting inflated estimates of the cost and scope of damage. Third, farmers frequently cannot provide the data necessary to estimate losses across an entire area or population. Scott and Townsend (1985) reported that estimates of monetary or percentage losses "often" could not be provided by survey respondents. Only 14 percent of the farmers responding to a survey on wild turkey damage (Craven 1989) stated that they could accurately assess damage. Sixty-two percent of farmers responding to a survey on damage caused by Canada geese (*Branta canadensis*) felt they could only "roughly estimate" goose damage (Heinrich 1988).

Heinrich (1988) argued that such inaccurate estimates lead to a probable overestimation of loss. A model of Canada goose damage in east central Wisconsin, based on goose use, physiological intake maxima, food preference and crop availability, strongly suggested maximum damage potential of $500,000 based on crop consumption alone. The addition of trampling loss and other plant damage increased the damage potential to $990,000. Both figures were well below the $1.6 million loss generated by extensive farmer surveys in both 1985 and 1986 (Heinrich and Craven 1988). Pomerantz et al. (1986) also called attention to the difficulties of self-reported, unverified estimates of damage, but noted that perceived losses, whether close to real losses or not, are what matter in the minds of the stakeholders.

Pomerantz et al. (1986) also concluded that self-reported estimates might be of questionable use as a basis for compensation. This conclusion has been supported by the fiscal experience of the Wisconsin Wildlife Damage Program since its inception in 1984 (Wisconsin Department of Natural Resources files). During the three-year period, 1988–90, administrative and abatement expenses averaged $350,000 per year and eligible claims (direct payments to farmers in addition to abatement costs) averaged $1,050,000. Generally, the program was viewed as highly successful; all counties with significant damage participated and few farmers with claims were excluded from participation by program requirements. Thus, the monetary requirements to manage a wildlife damage problem estimated in 1984 dollars (with a smaller deer herd) at $36.7 million have been less than $2 million per year.

Inexperience in survey use also can lead to problems. Survey methodology is backed by theory in the social sciences (*see* Dillman 1978, Arthur 1981, Filion 1981). There is much more to an effective survey than an assemblage of questions that seem germane to a resource management issue. Wildlife managers and researchers often are not trained in social science, which may result in poor survey design, invalid samples, or improper analysis or interpretation (T. Heberlein personal communication). This may lead to inappropriate or unsubstantiated conclusions. Survey results may be criticized by social scientists at the peer review or management level. We urge all wildlife biologists to investigate relevant social science literature, and seek the input of trained social scientists and survey technicians.

Anticipated response rates are useful in planning the scope of a proposed survey but nonresponse also must be considered. Response rates are generally excellent (70–90 percent) in wildlife damage surveys (*see* Pomerantz et al. 1986) compared to general information public surveys (20–30 percent, J. L. Aschwege personal communication). Scott and Townsend (1985) suggested that strong interest in the topic was related to the observed high response rate. In fact, Heberlein and Baumgartner (1978) analyzed 98 mailed questionnaires and determined that salience of the topic and number of contacts (follow up mailings or telephone contacts) explained 51 percent of the variance in final response rate. They presented a regression equation to predict response rates and, thus, minimize the necessary sample (and cost). Similarly, Brown et al. (1990) recently presented a theoretical model for mail surveys and a regression equation of the key variables involved with the final response for over 30 surveys they conducted on natural resource management topics, including several on wildlife damage.

Even excellent response rates still leave some nonrespondents who must be considered in survey analysis. Response rates of greater than or equal to 60 percent are often considered "acceptable" in mail surveys, however, response rates below 80 percent present serious concerns about nonresponse bias. As Brown et al. (1981:78) reported, respondents and nonrespondents do not always differ with respect to key variables, but this is the exception rather than the rule. Brown and Wilkins (1978) presented an example of how knowledge of nonrespondent characteristics gained through a nonrespondent follow-up to a survey that had a 68 percent response rate resulted in major adjustment in the value of the parameter of interest. Every mail survey design should include a nonrespondent follow-up procedure. These latter examples of survey design and interpretation illustrate why social scientists and the social science literature would be valuable assets to the wildlife manager contemplating conducting a survey on wildlife damage.

Conclusions

Surveys have provided, and will continue to provide, useful data for wildlife managers on wildlife damage and stakeholder attitudes. A survey can be employed to document or refute a suspected problem. Survey data can establish the timing of damage, the impact area, the crops or human activities damaged, and the extent of damage, given the limitations we have discussed. These data should be used to guide wildlife damage management programs and in the establishment of population goals for species frequently involved with damage complaints.

Wildlife managers should review previous surveys and generalized results, on such topics as tolerance, to evaluate the need for additional survey work. Utilization of previous efforts can reduce the length of survey instruments (i.e., eliminate some questions) and the size of survey samples.

Surveys continue to reveal basically positive feelings toward wildlife on the part of most stakeholders, even those who sustain significant losses from wildlife damage. This finding can be used to support moderation and compromise when vocal minorities call for drastic reductions in wildlife populations.

Managers and policy makers should consider, but not emphasize, calculations of monetary loss generated by surveys. As discussed, such figures are subject to inaccuracy, as well as abuse and misrepresentation. Successful wildlife damage management programs can be executed at costs well below estimated losses. Also, estimated losses are likely detrimental to the image of resource management and some individual species (e.g., deer) in the eyes of the general public who may have more empathy with some stakeholders (e.g., farmers) than with others (e.g., hunters).

Survey results should be released to the media and public through trained educators in agency information and education divisions, or Cooperative Extension Service staff so that limitations in survey methods can be presented and conclusions properly used.

References

Anonymous. 1990a. Highlights of the animal damage control survey. USDA Natl. Agric. Stats. Serv. 2 pp.

———. 1990b. Sheep and lamb losses—1989. Wyoming Agric. Stats. Serv. 2 pp.

———. 1991. Sheep and goal predator loss. USDA Natl. Agric. Statis. Serv. 12 pp.

Arthur, L. M. 1981. Measuring public attitudes toward natural resource issues—coyote control. USDA Econ. Res. Serv. Tech.Bull. No. 1657.

Brown, T. L. and B. T. Wilkins. 1978. Clues to reasons for nonresponse, and its effect upon variable estimates. J. Leisure Research 10(3):226–231.

Brown, T. L. and D. J. Decker. 1979. Incorporating farmers; attitudes into management of white-tailed deer in New York. J. Wildl. Manage. 43(1):236–239.

Brown, T. L., C. P. Dawson, and D. J. Decker. 1977. Deriving serial indices of farmer attitudes toward deer management levels in the Lake Plains region of New York. Outdoor Recreation Res. Unit Publ. 77–1, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY.

Brown, T. L., D. J. Decker, and C. P. Dawson. 1978a. Willingness of New York farmers to incur white-tailed deer damage. Wildl. Soc. Bull. 6(4):235–239.

Brown, T. L., D. J. Decker, and D. L. Huston. 1978b. Deriving social indices of farmer attitudes toward deer management levels (in the western Central Plain of New York). Outdoor Recreation Res. Unit Publ. 78-2, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, N.Y. 92 pp.

Brown, T. L., D. J. Decker and D. L. Huston. 1979. Public attitudes toward black bear in the Catskills. Outdoor Recreation Res. Unit Publ. 79–1, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 204 pp.

Brown, T. L., D. J. Decker, and D. L. Huston. 1980. Farmers' tolerance of white-tailed deer in central and western New York. Search: Agriculture No. 7, Cornell Univ. Agric. Exp. Stn. 16 pp.

Brown, T. L., D. J. Decker, and N. A. Connelly. 1990. Response to mail surveys on resource-based recreation topics: A behavioral model and empirical analysis. Leisure Sciences 11(2):99–110.

Connelly, N. A., D. J. Decker, and S. Wear. 1987. White-tailed deer in Westchester County, New York: Public perceptions and preferences. Human Dimensions Res. Unit Publ. 87–5, Dept. Nat. Resour., New York St. Coll., Agric. and Life Sci., Cornell Univ., Ithaca, NY. 80 pp.

Conover, M. R. and D. J. Decker. 1991. Wildlife damage to crops: Perceptions of agricultural and wildlife professionals in 1957 and 1987. Wildl. Soc. Bull. 19(1):46–52.

Craven, S. R. 1984. New directions in deer management in Wisconsin. Pages 65–68 *in* D. J. Decker, ed., Proc. 1st East. Wildl. Damage Control Conf., Coop. Ext., Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY.

———. 1988. The impact of wildlife damage on wildlife management programs in Wisconsin. Proc. Vertebr. Pest. Conf. 13:6–13.

———. 1989. Farmer attitudes toward wild turkeys in southwestern Wisconsin. Pages 113–119 *in* S. R. Craven, ed., Proc. 4th East. Wildl. Damage Control Conf. Univ. Wisconsin, Madison.

de Calesta, D. S. 1978. A public information program on predator damage and control. Proc. Vertebr. Pest Conf. 8:67–72.

de Calesta, D. S. and D. B. Schwendeman. 1978. Characteristics of deer damage to soybeans. Wildl. Soc. Bull. 6:250–253.

Decker, D. J., J. O'Pezio, and D. L. Huston. 1981. Comparison of farmers' attitudes toward deer abundance in two regions of New York having different agricultural and deer population characteristics. New York Fish and Game J. 288(2):202–207.

Decker, D. J., Mattfeld, and T. L. Brown. 1984b. Influence of deer damage on farmers' perceptions of deer population trends: Important implications for managers. Pages 191–194 *in* D. J. Decker, ed., Proc. 1st East. Wildl. Damage Control Conf., Coop. Ext. Dept. Nat. Resour., New York St. Col. Agric. and Life Sci., Cornell Univ., Ithaca, NY.

Decker, D. J. and T. L. Brown. 1982. Fruit growers' vs. farmers' attitudes toward deer in New York. Wildl. Soc. Bull. 10(2):150–155.

Decker, D. J. and K. G. Purdy. 1988. Toward a concept of wildlife acceptance capacity in wildlife management. Wildl. Soc. Bull. 16:53–57.

Decker, D. J., K. M. Loconti-Lee, and N. A. Connelly. 1989. Incidence and cost of deer related vehicular accidents in Tomkins County, New York. Human Dimensions Res. Unit Publ. 89–7, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 22 pp.

Decker, D. J. and T. A. Gavin. 1985. Public tolerance of a suburban deer herd: Implications for control. Pages 192–204 *in* P. T. Bromley, ed., Proc. 2nd East. Wildl. Damage Control Conf. Raleigh, NC.

Decker, D. J., R. A. Smolka, Jr., J. O'Pezio, and T. L. Brown. 1985. Social determinants of black bear management for the northern Catskill Mountains. Pages 239–297 *in* S. L. Beasom and S. F. Roberson, eds., Game Harvest Management. Caesar Kleberg Wildl. Res. Inst., Coll., Agric., Texas A&I Univ., Kingsville.

Decker, D. J., N. Sanyal, T. L. Brown, R. A. Smolka, Jr., and N. A. Connelly. 1984a. Reanalysis of farmer willingness to tolerate deer damage in western New York. Pages 31–45 *in* D. J. Decker, ed., Proc. 1st East. Wildl. Damage Control Conf., Coop. Ext. Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY.

Dillman, D. A. 1978. Mail and telephone surveys. John Wiley and Sons. New York, NY. 325 pp.

Enck, J. W., K. G. Purdy, and D. J. Decker. 1988. Public acceptance of beavers and beaver damage in wildlife management unit 14 in DEC Region 4. Human Dimensions Res. Unit Publ. 88–1, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 29 pp.

Filion, F. L. 1981. Importance of question wording and response burden in hunter surveys. J. Wildl. Manage. 45(4):873–882.

Flyger, V. and T. Thoerig. 1962. Crop damage caused by Maryland deer. Proc. Southeast Assoc. Game and Fish Commiss. 16:45–52.

Freeman, R. E. 1984. Strategic management: A stakeholder approach. Boston: Pitman. 276 pp.

Hafer, D. J. and S. E. Hygnstrom. 1991. Attitudes of Nebraska sheep producers toward predators. Great Plains Wildl. Damage Control Workshop Proc. 10:57–60.

Heberlein, T. A. and R. Baumgartner. 1978. Factors affecting response rates to mailed questionnaires: A quantitative analysis of published literature. Amer. Soc. Rev. 43:447–462.

Heinrich, J. W. 1988. Canada geese damage abatement and assessment in east-central Wisconsin. M.S. thesis, Univ.Wisconsin, Madison. 188 pp.

Heinrich, J. W. and S. R. Craven. 1988. Distribution and impact of Canada goose crop damage in east-central Wisconsin. Pages 18–20 *in* H. L. Stribling, ed., Proc. 3rd East. Wildl. Damage Control Conf. Gulf Shores, AL.

Heinrich, J. W. and S. R. Craven. 1992. Farmer attitudes toward geese near Horicon Marsh, WI. *In* D. H. Rusch, ed., Proc. 1st International Canada Goose Symp. Milwaukee, WI. In press.

Hygnstrom, S. E. and S. R. Craven. 1991. Raptor damage and nuisance problems in the United States. *In* B. G. Pendleton and D. L. Krahe, eds., Proc. Midwest Raptor Manage. Symp. Workshop. Natl. Wildl. Fed. Washington, D.C.

Jones, W. L. 1984. Christmas tree damage by white-tailed deer in West Virginia. M.S. thesis. West Virginia Univ. 77 pp.

Kube, J. H. 1983. Assessment of deer management by Illinois landowners. Div. Fish and Wildl, Illinois Dept. Conserv. 11 pp.

McDowell, R. D. and H. W. Pillsbury. 1959. Wildlife damage to crops in the United States. J. Wildl. Manage. 23(2):240–241.

McDowell, R. D. and F. C. Benson. 1960. The deer herd and landowner in Connecticut. Bull. 348, Univ. Connecticut. 15 pp.

McNeil, R. J. 1962. Population dynamics and economic impact of deer in southern Michigan. Game Div. Rept. No. 2395, Michigan Dept. Conserv. 143 pp.

Phillips, C. 1980. An attitude study of white-tailed deer management issues in Cook County, Wyoming. Proj. FW–3–R–25, Work Plan No. 3. Job No. 20W, Federal Aid in Wildlife Restoration, Res. and Development Div., Wyoming Game and Fish Dept. 128 pp.

Phillips, R. L. and F. S. Blon. 1988. Distribution and magnitude of eagle-livestock conflicts in western United States. Proc. Vertebr. Pest Conf. 13:241–244.

Pomerantz, G. A., C. Ng, and D. J. Decker. 1986. Summary of research on human tolerance of wildlife damage. Nat. Resour. Res. and Ext. Series No. 25. Dept. Nat. Resour., Cornell Univ., Ithaca, NY. 42 pp.

Porath, W. R., S. L. Sheriff, and D. J. Witter. 1984. Landowner attitudes toward deer and deer management. Proj. No. W–13–R–38, Study No. 49, Job No. 1, Federal Aid in Wildlife Restoration, Missouri. 55 pp.

Purdy, K. G. and D. J. Decker. 1985. Central New York beaver damage tolerance study. Human Dimensions Res. Unit Publ. No. 85–5, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 116 pp.

Purdy, K. G., D. J. Decker, and J. W. Enck. 1989. Deer management in New York's Hudson Valley region: An assessment of the interests and opinions of three key constituencies. Human Dimensions Res. Unit Publ. 89–1, Dept. Nat. Resourc., New York St. Coll. of Agric. and Life Sci., Cornell Univ., Ithaca, NY.

Purdy, K. G., D. J. Decker, R. A. Malecki, and J. C. Proud. 1985. Landowner tolerance of beavers: Implications for damage management and control. Pages 83–88 *in* P. T. Bromley, ed., Proc. 2nd East. Wildl. Damage Control Conf., Coop. Ext. Serv., Virginia Polytech Inst. and St. Univ., Blacksburg, VA.

Sayre, R. W. and D. J. Decker. 1990. Deer damage to the ornamental horticulture industry in suburban New York: extent, nature, and economic impact. Human Dimensions Res. Unit Publ. 90–1. Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 75 pp.

Scott, J. D. and T. W. Townsend. 1985. Deer damage and damage control in Ohio's nurseries, orchards, and Christmas tree plantings: The growers view. *In* P. T. Bromely, ed., Proc. 2nd East. Wildl. Damage Control Conf. Raleigh, NC.

Siemer, W. F. and D. J. Decker. 1991. Human tolerance of wildlife damage: Synthesis of research and management implications. Human Dimensions Research Unit, Series No. 91–7. Dept. Nat. Resour. Cornell Univ., Ithaca, NY. 24 pp.

Siemer, W. F., T. L. Brown, and D. J. Decker. 1991. A conceptual framework for analysis of agriculturists' deer damage control decisions. Nat. Resour. Res. and Ext. Series No. 35, Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 14 pp.

Spencer, D. A. 1983. Animal damage control in the eastern United States. Pages 17–25 *in* D. J. Decker, ed., Proc. 1st East. Wildl. Damage Control Conf., Coop. Ext., Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY.

Stoll, J. W. and G. L. Mountz. 1983. Rural landowner attitudes toward deer and deer populations in Ohio. Ohio Fish and Wildl. Rept. 10. 18 pp.

Tanner, G. P. and R. W. Dimmick. 1984. An assessment of farmers' attitudes toward deer damage in West Tennessee. Pages 195–199 *in* D. J. Decker, ed., Proc. First East. Wildl. Damage Control Conf. Coop. Ext., Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY.

Tatro, D. E. 1986. An analysis of deer damage in apple orchards in New York State 1981–1984. M.S. thesis, Cornell Univ., Ithaca, NY.

Trindle, B. E. and K. E. Menzel. 1989. 1988 Rural landowners' attitudes of landowners toward deer management. Nebraska Game Parks Commiss. Workplan A86. P.R. Proj. W15–R–43, 9 pp.

Wisconsin Department of Agriculture, Trade and Consumer Protection, and University of Wisconsin—Madison, Department of Wildlife Ecology, 1984. Wisconsin deer population and damage survey. Wisc. Agric. Res. Serv. 4 pp.

Michigan Deer Crop Damage Block Permit Study

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Introduction

When comparing agricultural crop damage, State Farm Bureau administrators, Wildlife Cooperative Extension specialists, state wildlife agencies and state agricultural agencies rated damage by deer to be more severe than damage by other types of wildlife. Of the 49 state wildlife agencies that reported, all indicated that deer were causing agricultural damage in their state (Conover and Decker 1991). Matschke et al. (1984) suggest that increased harvest of deer in agricultural areas may be more cost effective in reducing crop damage than fencing, scare devices, chemical repellents, lure crops and out-of-season shooting. Duncan (1990) specifically suggests that deer populations cannot be controlled by the harvest of antlered deer, but only by control of the mortality that occurs to female deer. Conover and Decker (1991) report that 90 percent of the states in 1987 manipulated hunting seasons and bag limits to reduce wildlife crop damage and 86 percent offered some form of special shooting permits to farmers.

In Michigan, the population of white-tailed deer (*Odocoileus virginianus*) prior to the 1989 hunting season was estimated to be two million. This four-fold increase from the 1971 population estimate of 500,000 occurred as a result of increasingly favorable habitat and weather conditions, in spite of more liberal deer hunting seasons and bag limits. As the deer population increased, damage to agricultural crops by deer increased (Reis 1990). Also, 46,784 vehicle/deer accidents were reported to the Michigan state police in 1989, a four-fold increase since 1971. Coupled with these people/deer conflicts, the number of out-of-season deer damage control permits issued to farmers, orchardists and nursery owners increased from 42 in 1976 to 1,406 in 1989 (Langenau 1991).

In 1989, the Michigan Natural Resources Commission approved an experimental Deer Crop Damage Block Permit (DCDBP) program. The objectives of the program were to: (1) utilize licensed hunters to reduce deer damage to agricultural crops; (2) focus the harvest of antlerless deer on specific properties; and (3) reduce the number of out-of-season deer damage control permits (Langenau1991).

A total of 5,331 block permits for antlerless deer were issued to participating eligible agriculturists in 1989. Eligible agriculturalists were defined as those who had suffered documented serious deer depredation to agricultural and horticultural crops in two of the past five years. The program was offered in 24 of the 83 counties in the state. Permits were $3 each and were valid for antlerless deer only. The number of permits issued was based on an agreement between the landowner and the local Michigan Department of Natural Resources (DNR) biologist to achieve a specific harvest goal. Permits were valid during regular archery, firearm and muzzleloader deer seasons for use by licensed hunters on the lands where the damage occurred and on adjacent private lands provided the adjacent landowner gave permission. They were not valid on adjacent public lands. Harvesting one or more deer with DCDBP permits did not restrict the number of deer a hunter could take with regular deer hunting licenses.

Under the 1989 program, 3,960 block permits were used to harvest antlerless deer (Reis 1990). Based on the success of the 1989 program, it was expanded state-wide in 1990 as a three-year experimental program. In 1990, the DNR issued 28,090 DCDBP permits to 1,463 agriculturalists who reported that hunters filled 15,653 (56 percent) of the permits with antlerless deer. A minimum of 10 permits was issued to each participating landowner. However, as the program expanded in 1990, so did public scrutiny. The media carried a variety of stories concerning the DCDBP program, some alleging problems and improprieties, while others espoused the value of the experimental regulations. As part of the experimental nature of the program, the DNR contracted with the Department of Park and Recreation Resources of Michigan State University to examine impartially the attitudes and reported behaviors of selected publics concerning the DCDBP program.

The objectives of this paper are: (1) to describe the situations associated with participation or lack of it among agriculturalists who were eligible for the DCDBP program; (2) to describe the attitudes of eligible agriculturalists, hunters and neighbors of participating agriculturalists about the program; (3) to report how eligible agriculturalists assess the efficacy of various deer crop damage control methods; and (4) to enumerate the reported hunter effort and harvest rates of deer on eligible farms.

Methods

Three self-administered, mail-back questionnaires with many common questions were developed to obtain information and allow comparison of responses among groups. The first questionnaire was developed for landowners eligible for the DCDBP program who participated in 1990 (*participants*) and landowners who were eligible but chose not to participate (*non-participants*). A second questionnaire was developed for neighbors directly adjacent to participating landowners (*adjacents*). A third questionnaire was developed for those who hunted with a DCDBP permit in 1990 (*DCDBP hunters*) and those who did not hunt with a DCDBP permit (*non-DCDBP hunters*).

The samples were obtained in different ways. A 20 percent sample of participating and non-participating landowners was systematically selected with a random start from the DNR mailing lists of agriculturalists with chronic crop damage problems. This resulted in a sample of 315 participants and 139 non-participants. Adjacents were selected by using a systematically selected 20 percent sub-sample of the participants sample and identifying all private landowners directly adjacent to the north (arbitrarily chosen direction) of the participating landowner. This resulted in a sample of 227 adjacents. The sample of DCDBP hunters was systematically chosen from the lists of hunters using DCDBP permits which each participating landowner was required to maintain as a condition of the DCDBP program. Using the hunter lists, 356 DCDBP hunters were systematically selected. A sample of 200 non-DCDBP hunters was randomly chosen from a DNR list of hunters who had not applied for any type of antlerless deer hunting license in 1990.

Questionnaires were mailed in March 1991 using procedures similar to those suggested by Dillman (1978). These included a first mailing of the questionnaire with a separate cover letter and a postage paid, business reply envelope. After three weeks, a second mailing of the questionnaire with a reply envelope and a revised, separate cover letter was sent to all non-respondents. After four more weeks, a third, and final mailing of the questionnaire with a reply envelope and a further revised cover letter was sent by certified mail to all those who had not yet responded.

Results

Of the sample groups, 92 percent of participants, 76 percent of non-participants, 82 percent of adjacents, 83 percent of DCDBP hunters and 67 percent of non-DCDBP hunters provided usable responses.

Characteristics of Participating and Non-participating Agriculturalists

Participating and eligible non-participating agriculturalists were most likely to report growing row (79 percent and 77 percent respectively) and forage crops (63 percent and 48 percent). Participating agriculturalists were more likely than non-participating agriculturalists to report serious deer crop degradation to row and forage crops (if grown) ($X^2 = 6.12$, 1df, $P = 0.013$, and $X^2 = 7.23$, ldf, $P = 0.007$). Seventy-one percent of participating agriculturalists and 60 percent of non-participating agriculturalists reported a great or moderate increase in deer populations on their property between 1986 and 1990. Participating agriculturalists reported that a significantly larger mean percentage of their household income (71 percent versus 62 percent) was derived from agriculture compared to responses from non-participating agriculturalists ($t = -2.02$, $P = 0.044$).

Participating farms had a mean acreage of 466 acres. Extrapolated to the 1,463 farms participating, approximately 681,758 acres (272,703 ha) were open for hunting under the program. This does not include any adjacent acreage that may have been open and comprises slightly less than 2 percent of Michigan's land area. There was no significant difference in the size of the participating and non-participating farms. Participating farms reported an estimated fall population of 80 deer per square mile. This was not significantly different than non-participating farms.

Attitudes Concerning the DCDBP Program

All sample groups were asked a Likert-scale question about their attitude concerning the DCDBP program (Table 1). Participating agriculturalists had the most favorable attitudes concerning the program with 91 percent moderately or strongly favorable. Non-DCDBP hunters were least likely to have a favorable attitude about the program with 44 percent strongly or moderately favorable and 44 percent strongly or moderately unfavorable. Sixty percent of the non-participating agriculturalists favored the program. Adjacent landowners had 51 percent who favored the program. Most (67 percent) DCDBP hunters responded with favorable attitudes. In all groups, except non-DCDBP hunters, the majority of respondents expressed favorable attitudes towards the DCDBP program.

Table 1. Overall attitudes concerning the DCDBP program in Michigan, 1990.

	Percentage of responses				
Group	Strongly unfavorable	Moderately unfavorable	Neither favorable or unfavorable	Moderately favorable	Strongly favorable
Participating agriculturalists	3	3	4	23	68
Non-participating agriculturalists	15	14	12	30	30
Adjacent landowners	21	16	12	26	25
DCDBP hunters	14	11	7	23	44
Non-DCDBP hunters	24	20	12	30	14

When asked an open-ended question about the one most important recommendation the respondent had for the DCDBP program, participating agriculturalists, non-participating agriculturalists, adjacent landowners, and DCDBP hunters were most likely to recommend that the program continue in its current form. Only non-DCDBP hunters recommend the program be discontinued. Of those who recommended changes in the program, landowners most often mentioned allowing DCDBP permits to be valid outside of regular deer hunting seasons, the elimination of the fee to landowners for DCDBP permits and a minimum permit option of less than 10 DCDBP per landowner. DCDBP and non-DCDBP hunters most frequently recommended that DNR biologists better justify the need for DCDBP permits on a farm by farm basis.

Efficacy of the DCDBP Program

Eligible landowners were asked to rate the effectiveness of selected deer crop damage control strategies (Table 2). In addition to the DCDBP program, strategies included Private Land Antlerless Deer Hunting Licenses, out-of-season shooting permits, scare devices, fencing and repellents. Private Land Antlerless Deer Hunting Licenses are bonus kill tags that any landowner of 40 or more contiguous acres and

Table 2. Rated effectiveness of selected deer crop damage reduction strategies by agriculturalists eligible for DCDBP program in Michigan, 1990.[a]

	Percent rating highly effective	
Strategy	Participating	Non-participating
DCDBP	57[b]	37
Out-of-season shooting permits	45	46
Private lands antlerless deer hunting permits	37	40
Fencing	10	9
Repellents[c]	<1	1
Scare devices[c]	<1	0

[a]Rating scale 1–5 with: 5 = highly effective; 3 = moderately effective; 1 = ineffective.
[b]Significant difference between groups using chi-square P = 0.05.
[c]One or more cells with an expected frequency of less than five, so no chi-square analysis done.

any number of his/her designates may apply for. Licenses are issued by lottery. The Private Land license may only be used on the landowners contiguous lands and adjacent private lands with permission. In 1991, 83 percent of such applicants received an antlerless permit totalling 116,337 Private Land Antlerless Deer Hunting Licenses (E. Langenau personal communication: 1992). Between 1989 and 1990, the number of out-of-season shooting permits declined 27 percent from 1,406 to 1,026 (Langenau 1991). No information is available on the use of scare devices, fencing or repellents in Michigan.

Participating agriculturalists were more likely to rate the DCDBP program as highly effective than any of the other strategies. Non-participating agriculturalists were most likely to rate out-of-season shooting permits as highly effective. Participating landowners were significantly more likely to rate the DCDBP highly effective than were non-participating landowners ($X^2 = 10.22$, 1df, $P = 0.001$). Methods that did not result in the lethal removal of deer were least likely to be rated as highly effective and included fencing, scare devices and repellents.

When asked if they planned to participate in the DCDBP program in 1991, 84 percent of the participants and 34 percent of the non-participants responded they would participate if the program was offered. Only 2 percent of the participants and 21 percent of the non-participants reported they would not participate in 1991.

Hunting Effort and Harvest Rate on Participating and Non-participating Farms

The reported 1990 deer hunting effort on participating and non-participating farms differed significantly. On participating farms a mean of 16 deer hunters hunted, while on non-DCDBP farms a mean of 10 deer hunters hunted ($t = -4.82$, $P = 0.000$). On a per-square-mile basis, participating farms had a mean of 21.9 deer hunters and non-participating farms a mean of 15.4 deer hunters.

Comparing the mean 1990 reported total deer harvest between participating and non-participating farms, participating farms harvested significantly more deer with a mean of 24 deer versus 10 on non-participating farms ($t = -7.34$, $P = 0.000$). The difference between the two groups was not significantly different in the harvest of antlered bucks.

The harvest of antlerless deer was significantly higher on DCDBP farms ($t = -6.35$, $P = 0.000$). Possessing a mean of 29 antlerless deer permits (DCDBP permits, Private Land Antlerless Deer Hunting Licenses and out-of-season shooting permits), participating landowners reported a mean antlerless harvest of 19 deer on their lands or adjacent lands where they had permission to use the permits. Non-participating agriculturalists possessed a mean of 10 antlerless deer permits and harvested a mean of 7 antlerless deer on their lands or adjacent private lands where they had permission. On a per square mile basis, participating agriculturalists reported an antlerless harvest rate of 26.1 deer per square mile, while non-participating agriculturalists reported a harvest rate of 10.7 antlerless deer per square mile.

The percentage change from 1988 to 1990 (prior to the implementation of the DCDBP) in hunters and harvest is substantial for both groups. The mean number of hunters increased 33 percent on participating farms, while increasing 11 percent on non-participating farms. The mean harvest of antlerless deer increased 138 percent on participating farms, while it increased 75 percent on non-participating farms. The mean total harvest of deer on participating farms increased 85 percent, while on non-participating farms it increased 25 percent, in part due to a decrease of 25 percent in the antlered buck harvest.

When DCDBP hunters were asked about their relationship to the participating landowner on whose land they hunted, 40 percent were friends of the landowner, 26 percent were members of the landowners immediate family, 12 percent had met the landowner through a mutual friend or relative, 8 percent were non-immediate family relatives, 7 percent were the landowners, 4 percent had no previous acquaintance with the landowner and 4 percent were employees of the landowner. Twenty-one percent felt they would not have had permission to hunt the landowner's property if it was not for the DCDBP program.

Eighty-nine percent of adjacent landowners reported that deer were legally hunted on their property with 62 percent of the adjacents personally hunting their lands in 1990. Of those with land open to some deer hunting, 38 percent allowed hunting by others or hunted themselves with their neighbor's DCDBP permits on their lands.

Discussion

The Michigan DCDBP program met the objectives of reducing out-of-season shooting permits, increasing the harvest of antlerless deer in chronic deer damage locations and utilizing licensed hunters during regular deer seasons to harvest the deer. Even though the program may have had a significant impact on lands with deer damage, it is a relatively small component of managing Michigan's state-wide deer herd. It accounted for 4 percent of the state-wide licensed harvest of deer and 8 percent of the antlerless harvest. Block permits comprised 8 percent of the total number of antlerless permits issued in 1990.

Other states have had varied experiences in controlling deer damage on farms with chronic problems using special programs. Erickson and Geissman (1989) concluded that a deer crop damage control program implemented in Missouri from 1976 through 1985 was ineffective at reducing deer crop damage when administered on a farm-by-farm basis. They instead recommend any-deer permits be available on a broader deer management unit basis. The Michigan program is substantially different from the Missouri program in that more farms received DCDBP (1,463 versus 465), the mean allotment of permits per landowner was greater in Michigan (19 versus 8) and only antlerless deer can be taken with DCDBP permits in Michigan compared to allowing the harvest of any deer with DCDBP permits in Missouri. In addition, Michigan already had in place a structure for private landowners and their designates to get individual bonus antlerless deer licenses through the Private Land Antlerless Deer Hunting License program.

Duncan (1990), reporting on the opinions of agriculturalists enrolled in Virginia's Damage Control Assistance Program (DCAP), stated that the most commonly mentioned problem with the program is that it limited each hunter to one DCAP permit. In Michigan, a hunter may use more than one DCDBP permit and the permits are bonus permits which do not count against harvests with regular licenses.

Conover and Decker (1991) suggest that increasing wildlife populations and more vulnerable agricultural crop varieties may be responsible for increasing wildlife damage to agriculture. Still, in agricultural areas, wildlife managers have a range of workable options that have an acceptable level of social approval, such as the DCDBP program in Michigan. However, suburban and urban wildlife damage control may present a more complex problem for wildlife managers with fewer management options being socially acceptable to local residents. The white-tailed deer is an especially important species that is increasing within metropolitan centers (Michigan Deer Damage Committee 1989, McAninch and Parker 1991). Aguilera et al. (1991) point out, most techniques being tested or used to control damage do not address management of wildlife populations at sizeable spatial levels. Rather, they are focused on moving the animal and the problem from one urban/suburban location to another in close proximity.

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References

Aguilera, E., R. Knight, and J. Cummings. 1991. An evaluation of two hazing methods for urban Canada geese. Wildl. Soc. Bull. 19:32–35.

Conover, M. and D. Decker. 1991. Wildlife damage to crops: Perceptions of agricultural and wildlife professionals in 1957 and 1987. Wildl. Soc. Bull. 19:46–52.

Dillman, D. 1978. Mail and telephone surveys. John Wiley and Sons, New York, NY. 325 pp.

Duncan, R. 1990. Landowner response to the Damage Control Assistance Program in Virginia. Paper presented at 26th Ann. Meeting of the Northeast Deer Study Group. Virginia Dept. Game and Inland Fisheries, Richmond. 7 pp.

Erickson, D. and N. Giessman. 1989. Review of a program to alleviate localized deer damage. Wildl. Soc. Bull. 17:544–548.

Langenau, E. 1991. 1990 Block permit experimental program: Preliminary evaluation. Michigan Dept. Nat. Resour., Lansing.

Matschke, G., D. deCalesta, and J. Harder. 1984. Crop damage and control. Pages 647–654 *in* L. Halls, ed., White-tailed deer: Ecology and management. Stackpole Books, Harrisburg, PA. 870 pp.

McAninch, J. and J. Parker. 1991. Urban deer management programs: A facilitated approach. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 56:428–436.

Michigan Deer Damage Committee. 1989. Michigan's deer damage problems: An analysis of the problems with recommendations for future research and communication. Michigan St. Univ. Agric. Exper. Sta., East Lansing. 97 pp.

Reis, T. 1990. 1989 Michigan deer seasons. Michigan Dept. Nat. Resour. Wildl. Div. Rept. No. 3128. Lansing. 15 pp.

Factors Influencing Game Damage Complaints in Montana

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Introduction

When wild herbivores consume plants perceived as forage or crop material vital to the economic survival of farmers or ranchers, game damage complaints ensue. Compensation and/or damage control programs have been established by most state wildlife agencies (Spencer 1984, Western Association of Fish and Wildlife Agencies 1985), but these programs are difficult to budget because demand for such programs varies widely from year to year (Reed 1981, Greene 1985). Although game damage complaints are frequently assumed to be driven by an interaction between animal population levels and weather (Boyd 1960, Reed 1981, Decker et al. 1984, Matschke 1984, Greene 1985, Scott and Townsend 1985, Hygnstrom and Craven 1987, Conover and Decker 1991), attempts to explain game damage levels using variables associated with these two factors have had little success (Tebaldi 1979, Lyon and Scanlon 1985). A few authors have acknowledged that a third factor, agricultural economic conditions, may also influence landowner tolerance and the number of game damage complaints filed (Boyd 1960, Carpenter 1967, Decker et al. 1984, Lyon and Scanlon 1985). The role of this factor has not been fully investigated.

Our objectives were: 1) to quantify the importance of game population levels, weather and agricultural economic conditions in determining game damage complaint levels; and 2) to develop a model that would assist wildlife management agencies in planning and allocating funds for game damage programs.

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Study Area Description

Data were collected from two of the seven Montana Department of Fish, Wildlife and Parks (MDFWP) administrative regions: Region Three (southwestern Montana) and Region Four (northcentral Montana). Region Three contains several major mountain ranges and river valleys including the Absaroka, Gallatin, Madison, Bridger, Crazy, Tobacco Roots, Gravelly and Bitterroot ranges, and the Yellowstone, Madison, Shields, Gallatin, Missouri, Boulder and Big Hole rivers. Agriculture is found mainly in the lower mountain valleys. Most (more than 70 percent) of the harvested cropland is irrigated. In 1988, out of approximately 260,000 hectares harvested, 69

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percent was hay, 17 percent wheat, 13 percent barley, and less than 1 percent oats (Montana Department of Agriculture 1990).

The topography of Region Four is generally less rugged with fewer mountain ranges and river valleys. The east front of the Rocky Mountains forms the western boundary of the region. The Big Belt and Little Belt Mountains occupy the southwest corner. The remainder of the region is characterized by a mixture of rolling hills, open plains and badlands breaks. Major rivers include the Missouri, Judith, Marias and Teton. Most (more than 80 percent) of the harvested crop land is not irrigated. In 1988, 57 percent of the approximately 925,990 hectares harvested was wheat, 27 percent barley, 15 percent hay, and less than 1 percent oats (Montana Department of Agriculture 1990).

Methods

Variables in three areas (game population levels, weather and agricultural economic conditions) were tested as predictors of game damage complaint levels. Only complaints related to damage by mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*) and elk (*Cervus elaphus*) were considered.

All data sets were compiled from public data bases. This approach was adopted to avoid additional impositions on landowners, to limit biases due to small interview samples or analysis of subjective feelings of game damage, and to see how useful existing data bases could be in explaining the variation in the number of game damage complaints filed from year to year. In addition, these sources would be readily available to agencies if they elected to use our models for planning.

The number of game damage complaints filed involving deer and/or elk were compiled from records at the MDFWP regional headquarters in Bozeman (Region Three) and Great Falls (Region Four). Complaints involving mule deer and white-tailed deer were grouped. In order to best match the MDFWP's budgeting period, the number of complaints filed were separated by fiscal years (July 1 to June 30). With the exception of hay, this time period also matched the market year for the agricultural crops used in the analyses. The market year for hay extends from June 1 to May 30. In Regions Three and Four, complaints were collected for 1974–75 through 1990–91, and 1972–73 through 1990–91, respectively. Game damage complaint records prior to these dates were incomplete.

Crop prices and crop production figures were collected from the annual Montana Agricultural Statistics Bulletins (Montana Department of Agriculture 1970–1991). Market year prices in both nominal and real dollars (base year = 1982) for hay, wheat, barley, oats and calves were used in the analysis. The Gross National Product Implicit Price Deflator (Economic Report of the President 1971–1991) was used to adjust prices for inflation. Market year prices (in both nominal and real dollars) for the current year, a one year lag of the current prices, and the current year's price minus the previous year's price, were used as independent variables in the models used to estimate complaint levels.

Weather data were collected from Climatological Data: Montana bulletins (National Oceanic and Atmospheric Administration 1972–1991). Data for monthly precipitation, maximum monthly snow depth and minimum monthly temperature were compiled by averaging the readings of several weather stations in each administrative region. Specific weather stations used in the compilations were chosen on the basis of their location and completeness of recordings over the time period examined.

Deer and elk population trends in each region were assessed using yearly harvest and population survey data. Harvest data for deer and elk included total harvest figures, hunter days per kill, and hunter percent success figures obtained from MDFWP hunting and harvest reports (MDFWP 1970–1991). Population trend counts for various hunting districts in each region were compiled to determine an overall population trend index for both deer and elk in each region.

Initial analyses involved the construction of correlation matrices (Zar 1991). In each region, variables associated with weather, population levels and economic conditions which were highly correlated with game damage complaint levels were selected for further analysis. Intercorrelation of variables was examined and specific variables were deleted or retained based on their biological or economic relevance.

Multiple regression analysis, using the SHAZAM econometrics computer program (*see* White 1978), was applied to the remaining variables to determine the percentage of variation in complaint levels that could be explained and to determine the precision with which complaint levels could be predicted. Models to predict the total number of complaints (including both deer and elk) were developed separately for each region. A stepwise procedure was used to select the best variables. The Durbin-Watson statistic and the von Neuman ratio were used to test for autocorrelation. The runs test was used to test for serial correlation. All tests were conducted at the 0.05 level of significance.

In each region, the regression model was constructed using past data (1972–73 through 1987–88 for Region Four; 1974–75 through 1987–88 for Region Three) and then tested for prediction accuracy using data for the three years 1988–89, 1989–90 and 1990–91. The mean absolute error and the root mean square error of prediction were computed to assess the prediction accuracy of each model (Kennedy 1986).

Results

In Region Three, the variable most highly correlated with the total number of complaints filed was the current year market price for hay in nominal dollars ($r = 0.87$, $P < 0.01$). Other agricultural prices, including lagged prices and prices in real dollars, were also correlated but not as strongly as nominal hay price (Adkins 1991).

Variables associated with winter severity that were significantly correlated with complaints included: November precipitation ($r = 0.61$, $P = 0.01$); maximum snow depth during December ($r = 0.49$, $P = 0.05$); and the mean minimum temperature during December ($r = -0.59$, $P = 0.02$) and February ($r = -0.52$, $P = 0.04$). Precipitation during May and June was negatively correlated with complaints ($r = -0.51$, $P = 0.05$).

The population variable most highly correlated with complaint levels was hunter percent success ($r = 0.78$, $P < 0.01$). The total yearly harvest ($r = 0.66$, $P = 0.01$), yearly population trend surveys ($r = 0.62$, $P = 0.01$) and hunter days per kill ($r = -0.61$, $P = 0.01$) were also correlated with complaint levels.

In Region Three, the model that explained the highest percentage of the variation in the total number of deer and elk complaints filed included three independent variables: the current year hay price (in nominal dollars); November precipitation; and precipitation in May and June (adjusted $R^2 = 0.853$; $F = 26.204$; 3, 10 df; $P < 0.001$; Table 1). Hay price and November precipitation had positive coefficients

Table 1. Statistics for the regression model used to predict the total number of deer and elk damage complaints filed during a fiscal year in Region Three, Montana.

Variable	Partial-R	B	SE (B)	T	P
Nominal hay price	0.869	1.042	0.187	5.546	<0.001
November precipitation	0.746	24.919	7.037	3.541	0.005
May–June precipitation	−0.728	−5.579	1.663	−3.356	0.007
Intercept	−0.324	−15.690	14.494	−1.083	0.300

Adjusted $R^2 = 0.853$, $F = 26.204$ (3, 10 df), $P < 0.001$

Prediction analysis

Year	Predicted	SE	Actual	Error
1988–89	87	10.53	108	21
1989–90	47	9.77	58	11
1990–91	44	9.05	36	−8

Mean absolute error = 13.33; Root mean square error = 25.02

while the coefficient for May–June precipitation was negative. The hay price variable had the highest partial correlation coefficient (partial $r = 0.869$).

In Region Four, the only variables significantly correlated with complaint levels were those related to winter severity. The variables with the highest correlation coefficients were monthly mean minimum temperature from November to February ($r = -0.77$, $P < 0.01$) and mean monthly maximum snow depth from November to March ($r = 0.80$, $P < 0.01$). Variables associated with agricultural prices and population levels were not significant.

The two independent variables identified in the best model to predict the total number of game damage complaints filed in Region Four were the current market year hay price (in nominal dollars) and the mean monthly maximum snow depth from November to March (adjusted $R^2 = 0.701$; $F = 18.595$; 2, 13 df; $P < 0.001$; Table 2). The snow variable (partial $r = 0.824$) was more important than hay price (partial $r = 0.532$).

In order to test the universality of the model developed for each region, the variables used to predict the total number of complaints in Region Three were applied to Region Four and *vice versa*. In each case, the resulting fit and prediction accuracy were poorer than that of the original models. In Region Three, the resulting model had an adjusted R^2 of 0.615 ($F = 11.36$; 2, 11 df; $P = 0.002$), a mean absolute error of 14.67, and a root mean squared error of 29.56. In Region Four, the resulting model had an adjusted R^2 of 0.276 ($F = 2.91$; 3, 12 df; $P = 0.078$), a mean absolute error of 23.33, and a root mean squared error of 51.21.

Discussion

The high degree of correlation between hay prices and game damage complaint levels in Region Three and the inclusion of the hay price variable in the models for both regions support the hypothesis that agricultural economic conditions can influence the number of complaints filed by landowners. The positive correlation indicates

Table 2. Statistics for the regression model used to predict the total number of deer and elk damage complaints filed during a fiscal year in Region Four, Montana.

Variable	Partial-R	B	SE (B)	T	P
Mean November–March maximum snow depth	0.824	7.745	1.479	5.237	<0.001
Nominal hay price	0.532	0.800	0.353	2.264	0.041
Intercept	0.562	49.564	20.219	2.451	0.028

Adjusted $R^2 = 0.701$, $F = 18.595$ (2, 13 df), $P < 0.001$

Prediction analysis

Year	Predicted	SE	Actual	Error
1988–89	68	21.52	52	−16
1989–90	43	19.51	24	−19
1990–91	40	19.30	26	−14

Mean absolute error = 16.33; Root mean square error = 28.51

that landowners complain more as the economic loss caused by game damage increases. Since hay is an intermediate good on most ranches, the economic loss is greatest when the market price is high (and the supply low) due to the high cost of replacing damaged or lost hay. In addition, if a rancher decided to sell the hay at market, the value of the lost crop material would be greater when the market price is high.

Several other authors (Carpenter 1967, Brown et al. 1978, Tanner and Dimmick 1983, Decker et al. 1984, Purdy 1987) have also reported a direct relationship between increasing economic loss and decreasing landowner tolerance. However, these authors often equated increasing monetary losses with higher animal numbers. While this may be true, it is not the full story. The willingness of a landowner to tolerate a given number of animals or to sustain a given level of damage may change from year to year based on the market value of the lost crop material, a factor beyond the control of wildlife managers.

Government income transfers and price supports for wheat, barley and oats may explain some of the lack of correlation between the price of these program crops and game damage complaint levels. The presence of these income transfers, which are earned on eligible lands from planting (and not necessarily from harvesting) the crop, may buffer the monetary losses caused by game damage. Therefore, the incentive to complain about game damage on economic grounds may be lessened.

These government income transfers and price supports may also contribute to the lower levels of correlation between agricultural prices and game damage complaint levels in Region Four than in Region Three. There are substantial differences in the agricultural enterprises and in the land uses existing in the two regions. In Region Three, a significantly higher proportion of the cropland is in hay; in Region Four, a significantly higher proportion of the cropland is in program crops such as wheat, barley and oats. For example, in 1987, 44 percent of the cropland in Region Three was in program crops compared to 85 percent in Region Four (U.S. Department of Commerce 1989). The proportion of farms with cattle operations in Region Four (56 percent) is also less than the proportion in Region Three (71 percent). In addition, in 1987, 25 percent of the total cash receipts for farms in Region Four were in the form of government payments, compared to 7 percent in Region Three (Montana Department of Agricultural 1988).

If the presence of program crops decreases the economic incentive to complain, fewer complaints per farm would be expected in Region Four than in Region Three. From fiscal years 1986–87 through 1990–91, there were 3.6 times more complaints per farm in Region Three than in Region Four (0.096 complaints per farm in Region Three compared with 0.026 in Region Four). Dusek (1984) reported that game damage complaints along the lower Yellowstone River in eastern Montana were more numerous from areas where the production of livestock and hay were the major agricultural activities.

Two other factors may also contribute to the greater number of complaints in Region Three than in Region Four. First, wheat, barley and oats are stored in grain bins on farms after harvest or sold off the farm at harvest. Therefore, the length of time that these crops are exposed to potential game damage is less than that of hay, which is often stored in unprotected stacks after harvesting. Second, the ratio of cropland acres to deer and elk numbers is approximately three to four times lower in Region Three than in Region Four.

Our results also support the hypothesis that game damage complaint levels are influenced by winter weather conditions. In each region, variables associated with maximum snow depth, precipitation levels and minimum temperatures during the winter months were correlated with complaint levels.

In Region Three, complaint levels were correlated with winter weather variables in specific months (i.e., November precipitation, December snow levels and mean minimum temperature). In Region Four, however, complaint levels were correlated to winter weather variables over a period of several months (i.e., November to March maximum snow depths). The time-specific correlations in Region Three may be due to the more mountainous terrain of the region. Bad weather (i.e., high precipitation, deep snow and cold temperatures) early in the winter might force the movement of ungulates from high elevation summer ranges to lower elevation winter ranges.

The negative correlation with precipitation in May and June in Region Three may indicate that wild ungulates make greater use of irrigated fields when the natural vegetation is dry. A lack of precipitation in May and June may retard the early growth of natural vegetation and the corresponding movement of deer and elk to higher elevation summer ranges. The lack of correlation between May and June precipitation and complaint levels in Region Four may reflect the lack of irrigated fields in that region (less than 20 percent of the cropland in Region Four is irrigated, compared to more than 70 percent in Region Three).

Neither the Region Three nor the Region Four model contained a population variable. However, it is widely believed that population numbers and game damage levels are directly related (Matschke 1984). If game damage levels reflect changes in local populations, the absence of a population variable may reflect the large scale used to develop both models. At the regional level, increased population sizes in one area may be offset by decreased population sizes in another area.

A drawback to applying these models for yearly prediction purposes is the temporal association of the dependent and explanatory variables. Both models perform well in explaining last year's complaints, but they will have limited use in forecasting the coming year's complaints since the data related to the explanatory variables cannot be collected until winter. Some of this problem can be avoided. The majority of complaints (more than 85 percent) in both regions are filed between October and June. By tracking the market year price of hay (which begins June 1) and assessing the possible severity of a winter by November or December, the models could be used to estimate the relative number of complaints that will be filed during the first half of the following year (January to June).

Management Implications

Although the specific variables important in determining complaint levels in other areas will vary, the results of this study should provide wildlife managers with valuable information regarding the general relationships which might lead to high game damage complaint levels. Specifically, our findings indicate that agricultural economic conditions can be an important factor in determining game damage complaint levels, particularly in areas where the major agricultural commodities are not eligible for government price supports and income transfers. Wildlife managers in these areas may be well advised to consider economic conditions when planning or allocating funds for game damage programs.

References

Adkins, R. J. 1991. An analysis of game damage and game damage complaints in Montana. M.S. thesis, Dept. Biology, Montana St. Univ., Bozeman. 90 pp.

Boyd, R. J. 1960. An evaluation of spring grazing on alfalfa by deer in western Colorado. Proc. West. Assoc. Game and Fish Commiss. 40:130–147.

Brown, T. L., D. J. Decker, and C. P. Dawson. 1978. Willingness of New York farmers to incur white-tailed deer damage. Wildl. Soc. Bull. 6:235–239.

Carpenter, M. 1967. Methods of repelling deer in gardens, orchards, and fields in Virginia. Proc. Ann. Conf. Southeast Assoc. Fish and Wildl. Agencies 20:233–235.

Conover, M. R. and D. J. Decker. 1991. Wildlife damage to crops: Perceptions of agricultural and wildlife professionals in 1957 and 1987. Wildl. Soc. Bull. 19:46–52.

Decker, D. J., N. Sanyal, T. L. Brown, R. A. Smolka, Jr., and N. A. Connelly. 1984. Reanalysis of farmer willingness to tolerate deer damage in western New York. Pages 37–45 *in* Decker, D. J., ed., Proc. First Eastern Wildl. Damage Control Conf. Cornell Univ., Ithaca, NY.

Dusek, G. L. 1984. Some relationships between white-tailed deer and agriculture on the lower Yellowstone River. Pages 27–33 *in* Dood, A., ed., Agriculture and wildlife. Proc. 1984 Ann. Meeting Montana Chapt. Wildl. Soc.

Economic Report of the President. 1971–1991. U.S. Govt. Print. Off. Washington, D.C.

Greene, A. F. C. 1985. The high cost of game damage. Colorado Outdoors 34:10–13.

Hygnstrom, S. E. and S. R. Craven. 1987. Home range responses of white-tailed deer to crop-protection fences. Pages 128–131 *in* Holler, N. R., ed., Proc. Third Eastern Wildl. Damage Control Conf. Auburn Univ., Auburn.

Kennedy, P. 1986. A guide to econometrics. The MIT Press, Cambridge, MA. 238 pp.

Lyon, L. A. and P. F. Scanlon. 1985. Evaluating reports of deer damage to crops: Implications for wildlife research and management programs. Pages 224–231 *in* Bromely, P. T., ed., Proc. Second Eastern Wildl. Damage Control Conf. North Carolina St. Univ., Raleigh, NC.

Matschke, G. H., D. S. deCalesta, and J. D. Harder. 1984. Pages 647–654 *in* Halls, L. K., ed., White-tailed deer: Ecology and management. Stackpole Books, Harrisburg, PA.

Montana Department of Agriculture. Montana agricultural statistics bulletins. 1970–1991. Montana Agricultural Statistics Service, Helena, MT.

Montana Department of Fish, Wildlife and Parks. Hunting and harvest reports. 1972–1991. Helena, MT.

National Oceanic and Atmospheric Administration (NOAA). U.S. weather bureau climatological data—Montana. 1972–1991. U.S. Department of Commerce, National Climatic Center, Asheville, NC.

Purdy, K. G. 1987. Landowners' willingness to tolerate white-tailed deer damage in New York: An overview of research and management response. Pages 371–375 *in* Decker, D. J. and G. R. Goff, eds., Valuing wildlife: Economic and social perspectives. Westview Press, Boulder, CO.
Reed, D. F. 1981. Conflicts with civilization. Pages 509–535 *in* Wallmo, O. C., ed., Mule and black-tailed deer of North America. Univ. Nebraska Press, Lincoln, NE.
Scott, J. D. and T. W. Townsend. 1985. Deer damage and damage control on Ohio's nurseries, orchards and Christmas tree plantings: The grower's view. Pages 205–214 *in* Bromely, P. T., ed., Proc. Second Eastern Wildl. Damage Control Conf. North Carolina St. Univ., Raleigh, NC.
Spencer, D. A. 1984. Animal damage control in the eastern United States. Pages 17–25 *in* Decker, D. J., ed., Proc. First Eastern Wildl. Damage Control Conf. Cornell Univ., Ithaca, NY.
Tanner, G. and R. W. Dimmick. 1983. An assessment of farmers' attitudes towards deer and deer damage in western Tennessee. Pages 195–199 *in* Decker, D. J., ed., Proc. First Eastern Wildl. Damage Control Conf. Cornell Univ., Ithaca, NY.
Tebaldi, A. 1979. Effects of deer use on winter wheat and alfalfa production. Wyoming Game and Fish. Research project no. FW–3–R–26. 25 pp.
U.S. Department of Commerce. 1989. Census of agriculture 1987—Montana state and county data. Part 26. Bureau of the Census, Washington, D.C. 343 pp.
Western Association of Fish and Wildlife Agencies. 1986. Report of the ad hoc committee on game damage and supplemental winter feeding. 80 pp.
White, K. J. 1978. A general computer program for econometric methods—SHAZAM. (Version 6.0, 1987). Econometrica 46:239–240.
Zar, J. H. 1984. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718 pp.

Future Challenges of Suburban White-tailed Deer Management

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Introduction

The past quarter-century has witnessed a period of major growth and spread of people, automobiles, suburban living and nonfarm rural land ownership. At the same time, white-tailed deer (*Odocoileus virginianus*) numbers have increased to unprecedented levels, and populations have expanded into areas with suburban development (Flyger et al. 1983). Deer in suburban landscapes cause significant economic losses to residential landowners, present safety hazards to motorists and are perceived as agents in the transmission of Lyme disease (Connelly et al. 1987, Decker 1987). Most suburban residents enjoy deer and many recognize the need for and expect deer population management programs. However, many suburban residents are unlikely to support the traditional approach to deer population control, given their protective view of wildlife, and their lack of participation in sport hunting (Decker and Gavin 1987).

Hesselton (1991) indicated that many "new" landowners on the suburban-rural fringe often withhold access to their property, and support local ordinances that effectively eliminate hunting. The Northeast Deer Technical Committee discussed "unmanageable deer populations" in suburban areas at their 1991 annual meeting in Lenox, Massachusetts. Many agency biologists equate the terms "unmanageable" and "unhuntable" when discussing problems with suburban deer herds. Hesselton (1991) suggested that wildlife agencies that are funded primarily by hunting, fishing and trapping licenses, suspend services (i.e., responding to nuisance wildlife control and wildlife law enforcement complaints) to communities which pass local anti-hunting laws. Kania and Conover (1991) emphasized that wildlife agencies should respond to societal changes rather than resist them, and thereby enhance the value of the wildlife resource for all citizens. In this paper, we explore the challenges facing biologists who manage suburban deer herds, and discuss whether "unhuntable" deer should necessarily be "unmanageable."

Sociopolitical Challenges

Hunter Access to Private Lands

Free-roaming, wild deer are a publicly owned resource that government agencies are mandated to manage for the public good. Because most wildlife in the eastern

United States is found on private lands, the ultimate success of deer management programs advocated by government agencies is dependent upon acceptance and cooperation of private landowners. Increases in land-posting, influenced in part by unethical behavior of hunters, landowner liability laws and a shift in attitudes of nonfarming rural landowners (Decker et al. 1982, Brown et al. 1984), has resulted in limited hunter access and uncontrolled deer population growth in some suburban areas. Also, suburban residents may lack understanding of predation and natural deer mortality processes, and could be influenced by the media attention of vocal animal rights or welfare groups. Several authors indicated that at least half of U.S. residents opposed hunting in the mid-1970s (Applegate 1975, Kellert 1978, Shaw et al. 1976), and that women and urban residents have the most negative attitudes towards hunting (Kellert 1978, Shaw 1977). Somewhat surprisingly, in suburban areas of southeastern and western New York approximately 75 percent of homeowners supported regulated hunting as a method to manage local deer populations (Sayre and Decker 1990). Educational programs targeted at private landowners that emphasize wildlife ecology and the role of hunting in wildlife management (Decker and Connelly 1990) may change the attitudes of suburban residents and reduce land-posting.

The size of land holdings in many residential areas with high deer densities creates another management dilemma. If hunting is to be an effective management tool, appropriate hunter distributions will be necessary to overcome safety concerns and spread the harvest more evenly across local deer populations. With 5-acre (2-ha) lot sizes, a sportsman may need permission from 5–10 contiguous, private homeowners in order to have enough land area to effectively hunt deer. Also, many suburban areas have safety-zone regulations which prohibit the discharge of firearms within 450–500 feet (150–200 m) of occupied dwellings or playgrounds; in these areas gun hunting is simply not feasible. As lot sizes decrease, the practicality of either bow or gun hunting as a management option is questionable.

Serious deer damage to natural and managed vegetation often occurs on private lands near parks or other large government-owned tracts which act as refugia. National and state parks, wildlife refuges, and greenways frequently were established as wildlife preserves with specific regulations prohibiting hunting. For some urban parks, changes in regulations may be possible through a well-designed public education program. In other situations, hunting will never be possible due to cultural values which society holds for the land (e.g., Gettysburg National Museum).

Hunter Ethics and Behavior

In-depth hunter education is needed to ensure deer taken for sport are killed quickly, cleanly and with appropriate respect (Heberlein 1991). Hunter safety courses are currently targeted at youth and new hunters, and are taught by dedicated, but minimally-trained volunteers. Every deer season, as the list of hunting accidents and fatalities begins to grow, it's obvious that common-sense regulations have been violated (i.e., shooting before or after legal hours, not positively identifying the target, etc.). Excessive media coverage of such accidents may increase suburban residents' reluctance to invite hunters onto their property. The most important factor influencing land-posting is hunter behavior (Decker et al. 1982). If the landowner image of hunters and other outdoor recreationists were to improve, there may well be a decrease in land-posting in suburban areas.

Heberlein (1991) has suggested that sportsmen complete both a basic course, and a master hunter course, with a required exam and field tests. Shooting proficiency tests are required before participating in a controlled deer hunt at Cary Arborteum in southeastern New York (Winchcombe 1991). Safety was an important consideration with these hunters, as 93 percent of 44 survey respondents said they hunted at Cary Arboretum because they felt it was a safe place to hunt. Adult-oriented, mandatory education courses, which should include shooting proficiency tests for all hunters, will greatly enhance the sportsmen's image and improve hunter relations with private landowners. Periodic refresher courses for experienced hunters, increasing the focus on hunter ethics, and additional training for instructors also would enhance the current situation.

Sportsmen also must police their own ranks in order to improve their public image and gain respect from suburban property owners (Mooney 1988). Wildlife agencies, with limited staff and budgets, cannot be expected to solve hunter behavior problems. Biologists must find innovative ways to reduce the peer pressure hunters face to fill their deer tags each season. This pressure often leads to poor choices, faulty decisions, and subsequent hunting accidents and fatalities. Also, each person has his/her own values and beliefs, which result in different criteria for defining unsafe or unethical hunting behaviors (J. W. Enck personal communication: 1992). Additional research is needed to clarify hunter motivations and philosophies, and the formation of these attitudes. Biologists must then use this attitudinal information and target communication strategies to modify inappropriate hunter behaviors through peer pressure.

Bucks-only deer harvests, which are preferred by many sportsmen, cannot stabilize numbers or reduce deer overpopulation. A successful deer reduction program requires an adequate number of doe-only or either-sex permits, and hunters must be educated and convinced that doe hunting is not detrimental to the herd (McCullough 1984). Decker and Connelly (1990) have stressed the need for better education of hunters regarding their role in wildlife management. This retraining of sportsmen will be difficult, as we effectively educated hunters to protect does during the 1940s through the 1960s. Decker and Connelly (1990) noted it will be a challenge to redirect most hunters' focus from taking bucks in order to satisfy their personal desires, towards broader management objectives (i.e., lowering deer numbers to reduce human health and safety risks, or plant damage). Hunters have different motivations for participating in their sport, and effectively modifying their behavior will require extensive and sophisticated communication strategies (Decker and Connelly 1989).

Health and Safety Issues

Health and safety risks associated with Lyme disease and deer-related vehicle accidents (DRVAs) were the primary deer-related concerns of homeowners in New York (Sayre and Decker 1990). Decker and Gavin (1987) postulated that if deer-related concerns increased in Islip, Long Island, more residential landowners would prefer fewer deer in the future. These suburbanites recognized they had paid a price for tolerating deer: damage to landscape plantings and vegetable gardens, hazard of DRVAs, and potential disease transmission. However, Islip residents generally held a negative view of hunting and did not personally participate in the sport. Consequently, either a nontraditional control method, or an effective educational effort before a hunt would be required (Decker and Gain 1987).

The distribution of immature deer ticks (*Ixodes dammini*) has recently been correlated with deer density (Wilson et al. 1990). In southeastern New York, where deer ticks are endemic (Spielman et al. 1985), Lyme disease was the primary deer-related concern of homeowners (Sayre and Decker 1990). Deer tick populations now occur in most New York counties (J. J. Howard personal communication: 1992), and as the spirochete causing Lyme disease becomes established in tick populations in other parts of the state, tolerance of deer in suburban areas will likely decrease. This will intensify the need for new, nontraditional approaches for deer population regulation. Biologists will need to determine the risks of contracting Lyme disease which correspond with various deer densities, and develop educational programs to reduce these risks in residential areas. There is still much controversy concerning the relationship of adult deer tick and deer numbers, and the role of deer as a reservoir or vector for Lyme disease transmission to humans.

The potential for DRVAs is directly correlated with deer population density, and DRVAs increased dramatically in Princeton, New Jersey, after the enactment of a no-firearms-discharge law by the Township Committee in 1972 (Kuser and Wolgast 1983). The original intent of the ordinance was to protect public safety, although there were no records of a resident being injured by a hunter. Ironically, the ordinance had the opposite effect, as two motorists and a bicycle rider have been injured by deer. Kuser and Applegate (1986) sensed that public opinion supporting deer control was mounting, and that steps to reduce deer numbers would be taken until DRVAs began to decline. They predicted there would be a return to shotgun deer hunting once the township's residents were certain other possible solutions were ineffective or impractical.

Public Involvement in the Deer Management Decision-making Process

Kania and Conover (1991) highlighted the danger of a governmental agency forcing traditional wildlife management programs upon unwilling citizens. State and federal resource agencies are entrusted to manage deer and other wildlife for all citizens to enjoy. Several states are experimenting with new techniques for including stakeholder groups (i.e., farmers, sportsmen, motorists, homeowners, etc.) in deer management decisions, thereby increasing involvement in and public support for agency programs. In Wisconsin, a citizens' ad hoc committee on deer management was appointed by the state Natural Resources Board in response to deer herd problems (Craven 1991). Twelve representatives from five stakeholder groups met seven times during a five-month period. The committee formulated a list of 23 recommendations which was submitted to the Natural Resources Board. Committee members were satisfied with the final report, and under criticism from their constituents, stakeholders strongly defended the process and the product.

During 1990, Cornell Cooperative Extension (CCE) and the New York State Department of Environmental Conservation (DEC) cooperatively organized citizen task forces in 15 deer management units (DMUs) across New York (Hall 1991, Stout et al. 1991). DEC and CCE selected 8–10 task force members in each DMU to represent a broad range of stakeholder groups. CCE county agents facilitated meetings, and DEC staff provided technical advice. Committee members discussed the costs and benefits of deer populations at various densities, and determined the best population level for their DMU. Thirteen of the 15 task forces reached consensus and recommended a deer population objective to DEC. Based on the success of this pilot effort, an additional 18 DMUs will experiment with task forces during 1991 and 1992.

These examples indicate the willingness of citizens to participate in the deer management decision-making process. Including stakeholders in the process enhances agency credibility and increases public support for other programs and activities. However, these citizen involvement efforts have not always received overwhelming support from agency biologists, who believe that important wildlife management decisions are the purview of trained professionals. Timm (1991) cautioned that public perceptions of a management situation may be quite different from the management realities. We believe biologists can bridge the gap between perception and reality with effective educational programs. Public involvement in key management decisions is but one of many potential methods for informing key opinion leaders in the community. Wildlife professionals cannot continue to "act as judge and jury for all wildlife management decisions" (Miller 1991), or "the 90 percent of citizens that do not hunt may realize that their wildlife agency is interested in managing their wildlife resource not for their benefit but for someone else's" (Kania and Conover 1991:225).

Local Ordinances

The authority of states to regulate hunting has been clearly defined by law, and states' rights have been upheld in court. However, a New Jersey State Supreme Court decision indicated that a township can regulate the discharge of firearms to protect the safety of its citizens (Kuser and Wolgast 1983), and other county or town governments have passed similar local laws. This results in a legal dilemma, as these local laws can effectively ban gun or bow hunting within a community. Most townships which decide to ban hunting perceive that the safety of their residents will be increased (McDowell and Applegate 1976).

To reduce the proliferation of local no-discharge ordinances, wildlife agencies must do more to inform people of the actual risks and costs of DRVAs, and the potential for contracting Lyme disease in areas with high deer populations. As more people are directly affected by deer health and safety concerns, public opinion may shift towards deer control (Kuser and Applegate 1986), and the repeal of local laws. Proactive educational programs targeted at opinion leaders within affected communities can improve the working relationship between local township governing boards and wildlife management agencies. In some cases, citizens may require the consideration of nontraditional deer control methods before they would support either gun or bow hunting.

Court Injunctions

Groups with strongly-held minority opinions may choose to use the courts as a last resort to stop hunting or other controversial wildlife management activities. The primary defense wildlife agencies have against these attempts to block deer population management programs is to ensure that data collection is conducted in a scientific manner which will withstand public scrutiny. Increasingly, biologists will be held accountable for their management decisions. Good recordkeeping and data analyses will enhance our professional credibility and ensure that management programs will withstand court challenges. Keeping people informed of the need and reasons for specific management decisions will increase the chances that cases will be decided in favor of the wildlife agency should a trial be necessary.

Management and Research Challenges

Effectiveness of Archery versus Gun Hunting

Because of firearms restrictions in suburban areas, some wildlife agencies propose bowhunting as a tool to regulate deer numbers. Few data are available to determine the cost-effectiveness of archery hunting for controlling deer population growth, and information to date has not been encouraging. In Princeton Township, New Jersey, deer bowkill increased dramatically following a no-firearms-discharge ordinance enacted in 1972 (Kuser and Applegate 1986). However, it became obvious that bowhunting alone was not an effective deer population control measure, as DRVAs also greatly increased in the absence of shotgun hunting (Kuser and Wolgast 1983).

Bowhunters registered 80 deer during the 1990 hunt at Rock Cut State Park (RCSP), Illinois, despite making a total of 2,637 hunter-trips (n = 723 hunters) during a 39-day season (Witham 1991). The bowhunt alone did not reach the target of 214 deer removals that were needed to reduce herd population growth. Sharpshooters were employed to remove an additional 134 deer after the bowhunt in order to reach the management goal. Hunter participation reached 90 percent of the potential maximum number of trips, as RCSP could accommodate 75 hunters/day for the 39-day season. Even with increases in season length or hunter densities, it is very unlikely that archery hunting alone could remove enough deer to meet management objectives.

Based on these examples, it is doubtful that bowhunting alone will cause significant reductions in deer-damage complaints in suburban landscapes, or stabilize deer population growth. With firearms safety-zone regulations, gun hunting also will not be practical for many residential areas. Consequently, socially acceptable deer-removal solutions besides sport hunting will still be required for many suburban landscapes.

Separate Regulations for Suburban Areas within Deer Management Units

Wildlife agencies often develop DMUs based on similarity of habitat type and deer densities. DMUs may vary in size from county-sized parcels to entire sections of a state. This system has worked relatively well in rural areas for more than 40 years. However, metropolitan areas within DMUs usually receive the same management approach as the surrounding rural habitats.

Deer are very adaptable, and densities in suburban areas currently far exceed previous expectations of biologists. For example, Kuser and Applegate (1986) estimated densities in excess of 50 deer/sq. mi. (19 deer/sq. km) in 17-square-mile (44 sq. km) Princeton Township, New Jersey. Deer numbers reached these unprecedented levels following a ban on the discharge of firearms, leaving DRVAs and bowhunting as the primary sources of deer mortality (excluding old age) within the township. This trend is becoming the rule rather than the exception for many metropolitan areas with good deer habitat. For example, deer densities may exceed 100/sq. mi. (39 deer/sq. km) in portions of the Town of Irondequoit near Rochester, New York, following a 1976 ban on bow and firearms discharge (J. Hauber personal communication: 1992).

Due to the complexity of town-by-town deer management, or zone management within townships, state wildlife agencies have frequently resisted change and chosen an all-or-nothing approach to gun hunting; unfortunately, in Princeton they got nothing (Kuser and Applegate 1986). The situation in Rochester remains controversial despite more than 10 years of discussion and heated debate. It is time for wildlife agencies to reexamine the DMU approach in suburban situations, and work with local governments and citizens to develop new and innovative concepts for managing high-density deer herds living in close proximity to people. Also, agencies must find creative ways to capture the financial support of suburbanites in order to pay for the specialized deer management necessitated by the situation and landowner attitudes. Residents must realize that there are costs associated with tolerating high deer densities, and if the damage-tolerance level of homeowners is exceeded, management programs to reduce deer populations are quite expensive.

Population Modeling and Census Methods

Harvest information collected during regular gun seasons is frequently used to develop deer physical condition indices and monitor deer population trends over time for DMUs in many states. Consequently, few data are available for suburban areas with archery-only seasons, or no hunting seasons at all. DRVAs and damage complaints provide the only available indices to changes in deer population size. Although these indices suggest that deer numbers have exceeded both biological and cultural carrying capacity (Ellingwood and Caturano 1988) in many metropolitan areas, they do not provide estimates of herd size or establish target numbers for deer control. When citizen task forces assist with setting deer population goals, often one of the first questions asked is, "how many deer do we have?" Biologists will need to refine and improve deer census methods for suburban areas in order to answer this question. If biologists expect public support for management programs, population estimates must withstand both public scrutiny and court challenges. Wildlife agencies must obtain reliable information that can be used to correlate deer population estimates with DRVA and damage statistics. The goal should be to provide reliable answers to questions such as, "how many does and bucks must be removed annually in a given unit to reduce DRVAs by 75 percent?"

Repellents and Fencing

Wildlife agencies frequently recommend fencing and/or repellents to address site-specific deer problems. These solutions treat only the symptoms of deer overpopulation in suburban areas. Ellingwood and Caturano (1988) stressed that these techniques were designed to supplement, not replace, deer population management. Safety concerns limit the use of electric fencing in suburban areas, and local ordinances have been passed to restrict their use. Repellent performance is variable, and under the best conditions, deer browsing may only be reduced by only 70–80 percent. As deer densities increase and available food resources decrease, repellent effectiveness declines.

New York homeowners listed fencing as the method most often used to protect suburban landscapes from deer damage (Sayre and Decker 1990). Combining fencing with repellents enhances the effectiveness of both materials (Jordan and Richmond 1991). Additional research will likely improve the cost-effectiveness of these techniques. However, fencing and repellents are not a long-term solution to deer overpopulation problems.

Deer Contraception

Control of free-ranging deer populations with contraceptives continues to be investigated. Several chemicals are available which will reduce or eliminate deer pregnancies (Matschke 1977, Matschke 1980, Roughton 1979), but no cost-effective delivery system is currently available. Steroid implants have suppressed deer ovulation for two breeding seasons, however, for effective management, an implant should last for the reproductive life of the animal (Matschke 1980). Recent advances in remotely-delivered immunocontraception for captive, unrestrained deer (Turner et al. 1992), indicate it may be possible to solve this technical problem. However, current methods still require three injections, and the development of a single-dose vaccine would be necessary. Also, with remote delivery, methods must be developed for identifying treated versus untreated does in free-ranging herds.

Fertility control for free-ranging deer requires much additional research (Kirkpatrick and Turner 1991). Immunocontraception may affect long-term deer behavior patterns and social organization (Turner et al. 1992), as some treated does continued to cycle after not becoming pregnant. Although there is increased public pressure to develop nonlethal deer control techniques (Kellert 1991), contraceptive technology is still experimental, and it will likely be several years before practical chemicals and delivery systems become available.

Summary

Many of the challenges we mention are not new, in fact, wildlife agencies have grappled with some of these issues for more than a decade. However, as suburban deer populations increase, and we see greater development pressures on rural lands, these problems will likely intensify and become more prevalent in the future. There will be no quick-fix or magic bullet that will resolve the suburban deer management challenges we face.

Because conflicts between people and deer in residential landscapes are increasing, the wildlife management profession is being scrutinized by greater numbers of citizens and stakeholder groups. Our future credibility and program support may well depend on the merit of our management recommendations, and the way we handle controversial deer management situations. More than 90 percent of Americans will live or work in metropolitan areas by the year 2000 (Shomon 1970). Mismanagement of highly visible human/wildlife conflicts will undoubtedly attract media attention and erode public confidence in our profession. On the other hand, biologists should not be afraid to promote successful programs, and work closely with key media contacts to highlight success stories and enhance agency support.

Government agencies must accept and encourage input from a broader array of stakeholder groups in order to effectively address suburban wildlife management problems. Agencies will need to build communication channels with key community opinion-leaders. Field staff should be as comfortable talking with town and county officials, businessmen and homeowners associations, as they are speaking with members of the local sportsmen's club. It's important that nontraditional stakeholders understand that sportsmen are primarily responsible for many of the wildlife management success stories and outdoor recreation opportunities all of us enjoy.

Several times, the educational needs of landowners, homeowners, hunters and other stakeholder groups have been mentioned. However, good communication involves a two-way exchange of ideas, and also should result in a learning process for professional wildlife biologists. Careful documentation of activities and programs is necessary for critical evaluation and the refinement of messages and delivery methods. It's important to determine *why* specific programs either worked or failed, so that time, energy and dollars can be spent on the most productive educational approaches. Biologists also must evaluate the attitudes and beliefs of various stakeholders, so that messages can be targeted for specific audiences.

Finally, we address the question of "unhuntable" versus "unmanageable" deer populations. There is little doubt that gun hunting is currently the most cost-effective method for reducing deer numbers (Ellingwood and Caturano 1988). However, biologists lose credibility and public support for wildlife programs, when we approach a wide array of deer management situations and suggest the same solution to resolve all problems. We must be more sensitive to public attitudes and values, and become better listeners. In many cases, hunting will often be the best management option. However, biologists should be aware that management decisions reflect our own value judgements, and are based partly on scientific evidence and the effectiveness of known alternatives, and partly on beliefs concerning human uses of wild animals (Richmond 1973, Decker et al. 1991). Other deer management stakeholders will exhibit a wide range of values, beliefs and opinions concerning hunting and ethical sportsmen behavior. Biologists must give each of these appropriate consideration. If people are willing to devote volunteer time and effort, and research dollars to improve nontraditional management techniques (i.e., deer contraception), or explore other nonhunting alternatives, wildlife agencies should not simply dismiss these ideas because they are currently impractical. After all, how many of us would have made the prediction in 1975 that most biologists would have a personal computer at their desk in 1990! We contend that few deer populations are truly "unmanageable," as long as biologists are willing to experiment with creative, nontraditional approaches.

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References

Applegate, J. E. 1975. Attitudes toward deer hunting in New Jersey: A second look. Wildl. Soc. Bull. 3:3-8.

Brown, T. L., D. J. Decker, and J. W. Kelley. 1984. Access to private lands for hunting in New York: 1963-1980. Wildl. Soc. Bull. 12:344-349.

Connelly, N. A., D. J. Decker, and S. Wear. 1987. Public tolerance of deer in a suburban environment. Proc. East. Wildl. Damage Control Conf. 3:207-218.

Craven, S. R. 1991. Public involvement in wildlife damage management: the situation in Wisconsin. Proc. East. Wildl. Damage Control Conf. 5:(in press).

Decker, D. J. 1987. Management of suburban deer: An emerging controversy. Proc. East. Wildl. Damage Control Conf. 3:344–345.
Decker, D. J. and N. A. Connelly. 1989. Motivations for deer hunting: Implications for antlerless harvest as a management tool. Wildl. Soc. Bull. 17:455–463.
Decker, D. J. and N. A. Connelly. 1990. The need for hunter education in deer management: Insights from New York. Wildl. Soc. Bull. 18:447–452.
Decker, D. J. and T. A. Gavin. 1987. Public attitudes toward a suburban deer herd. Wildl. Soc. Bull. 15:173–180.
Decker, D. J., T. L. Brown, S. J. Tuttle, and J. W. Kelley. 1982. Posting of private lands in New York: A continuing problem. Conserv. Circ. 20(7). Dept. Nat. Resour., New York St. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 6 pp.
Decker, D. J., R. E. Shanks, L. A. Nielsen, and G. R. Parsons. 1991. Ethical and scientific judgements in management: Beware of blurred distinctions. Wildl. Soc. Bull. 19:523–527.
Ellingwood, M. R. and S. L. Caturano. 1988. An evaluation of deer management options. Northeast Deer Tech. Comm. Publ. No. DR–11. 12 pp.
Flyger, V., D. L. Leedy, and T. M. Franklin. 1983. Wildlife damage control in eastern cities and suburbs. Proc. East. Wildl. Damage Control Conf. 1:27–32.
Hall, M. 1991. Citizen task force on deer management. Proc. East. Wildl. Damage Control Conf. 5:(in press).
Heberlein, T. A. 1991. Changing attitudes and funding for wildlife—preserving the sport hunter. Wildl. Soc. Bull. 19:528–534.
Hesselton, W. T. 1991. How government agencies should respond to local governments that pass antihunting legislation. Wildl. Soc. Bull. 19:222–223.
Jordan, D. and M. E. Richmond. 1991. Effectiveness of a vertical 3-wire electric fence modified with attractants or repellents as a deer exclosure. Proc. East. Wildl. Damage Control Conf. 5:(in press).
Kania, G. S. and M. R. Conover. 1991. How government agencies should respond to local governments that pass antihunting legislation—a response. Wildl. Soc. Bull. 19:224–225.
Kellert, S. R. 1978. Attitudes and characteristics of hunters and antihunters. Trans. N. Am. Wildl. and Nat. Resour. Conf. 43:412–423.
———. 1991. Changes in deer management and public attitudes. *In* S. Lieberman, ed., Current issues in deer management in urbanizing regions. U.S. Humane Soc., Washington, D.C., Princeton Univ. Press, Princeton, NJ. (In press).
Kirkpatrick, J. F. and J. W. Turner. 1991. Contraception as an alternative to traditional deer management techniques. *In* S. Lieberman, ed., Current issues in deer management in urbanizing regions. U.S. Humane Soc., Washington, D.C., Princeton Univ. Press, Princeton, NJ. (in press).
Kuser, J. E. and J. E. Applegate. 1986. Princeton Township: The history of a no-discharge ordinance's effect on deer and people. Trans. Northeast Sect., The Wildl. Soc., Hartford, CT.
Kuser, J. E. and L. J. Wolgast. 1983. Deer roadkill increases with no-firearms-discharge law. Bull. NJ Acad. Sci. 28:71–72.
Matschke, G. H. 1977. Fertility control in white-tailed deer by steroid implants. J. Wildl. Manage. 41:731–735.
———. 1980. Efficacy of steroid implants in preventing pregnancy in white-tailed deer. J. Wildl. Manage. 44:756–758.
McCullough, D. R. 1984. Lessons from the George Reserve, Michigan. Pages 211–242 *in* L. K. Halls, ed., White-tailed deer: Ecology and management. Stackpole Books, Harrisburg, PA.
McDowell, R. L. and J. E. Applegate. 1976. "Operation Good Neighbor"—an approach to solving the problems of hunting at the rural/urban interface. Trans. Northeast Sect., The Wildl. Soc. 33:137–139.
Miller, J. E. 1991. Conference summary and a look to the future. Proc. East. Wildl. Damage Control Conf. 5:(in press).
Mooney, R. 1988. How to bag slob hunters. Outdoor Ethics Vol. 7(4):6–7.
Richmond, M. E. 1973. Land animals. New York Acad. Sci. 216:121–127.
Roughton, R. D. 1979. Effects of oral MGA on reproduction in captive white-tailed deer. J. Wildl. Manage. 43:428–436.
Sayre, R. W. and D. J. Decker. 1990. Deer damage to the ornamental horticulture industry in suburban New York: Extent, nature and economic impact. Human Dimensions Res. Unit Series 90–1, New York St. Coll. Agric. Life Sci., Cornell Univ., Ithaca. 75 pp.

Shaw, W. W. 1977. A survey of hunting opponents. Wildl. Soc. Bull. 5:19–24.

Shaw, W. W., E. H. Carpenter, L. Arthur, R. L. Glum, and D. J. Witter. 1978. The American disposition toward hunting in 1976. Wildl. Soc. Bull. 6:33–35.

Shoman, J. J. 1970. More wildlife in urban America. Conservation 24:2–7.

Spielman, A., M. L. Wilson, J. F. Levine, and J. Piesman. 1985. Ecology of *Ixodes dammini*-borne human babesiosis and Lyme disease. Annu. Entomol. 30:439–460.

Stout, R. J., D. J. Decker, and B. A. Knuth. 1991. Agency and stakeholder evaluations of citizen participation in deer management decisions: Implications for damage control. Proc. East. Wildl. Damage Control Conf. 5:(in press).

Timm, R. M. 1991. Perceptions and realities: When does 2 + 2 = 5? Proc. East. Wildl. Damage Control Conf. 5:(in press).

Turner, J. W., Jr., I. K. M. Liu, and J. F. Kirkpatrick. 1992. Remotely delivered immunocontraception in captive white-tailed deer. J. Wildl. Manage. 56:154–157.

Wilson, M. L., A. M. Ducey, T. S. Litwin, T. A. Gavin, and A. Spielman. 1990. Microgeographic distribution of immature *Ixodes dammini* ticks correlated with that of deer. Med. and Vet. Entomol. 4:151–159.

Winchcombe, R. J. 1991. Minimizing deer damage to forest vegetation through aggressive deer population management. Proc. East. Wildl. Damage Control Conf. 5:(in press).

Witham, J. H. 1991. Reduction of local deer herd at Rock Cut State Park. Contract Completion Rept., Illinois Dept. Conserv., Div. Wildl. Resour. 41 pp.

Professionalism in Wildlife Damage Management: Issues and Directions

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Introduction

The field of wildlife damage management is specifically directed toward resolving the conflicts that occur when wild animals collide with people's interests in the areas of plant and animal agriculture, human health and safety, property damage, and endangered and valued species management. The wildlife damage management professional attempts to resolve these conflicts.

Wildlife damage management personnel, taken as a whole, suffer from a range of issues affecting their professional image as perceived by both the general public and the wildlife biologist community. These issues include perceptions regarding sufficient levels of education and experience, attitudes toward the wildlife resource in general and certain species in particular, lack of sensitivity to public concerns and animal welfare, and hidden partnerships with special interest groups.

Although wildlife damage management personnel may disagree with the particulars from their critics, we feel these issues are serious challenges to the professional integrity of wildlife damage management researchers, teachers and managers (Miller 1987). They must be addressed in a manner that will lead to total professional acceptance of wildlife damage management personnel by the wildlife biology community, recognizing the need for free and open debates of philosophies and methodologies. Understanding of professional wildlife damage management by public clientele including government agencies, special-interest organizations and commodity user groups must also be achieved.

Wildlife damage management professionals are employed by a wide range of agencies and organizations. Within the federal government, the Animal Damage Control program, a branch of the U.S. Department of Agriculture's Animal and Plant Health Inspection Service, is primarily responsible for resolving conflicts between humans and wildlife. Within other federal agencies, however, there are individuals dedicated to resolving wildlife damage issues. These agencies include the U.S. Forest Service, Bureau of Land Management, Army Corps of Engineers, Fish and Wildlife Service, Department of Defense, and Bureau of Indian Affairs, as well as others. Most state fish and wildlife agencies have some type of a wildlife damage management program, although the species of concern, funding patterns and agency approach vary widely state-to-state. A number of universities have professors or specialists conducting research and extension programs in this field. State departments of health or agriculture also have wildlife damage management programs, especially with wildlife disease transmission reduction programs and programs to reduce bird, rodent, lagomorph and predator damage to plant and animal agricultural products. County and city governments often have dedicated personnel to resolve nuisance urban wildlife complaints as well to monitor and manage commensal rodents and birds. Finally, there is an emerging role for private wildlife damage managers in resolving wildlife damage complaints. Thus, wildlife damage management professionals come from a wide range of professional settings.

Kennedy (1985) argued that wildlife biologists and managers have a unique professional culture, consisting of a distinctive language, technology and artifacts (including appearance), social structure, and professional value system. Utilizing similar criteria, there is an obvious and distinctive professional "subculture" which surrounds those employed in wildlife damage management. This is, in fact, a fundamental reason why there are professional differences between "mainstream" wildlife biologists and those active in the prevention and monitoring of wildlife damage. There are differences in the language, technology, social structure and professional value systems of these two subcultures. We believe there is, in general, a negative perception toward wildlife damage management activities from the average mainstream wildlife biologist. Although alternative points of view should be encouraged, there is a disturbing lack of support for wildlife damage managers from their peers. This is contrary to the normal and traditional professional peer support system. For example, when the Cooperative Fish and Wildlife Research Units were threatened with elimination within the U.S. Fish and Wildlife Service, wildlife biologists and their professional agencies and organizations came to their support. McCabe (1985:343) concluded from this that "When Cooperative Unit professionals are in jeopardy, all wildlife professionals are affected. We must not stand by like a group of wildebeast and moo meekly as a bureaucratic lion devours others of our kind. A professional adversary may take any number of forms, but wherever and whenever, our response must be unified and forceful." For reasons that are not fully understood, wildlife damage managers probably would not receive a similar amount of professional support if, say, the federal ADC program was confronted with elimination.

In addition to friction between these professional subdisciplines, many wildlife damage managers feel alienated from the general public, a view which is easily documented and which has resulted in an unwritten policy of isolation. Kennedy (1985:571) has remarked for wildlife biologists in general, "In an era of challenge and change, a profession may succumb to a defensive, bastille-mentality that views itself and dissenting publics as a contest of right and wrong, the informed vs. the uninformed, the rational vs. the emotional." It is our collective position, and the theme of this paper, that this mentality is unprofessional and detrimental. Furthermore, to maintain such an adversarial relationship with the public is to deny that the various non-professional publics are valid stakeholders with sincere concerns about the use and abuse of publicly-owned natural resources. Increasingly, the public is questioning natural resource management decisions and the way those decisions are made (Lautenschlager and Bowyer 1985, Schmidt 1990). Wildlife damage management is not exempt from this process.

Wildlife damage management practitioners are being asked to perform specialized wildlife management activities such as trapping, shooting or habitat alteration to a degree qualitatively different than other wildlife managers. For example, the general public accepts the annual distribution of millions of non-specific (covering multiple species or unspecified individuals from a population) hunting permits to kill a wide variety of wild animals by minimally-trained hunters, but expects specially-trained personnel to document the effort involved in removing defined individuals or sets of individual animals, often with specific permitting and reporting requirements. Coyotes (*Canis latrans*) are often legally taken in conjunction with ungulate hunting programs, fur harvesting programs or nonspecific sport hunting programs, but there is considerable public and professional pressure to kill livestock depredating coyotes only when specific individual coyotes can be identified and removed, and then, only when it can be done at zero risk to other animals and the environment, without any suffering to boot! We recognize and accept these pressures, but we do identify them as more specific and demanding, compared to wildlife management activities in general. It is in this social and professional arena that wildlife damage management must operate, and that professionalism in wildlife damage management must take into account (Schmidt 1989).

We believe it is more important than ever that wildlife damage management personnel are professional in all aspects of their conduct. Increasing numbers and segments of people in society are watching and judging wildlife management as a whole, including damage management. Refining professional concerns must be the first step in developing a widely acceptable, effective and economical program for the 21st century and beyond.

It must be recognized that social values drive the management of natural resources (Schmidt 1992, Schmidt et al. 1992). Science, strained through the sieves of wildlife biology and ecology, cannot tell us whether it is or is not appropriate to kill a single elk (*Cervus elaphus*) or gray wolf (*Canis lupus*), or to save California condors (*Gymnogyps califorianus*) from extinction. The justification to kill or protect any animal comes from human value systems, which are constantly changing (Powell 1982). Failure to recognize the importance of social values in giving direction to natural resource management decisions is a primary cause of wildlife management decisions being taken out of the hands of professional biologists (Decker et al. 1991). We believe that wildlife professionals should take a leading role in managing natural resources. Professionalism is an important mechanism for developing, refining and building public trust. As professionals, "we need to make a commitment to the full range of values which society assigns to wildlife resources, and we need to strengthen the teaching, research, and application of our science" (Wagner 17:359).

We have developed a list of action items which will steer wildlife damage management personnel toward this goal. Action items include the development of standards relating to ethics and conduct, a projection of a professional image, the refinement of communication outlets, and continuing education programs specific to wildlife damage management. We do not intend to imply that all wildlife damage management professionals are in need of remedial education. Indeed, there are a number of devoted wildlife damage professionals who have been awarded for their professionalism. In this paper, we develop these topics as suggestions to the profession. Finally, we review current efforts within the U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Animal Damage Control (ADC) agency to develop philosophies and strategies for reaching these goals.

Ethics and Conduct

Gilbert (1971) defined a professional as an individual with an ethical outlook, plus training and capabilities. The Wildlife Society's (TWS) certification program for professional wildlife biologists includes a section on ethical requirements. All applicants for certification must "pledge to uphold and conduct their activities in accordance with the Code of Ethics and the Standards for Professional Conduct as prescribed by The Wildlife Society" (Yoakum et al. 1987:44). This code of ethics is professionally binding to the certified wildlife biologist, although it is meant to apply to all members of TWS. Each certified wildlife biologist, in striving to meet the objectives of TWS, pledges to:

1. Subscribe to the highest standards of integrity and conduct;
2. Recognize research and scientific management of wildlife and their environments as primary goals;
3. Disseminate information to promote understanding of, and appreciation for, values of wildlife and their habitats;
4. Strive to increase knowledge and skills to advance the practice of wildlife management;
5. Promote competence in the field of wildlife management by supporting high standards of education, employment, and performance;
6. Encourage the use of sound biological information in management decisions; and
7. Support fair and uniform standards of employment and treatment of those professionally engaged in the practice of wildlife management.

The development of a code of ethics defines the minimum ethical standard for a profession. It is important to recognize that this is a *self-imposed standard*. The profession itself defines what is acceptable and what is not, and individuals have the choice to join or not to join. Thus, activities and behaviors not meeting the minimum standards defined in the code of ethics are, by definition, unethical behaviors. This development and acceptance process is not a rapid procedure. TWS took 15 years (1948–1963) to develop its first code of ethics (Swank 1987), with a revised code approved in 1978.

How does this apply to the wildlife damage management subculture? Robert Sutton, Jr. (1967:44), former Chief of the Branch of Animal Control in the Bureau of Sport Fisheries and Wildlife, stated that "It is incumbent upon us, as [wildlife damage management] professionals, to adopt ethical standards and live within them. This should be our highest goal." Twenty-five years later, there has been no profession-wide adoption of ethical standards in the area of wildlife damage management, except for those biologists certified by The Wildlife Society, although the need for standards is still recognized (Acord 1991).

We believe that the social and biological complexity of the wildlife damage management field requires additional ethical requirements, above and beyond those required by The Wildlife Society. These include:

- specific statements *requiring* strict adherence to relevant laws, regulations and policies;

- specific standards of conduct *to include* the traits of honesty, integrity, sincerity, dedication and a respect for varying viewpoints on wildlife damage management;
- *support and utilization* of non-lethal methods, when practical and economical, of resolving human-wildlife conflicts;
- *commitments* to utilize humane, selective, effective and socially acceptable management techniques; and
- *commitments* to resource protection, utilizing the full spectrum of professional techniques and abilities.

Dorrance (1983:320–321) recognized the public's concern over lethal methods of wildlife damage management when he stated that "Prevention of wildlife damage with nonlethal techniques should be the *primary* goal of all problem wildlife programs" (emphasis added). We believe that this philosophy fits well into the beliefs of most Americans, and it should be seriously considered by wildlife damage management professionals. The wildlife damage management profession itself needs maturing (McAninch 1991).

Professional Image and Communication

"Wildlife professionals must act like professionals" (Svoboda 1980:96). Todd (1980:59) stated that "Wildlife management agencies must mount campaigns to become known, accepted friends and benefactors of all wildlife." These comments reflect concerns over professional image. For some, image is a reflection of what a wildlife professional produces in his or her career. On another scale, image can be focused on specifics such as dress and behavior (Thomas 1985).

In the area of wildlife damage management, professional image will be best served by a combination of approaches. Perhaps most significant is the development of a public and professional image that promotes a deep empathy for alternative viewpoints. Professionals in wildlife damage management need to develop an appreciation for the legitimacy of alternative viewpoints of what they do and how it is done. In light of these concerns, the profession needs to turn a critical eye toward developing procedures acceptable to other wildlife professionals and society. Examples of criticisms from wildlife professionals include the following statements. "The poisoning of nuisance or depredating animals, such as Norway rats, starlings, or coyotes, should be done with the most humane of effective poisons" (Schmidt and Bruner 1981:290). "Game departments now support practices which, though efficient, will in [the] future be banned because they are inhumane. Catching animals by steel, leg-hold traps is a nasty example. Shooting or crippling wolves and coyotes from aircraft is another" (Scheiffer 1976:53). "Poisoning [of predators damaging livestock] should be outlawed except for emergency use by qualified personnel" (Allen 1973:89).

It may be simply a matter of professional trust (Slovic et al. 1991). Does the public trust the current system to solve wildlife damage problems within the public's framework of values? One of five major objectives for the National Institutes of Health in 1992 is to "continually earn the public's respect, trust, and confidence as we carry out our mission" (Palca 1992:530). Trust is a commodity that is easily lost yet slowly gained. Wildlife damage management activities in the past may have contaminated the current views of both the general public and wildlife professionals. If this is the case, then the role of the professional wildlife damage manager will be to rekindle that trust. This will not be done overnight, and it must involve wildlife damage professionals from across the spectrum of organizations and agencies which employ them.

Thomas (1985) stated that wildlife biologists cannot be truly effective without possessing and utilizing good communication skills. This is no surprise to most wildlife biologists, but wildlife damage management professionals must pay special attention to this message. Accurate perceptions of the need for the professional's role in resolving wildlife damage concerns requires that the message be accurate, timely and, above all, credible. This means that every wildlife damage manager should be able to talk to a reporter, write a newspaper column, or discuss controversial issues with the city council, Rotary Club or the state legislature, without embarrassing the profession. It also means that wildlife damage managers must get involved in their professional societies, attending meetings, contributing to the appropriate journals and volunteering for committees (Berryman 1989, Reidinger 1990). Again, this is no surprise; however, we believe that wildlife damage management professionals must address these issues with the same commitment they give to the rest of their professional performance. It is in the best interest of the wildlife damage management professional to develop communication skills and to project a sophisticated, polished role to the public and the wildlife community (Owens 1991).

Continuing Education

The need for continuing education in the wildlife management field is not a new one. George et al. (1974:62) recommended that "at least 20 percent of the working time of the natural resource manager—the equivalent of one day a week—should be devoted to regularly scheduled continuing-education activities." Yoakum and Zagata (1982) concluded that professional wildlife biologists should be recognized by their specialized education and experience, a peer evaluation of their education and experience, commitment to a code of ethics, and dedication to a continuing education program. Allen (1973:89) noted the need for predator management programs to be carried out by professionals with broad wildlife management training. Thomas (1985:1) pointed out that "The professional is always in the process of education."

There are opportunities for specialized continuing education in the area of wildlife damage management, including three biennial national conferences: the Vertebrate Pest Conference, the Great Plains Wildlife Damage Control Workshop, and the Eastern Wildlife Damage Control Conference. However, there are few courses at North American universities, and there are few continuing education classes on specialized topics relating to wildlife damage management. This needs to be rectified, and wildlife damage managers must be assertive in both taking and teaching these classes. Continuing education goes beyond the classroom, however. Aldo Leopold (1933:413) stated that "The teaming of school-trained with unschooled but experienced and open-minded field workers has stimulated both." We agree.

Developing a Future for the Animal Damage Control Program

In light of the professionalism issue, it is important to highlight some of the specific initiatives that the ADC program has planned or has already undertaken that demonstrate a commitment to professionalism.

Acord (1991) addressed the future of the ADC program and the paradigm shift that will be required by wildlife professionals both inside and outside the program. Since that time, the ADC program has been working internally and with cooperators and critics to take a hard look at both the program as it exists today and any changes needed for it to exist and fulfill its congressional mandate into the future. This "futuring" process was initiated last year in an effort to ensure that ADC could continue to provide responsive service to its expanding constituency, while also addressing environmental and animal welfare concerns about activities of the program.

This task was approached through a process involving all levels of employee representation—a vertical slice through the program from the field to the administrators. Representatives from the wildlife management profession outside ADC were also included. Viewpoints were solicited from a wide range of interested parties, including animal welfare groups, agricultural interests and the wildlife management community. Three separate working groups were established to address each of three broad areas of emphasis relative to how the ADC program is conducted. These were identified as:

- *Professionalism*—which includes emphasis on education requirements, membership in professional societies, publishing of technical papers, relations with other agencies, ethics, conduct and a professional image;
- *Methodology*—which concerns total implementation of the Integrated Pest Management (IPM) approach to damage resolution and research, and the adoption of effective, socially acceptable technology; and
- *Management*—which focuses on a more strategic way of thinking and an orientation toward public accountability, environmental sensitivity and a scientific approach to wildlife damage management.

These groups were to develop a consensus around each issue, to modify or expand its elements, get input from peers, and agree on recommendations for ways to implement positive changes. Their goal was to develop a strategy for how the ADC program will evolve in the years ahead. It would be premature to elaborate now in any great detail about the substance of these recommendations, but significant philosophical and attitudinal changes within the program will and must be involved. Increased emphasis also will be placed on professional development for ADC employees.

Professionalism in ADC is one of the most important issues dealt with in ADC's strategic planning efforts, and increased emphasis is being placed on professionalism within the program. ADC employees are encouraged to become involved with The Wildlife Society at the chapter, section and national levels, their respective Regional Associations of Fish and Wildlife Agencies, and other professional societies. ADC has joined the International Association of Fish and Wildlife Agencies as a full member. ADC employees are becoming increasingly involved with colleges and universities in teaching, research or advisory capacities. All of these efforts are intended to help promote an understanding of wildlife damage management in the professional and academic community, and provide continuing education opportunities for current and future ADC employees as well.

An additional initiative ADC has entered into with the academic community is a cooperative agreement with Utah State University's (USU) College of Natural Resources (Schmidt et al. 1992). Through this agreement, USU is developing a model academic program in wildlife damage management at the undergraduate and graduate levels. All course outlines and supplementary materials will be available to share with the faculties of other colleges and universities interested in developing similar programs. This program is expected to contribute to a greater overall awareness among students and members of the wildlife profession about both the need to manage wildlife damage and the science involved in the whole process of wildlife damage management. The USU program will also involve the establishment of an extension program in wildlife damage management with emphasis on national outreach efforts to involve the public.

ADC considers its employees to be the program's single most valuable resource. While we have discussed professionalism in the context of science, other efforts are underway on other aspects of professionalism. ADC personnel are participating in specialized developmental training provided by APHIS. Examples of Agency training available include the Leadership, Education and Development (LEAD) program and the Women's Executive Leadership (WEL) program for mid-level managers. Employees in ADC's headquarters office also participate in an intensive Staff Officer Training program. The rotation of field personnel through the national headquarters office provides these employees with a perspective that contributes greatly to their overall understanding of program issues and their value as professional managers. Participation in these programs provides positive benefits not only to the individual, but to the program and the public as well.

ADC is becoming increasingly involved in efforts to educate the public about the realities of wildlife damage and how such damage is managed. Part of this effort includes initiatives to improve communication, specifically with those organizations who seem to be confused about the way ADC activities are conducted. There will likely never be total agreement on all points between ADC and some of its critics, but by approaching differences with openness and a willingness to listen to the other side's concerns, the differences can be lessened, and understanding can be improved. There is now within ADC a greater receptivity to new ways of thinking about traditional issues, methodologies and management philosophies than ever before.

An additional aspect of ADC's efforts to promote public education has been the identification of information and education needs, and our development of a communications plan around those needs. Informational materials about the program have been developed and an informational video about ADC and the need for wildlife damage control is in production. ADC now benefits from the valuable assistance provided by trained public affairs specialists in APHIS who help in dealing with media inquiries and prepare press releases. These people have been very instrumental in focusing the media on the positive aspects of ADC and the need for responsible wildlife damage control.

ADC is becoming increasingly involved in the preparation of environmental documents as required by the National Environmental Policy Act (NEPA). ADC employees are taking advantage of opportunities for NEPA training and to be full partners in the preparation of NEPA documents. ADC personnel are now routinely involved in the development of environmental assessments for work conducted on lands administered by the U.S. Forest Service (USFS) or the Bureau of Land Management (BLM). Although this involvement has, in some cases, become time-consuming, there is a positive side to this situation. By working to ensure that NEPA compliance has been addressed, ADC can demonstrate that program decisions are environmentally sound and publicly accountable. When the final programmatic Environmental Impact Statement is released, with the USFS and BLM included as cooperating agencies, the program will have cleared a major hurdle in documenting and disclosing the environmental impacts of all of ADC's activities.

The foregoing examples of current ADC activities are indicative of the elevated importance given to the issue of *professionalism* in wildlife damage management. But perhaps most significant is the realization that the wildlife damage problems of today are ecologically, scientifically and socially complex, and that their solution requires more than simply the removal of a damaging animal.

The development of professional wildlife damage specialists within the wildlife management profession is the critical first step in solving tomorrow's problems. It cannot and will not be ignored. Wildlife damage management activities are important to the well-being of the nation, to the quality of life of its citizens and to the well-being of wildlife themselves. Professional wildlife damage managers must be able to continue to mediate conflicts between humans and wildlife into and beyond the next century.

Conclusions

In 1978, the field of "conservation biology" was formed (Gibbons 1992). The mission of this new field was "to develop new guiding principles and new technologies to allow society to preserve biological diversity" (S. A. Temple *in* Gibbons 1992:20). Perhaps we need a "conservation biology" type of ethic that enables wildlife damage management professionals to develop new guiding principles and new technologies to preserve biological diversity while protecting agriculture and human health and safety. Clearly, the challenge for the future is in resolving the conflicts that occur between humans and wildlife while reconciling public and professional value systems which tend to overlap in some areas and not in others. There are multiple publics, just as there are multiple philosophies within the professional wildlife community. The controversial nature of wildlife damage management lends itself well to a role as a leader in wildlife professionalism.

References

Acord, B. R. 1991. Animal damage control: Are we prepared for the next century? Proc. Great Plains Wildl. Damage Control Workshop 10:18–22.

Allen, D. L. 1973. Report of the committee on North American wildlife policy. Wildl. Soc. Bull. 1:73–92.

Berryman, J. H. 1989. Animal damage control: The challenge of the 90's. Proc. Great Plains Wildl. Damage Control Workshop 9:2–4.

Decker, D. J., R. E. Shanks, L. A. Nielsen, and G. R. Parsons. 1991. Ethical and scientific judgements in management: Beware of blurred distinctions. Wildl. Soc. Bull. 19:523–527.

Dorrance, M. J. 1983. A philosophy of problem wildlife management. Wildl. Soc. Bull. 11:319–324.

George, J. L., S. S. Durbin, and B. M. Nead. 1974. Continuing education needs of wildlife and fisheries managers. Wildl. Soc. Bull. 2:59–62.

Gibbons, A. 1992. Conservation biology in the fast lane. Science 255:20–22.

Gilbert, D. L. 1971. Professionalism and the professional. BioScience 21:803–805.

Kennedy, J. J. 1985. Viewing wildlife managers as a unique professional subculture. Wildl. Soc. Bull. 13:571–579.

Lautenschlager, R. A. and R. T. Bowyer. 1985. Wildlife management by referendum: When professionals fail to communicate. Wildl. Soc. Bull. 13:564–570.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, NY. 481 pp.

McAninch, J. B. 1991. Wildlife damage management in the 90s—does the professional fit the profession? Proc. Great Plains Wildl. Damage Control Workshop 10:171–174.

McCabe, R. A. 1985. Along the way: A profession and its society in retrospect. Wildl. Soc. Bull. 13:336–344.

Miller, J. E., 1987. A need for professionalism in wildlife damage control. Proc. Eastern Wildl. Damage Control Conf. 3:349–354.

Owens, R. D. 1991. Environmentalism and animal welfare: Cornerstones of wildlife damage management. Proc. Great Plains Wildl. Damage Control Workshop 10:33–38.

Palca, J. 1992. NIH's slimmed-downed strategy. Science 255:530.

Powell, R. A. 1982. Ecological "nonarguments" and human value judgements. Wildl. Soc. Bull. 10:141.

Reidinger, R. F., Jr. 1990. Thoughts on the future of vertebrate pest management. Proc. Vertebr. Pest Conf. 14:2–4.

Scheffer, V. B. 1976. The future of wildlife management. Wildl. Soc. Bull. 4:51–54.

Schmidt, R. H. 1989. Vertebrate pest control and animal welfare. Pages 63–68 *in* K. A. Fagerstone and R. D. Curnow, eds., Vertebrate pest control and management materials: 6th vol. ASTM STP 1055. Am. Soc. Testing and Materials, Philadelphia, PA.

———. 1990. Why do we debate animal rights? Wildl. Soc. Bull. 18:459–461.

———. 1992. Why bad things happen to good animals. Proc. Vertebr. Pest Conf. 15:in press.

Schmidt, R. H. and J. G. Bruner. 1981. A professional attitude toward humaneness. Wildl. Soc. Bull. 9:289–291.

Schmidt, R. H., D. L. Brooks, and T. P. Salmon. 1992. Social, political, legal, and ethical aspects of animal damage management in forestry. Pages 395–404 *in* H. Black, ed., Silvicultural approaches to animal damage management in Pacific northwest forests. U.S.D.A., For. Serv., Gen. Tech. Rept. PNW-GTR-287.

Schmidt, R. H., M. R. Conover, R. D. Dueser, F. F. Knowlton, and T. A. Messmer. 1992. Training tomorrow's specialists in wildlife damage management. Proc. Eastern Wildl. Damage Control Conf. 5. In press.

Slovic, P., J. H. Flynn, and M. Layman. 1991. Perceived risk, trust, and the politics of nuclear waste. Science 254:1603–1607.

Sutton, R. M., Jr. 1967. Animal control—progress, problems, and professionalism. Proc. Vertebr. Pest Conf. 3:41–44.

Svoboda, F. J. 1980. Professionalism and wildlife management on private lands. Wildl. Soc. Bull. 8:96–97.

Swank, W. G. 1987. Professionalism in The Wildlife Society. Wildl. Soc. Bull. 15:55–67.

Thomas, J. W. 1985. Professionalism—commitment beyond employment. Cal-Neva Wildl. Trans. 21:1–10.

Todd, A. W. 1980. Public relations, public education, and wildlife management. Wildl. Soc. Bull. 8:55–60.

Wagner, F. H. 1989. American wildlife management at the crossroads. Wildl. Soc. Bull. 17:354–360.

Yoakum, J. D., D. J. Armentrout, R. H. Barrett, R. T. Golightly, and M. White, comp. 1987. The professional wildlife biologist.Western Section of The Wildlife Society, Sacramento, CA. 53 pp.

Yoakum, J. and M. Zagata. 1982. Defining today's professional wildlife biologist. Wildl. Soc. Bull. 10:72–75.

Closing Comments

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I am honored to have the opportunity to cochair this special session at the 57th North American Wildlife and Natural Resources Conference with John Weigand, representing The Wildlife Society (TWS), in coordination with the Wildlife Management Institute. It has been a pleasure to work with the speakers you have just heard, as well as with fellow TWS Council members in planning and conducting the session. As John Weigand stated in his opening remarks, this is not the first time the subject of wildlife damage management has been addressed at this conference. However, it is the first session on this topic cosponsored by The Wildlife Society at the North American since 1974.

Obviously, as you have just heard from the presentations, programs in wildlife damage management are subject to constant change and are influenced by many diverse and often conflicting factors. The increasing complexities of implementing programs today reflect little resemblance to programs conducted in the 1940s, and even through the 1960s, even though the array of species we work with hasn't changed significantly. Some of these species, however, may have altered their behavior patterns or become more adaptable to habitat changes and interaction with humans.

People and their interests have changed, however, as most of the population in the United States today is at least three to four generations removed from the land. Futurists predict that by the year 2000, 80 percent of the people in the United States will live in urban settings. Some would think that as this has taken place over the last 60–70 years, there would be fewer problems between people and wildlife. However, the problems have shifted and, as populations of many wildlife species have increased, so has our human population, particularly in urban areas. Concurrently, in many areas, as human populations have increased, so has urban expansion into what had been rural or wild lands. The result, as implied by Mr. Berryman and subsequent speakers in the session today, is more human/wildlife interaction. In addition, as noted by several of our speakers today, partially as a result of a loss of kinship to the land, misperceptions influencing public attitudes and a lack of knowledge about wildlife, the essential need for management of wildlife is poorly understood by the majority of our public. Yet, the public is exposed to much more media information than ever before, much of it fantasy and some of it factual.

As Mr. Berryman noted, and as others have alluded before him, one of the complexities and major sources of frustration to those professionals working with wildlife damage management is the divergent views of those within the wildlife community. Unfortunately, depending on how you want to look at it, there seems to be a tendency within some of the wildlife community to denounce wildlife damage management, game management and consumptive use of wildlife, and to look down their noses at areas of the profession in which they've never worked nor taken the time to objectively examine. I do not, however, believe that this trend is growing among those who are members of The Wildlife Society. In fact, I believe that The Wildlife Society has cautiously, but progressively, tried to address the diverse concerns of its professional constituency and to provide policy and position statements approved by TWS Council and the majority of the membership for use by all natural resource professionals. If you haven't reviewed the Conservation Policies of The Wildlife Society in several years, I would encourage you to do so. Single copies of the conservation policies of The Wildlife Society are available free of charge to any current TWS member. You may be surprised at the scope and usefulness of these policies.

As you may have observed, in the paper on "Decision Making For Wildlife Management," presented by Dennis Slate, the process used by professional wildlifers to determine the "best" management strategy is not an easy "knee-jerk" decision. In fact, the process requires consideration of multiple risks/benefits and often interdisciplinary and innovative approaches. As practitioners and policy makers on wildlife damage management programs, we must become capable and confident in dealing with a longer checklist and more complexities in the decision-making process. We also must be increasingly cognizant of the risk management concepts, as described in the paper by Barbara Knuth and her co-authors, as we wrestle with the integration of both the human and biological dimensions of wildlife management.

From the paper on "Survey Use and Landowner Tolerance" presented by Scott Craven, we were reminded again that some of the tools and methodologies we use in our decision making must be carefully evaluated and modified over time to ensure scientific credibility and to address changing values and perceptions.

The "Michigan Deer Crop Damage Block Permit Study," presented by Charles Nelson, demonstrated the feasibility of developing and implementing a wildlife management harvest strategy along with a public education program and an evaluation process. As we continue, particularly in the eastern United States, to become more responsive to concerns of private landowners and their wildlife management needs, such information should be useful to both educational and operational management agencies.

The presentation by Raymond Adkins on "Factors Influencing Game Damage Complaints in Montana" attached additional complexities to the management decision-making process. The use of compensation, and/or allocation of funding from traditional sources to alleviate damage problems caused by game species to farmers and ranchers is not a new approach but one that requires effective management and education. The implications require the need to carefully monitor and evaluate the agricultural economic situation in relation to the complaint levels and the necessary management strategies.

Clearly, one of our wildlife management success stories is the restoration and expansion of the white-tailed deer population throughout the eastern United States. Paul Curtis addressed the consequences of the increase in white-tailed deer to urban populations of humans, their desires, and their perceived and real health concerns and values. Again, the decision making becomes more complex and dictates a need for more diversity of management tools and alternatives. This involves the integration of varied community perspectives and leadership.

In the final paper, "Professionalism in Wildlife Damage Management," Robert Schmidt reiterates many of the complexities associated with professionalism in wildlife damage management. Although the focus of this paper was on the professionalism of employees of the APHIS/ADC operational program, clearly, the message is appropriate for other professionals who devote much of their work time and expertise to wildlife damage management. The conclusion of this paper builds on some major points often emphasized by other wildlife professionals in recent years, e.g., "wildlife damage management must be considered an important component of every wildlife management plan, program, and activity. It is the safety net that can help reassure the public that we are prepared to deal responsibly with every eventuality—successes and failures" (Hodgdon 1991).

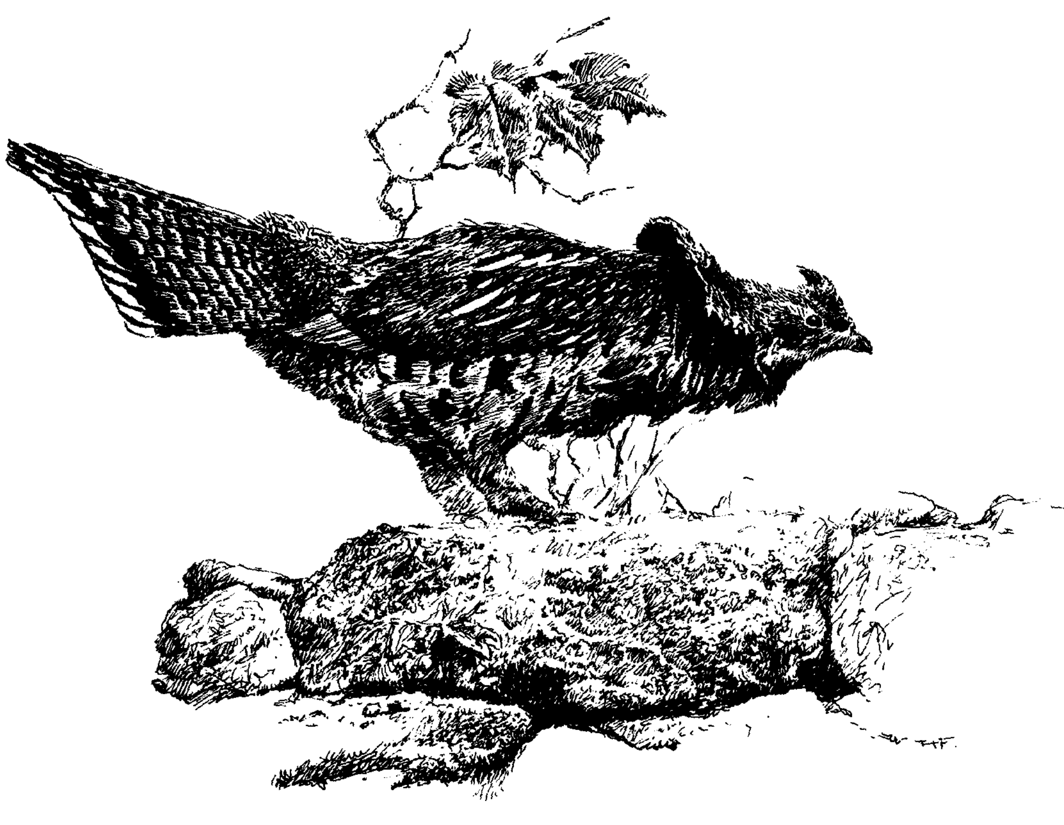
Those of us who have worked in wildlife damage management for a number of years recognize that we must be proactive, progressive, and scientifically and biologically responsible for our actions and programs. However, we must not, and should not, be apologetic for such work in wildlife damage management or for our other programs in wildlife management. They are essential to natural resource sustainability and in the best interests of people and wildlife. As noted by Miller (1987), wildlife damage management is as complex, challenging, scientific, productive, enjoyable, and requires as much or more accountability and responsibility as any other scientific natural resource discipline. It must be afforded appropriate funding and support, and should be conducted without apology or excuses.

For those who wish to learn more about wildlife damage management, there are three regional, technical meetings held every two years: the Vertebrate Pest Conference, the Great Plains, and the Eastern Wildlife Damage Workshops. These conferences/workshops are usually announced in the TWS *Wildlifer* as well as by agency, organization and institution networks.

References

Hodgdon, H. E. 1991. Wildlife damage management: Policy and professional considerations. Proc. 5th Eastern Wildl. Damage Control Conf. (Available 1992). Ithaca, NY. 9 pp.

Miller, J. E. 1987. A need for professionalism in wildlife damage control. Proc. 3rd Eastern Wildl. Damage Control Conf. Gulf Shores, AL. Pages 349–354.



Special Session 2. *A New Era of Conservation Information*

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A Field Guide to "The New Era" in Conservation Information

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About a century ago, George Santayana observed that "those who cannot remember the past are condemned to fulfil it." Americans are fond of quoting Santayana, but when it comes down to action, we don't seem to put much stock in his view of history. We've seldom shown much interest in using the past as a guide to the future. We tend to put our faith in new solutions, believing, as we often do, that each generation faces a set of new qualitatively different problems. The wildlife conservation community is no exception.

We're here today to consider the "new era" in conservation information, implying that we have broken important new ground in our recent public relations efforts. In fact, I doubt that we have. The tools we use and the messages we send have shown surprisingly little change in four generations. In 1936, Wyoming's governor, Leslie Miller, applauded the creation of "a series of bulletins which will advise the citizens of the State of the work of the Department. . . . I hope the information which will be thus forthcoming to those interested in wildlife matters will be another contribution to the movement which seems to be gaining nation-wide momentum" (Blair 1987). That "series of bulletins" eventually became *Wyoming Wildlife* magazine. The "nation-wide momentum" to which Miller alluded was no rhetorical flight—fledgling conservation departments across the country were expanding their wildlife work and recognizing the need for similar publications. Fifty years later, we're being treated to a flurry of golden anniversaries, as these periodicals celebrate their longevity and success. The magazines are thicker now, more colorful, but they are essentially what they have always been, "information . . . to those interested in wildlife matters. . . ."

It's generally agreed that electronic media will be critically important in our future conservation information efforts. The information/education (I&E) specialists of 40 years ago certainly would have agreed. The Colorado Division of Wildlife was on radio in Denver in 1947 (Barrows and Holmes 1990). In the early 1950s, "The Singing Forester," Woody Bledsoe, began a highly successful career as a radio conservationist for the Missouri Department of Conservation (Keefe 1987). Many departments, including Iowa (Madson 1992), Missouri (Keefe 1987) and Colorado (Barrows and Holmes 1990), had established a television presence by the mid-1950s.

Today's information/education divisions pride themselves on their conservation education efforts, but outreach to schools has traditionally been the backbone of I&E work. The Missouri Conservation Commission established an education section in the department in 1941. They recognized ". . . the important part that education, particularly among schools and colleges, must have in the conservation program. . ." (Keefe 1987).

It's nearly impossible to name an I&E activity that doesn't trace its roots to the innovative leaders who shaped conservation in the 1930s, 1940s and early 1950s. We're better funded now, better staffed and probably a little better trained, but we're really only refining techniques that were introduced to the field 40–50 years ago. Judged by any standard short of the geologic time scale, that's an old era.

The times call for something more. In the last five years, the very concept of wildlife management has been called into question, and the motives of professional conservationists are regularly challenged by nearly every American with an interest in wildlife. If wildlife conservation is to survive, we're going to need breakthroughs in conservation information—a new era. Here are some of the field characters I think we will be able to use to identify it when it arrives:

A Regular Assessment of Public Opinion

The Game Division in the Wyoming Game and Fish Department spends roughly $200,000 a year on surveys. The biologists in charge of managing Wyoming's game species couldn't do without these surveys—they define success and hunter effort, reveal preferred hunting areas, and occasionally even tell us a little about what hunters think of our department. In its infancy, game management had no other information to go by. Seasons and harvest quotas were set with nothing else. In a pinch, we could probably make that approach work today.

Conservation information staffs are expected to manage public opinion in about the same way biologists are expected to manage deer. The task in public relations may be even more complex than it is in classic game management, considering the variety and intensity of opinions on nearly every subject related to wildlife conservation and bearing in mind that deer don't vote. But the relative difficulty of the two jobs is really irrelevant—the public relations manager is simply unequipped to attack the problems he faces. He may have a faint seat-of-the-pants understanding of his department's traditional constituents, although the growth of dozens of special-interest groups among hunters and anglers has made that far more difficult. The new constituencies demand different approaches, but what are they? Our grasp of animal rights positions is poor at best; we've had only limited contact with dedicated birders and wildflower enthusiasts. Then there is the huge majority of the American public who may not know we exist . . . or care. How do we reach these groups and what do we say once we have their attention?

Regular public opinion surveys won't solve those problems for us, but they will at least define them better. A few departments have used surveys to accomplish narrowly defined objectives, but annual or even monthly surveys for background information are still unheard of. In the new era, opinion managers will have ways to measure the commodity they are supposed to manage.

A Planned Approach

As wildlife conservation has come of age, professionals in the field have been faced with a bewildering variety of demands. Federal and state statutes have mandated a whole new approach to environmental work; emerging special interest groups have added to the pressure. Little wonder that conservation agencies have embraced strategic planning with such enthusiasm.

The strategic planning cycle seeks answers to four fundamental questions (Crowe 1983): where are we? where do we want to go? how do we get there? did we make it? The wildlife management profession began looking for ways to answer those questions two generations before strategic planning was invented. We have increasingly sophisticated ways of estimating wildlife populations, tracking the changes that occur in those populations and defining the critical environmental factors driving those changes. Our technical expertise has dovetailed well with the demands of strategic planning.

In the new era coherent planning will underlie all conservation public relations work. Several conservation agencies have tried to apply strategic planning to public relations. It's a step in the right direction, but it is doomed to failure until we institute regular opinion surveys. Until then, we won't be able to answer three of the four strategic planning questions. We won't know where we are, how we should proceed or whether we reached our goals.

A Willingness to Listen

The public relations niche in wildlife conservation has traditionally been called "information/education." At least 30 of the nation's 51 wildlife agencies still use some variant of the phrase to identify their public relations divisions. The term itself is innocuous enough; the implications I see in it are probably a product of my experience in conservation work. There is a faint paternal overtone to the words "information/education," a sort of "sit still, children, and we will undertake your education" attitude. In my experience, this implication is no accident. Professional wildlife managers credit themselves with making decisions based on fact. To the extent that this is true, the thinking goes, the public is bound to support our decisions as long as they have all the facts.

The fallacy in this reasoning lies in the initial assumption. Hardly any of our wildlife management decisions are based solely on fact. We can manage most species anywhere in a wide range of population sizes. The specific levels we choose are influenced far more by political realities than by biological constraints. In the past, wildlife agencies have tended to make those political choices with very little consultation. It then fell to the "information/education" staff to sell the choices to a variety of publics. The sales pitch consisted of a long lecture administered in person, in print or on film, which strove to dispel the ignorance of the audience. It should come as no surprise that the audience has often resented that attempt; the surprise is that they have occasionally tolerated it.

Several years ago, I shared lunch with a successful advertising executive, the man who first sold Gaines Burgers to America (and that *took* some selling). He had a fascinating attitude toward his profession. "Many people assume that an advertiser makes people want a product," he said. "In fact, the reverse is closer to the truth. A good advertiser finds out what product people want, then sells it to them."

There is a fundamental give-and-take in this approach, a pattern that is often missing in conservation information. The basic tenets of wildlife conservation simply can't be compromised, but there is room in most wildlife management problems for a range of solutions. Our public relations will improve as we involve more people in our problem solving. *Two-way* communication with our conservation constituents will be an important part of the new era.

A Wider Audience

Hunters (and by that I mean people who hunt terrestrial or aquatic game for meat, fur, feathers or trophies) have been the core of the conservation constituency throughout the twentieth century, and they will continue to be a vital part of wildlife conservation for decades to come. There's no more dependable motivation than self-interest. Conservation professionals understand hunters; in most cases, we are hunters ourselves. Whatever our differences with this public, we can get in touch whenever we feel the need.

Over the last twenty years, we've developed or deepened our liaisons with other groups. Non-hunting organizations like the Sierra Club, Wilderness Society, and various Audubon Societies are pressing us for action on a much broader front and may not have much patience with the real or imagined constraints that limit a bureaucracy's activities. Then there are the anti-hunting organizations—groups such as PETA, ARM and the Fund for Animals. Our relationships with these constituents are seldom comfortable, based as they often are on mistrust, misunderstanding and intense differences of opinion. But, comfortable or not, they aren't going away. Anti-hunting and animal rights interests will shape parts of our future agenda—we have no choice but to deal with them.

Hunters, non-hunters and anti-hunters all do us one huge favor. They care enough about what we do to stay in touch. The most troublesome group in conservation public relations is that huge majority of the American public that really doesn't care. We know they exist; we have information showing that many of them care about wildlife. In 1985, 105 million people participated in some wildlife-related recreation around their homes (U.S. Fish and Wildlife Service 1988). We also know that, by the standards of hunters, they don't contribute much to wildlife conservation work.

We've known all this for almost as long as there have been wildlife conservation agencies. We've talked about expanding our base of support; we've criticized ourselves for constantly "preaching to the choir," and we seem no closer to recruiting a majority of Americans than we were a century ago. In fact, there are signs that other sectors of the environmental movement are gaining their support while we neglect them.

In the new era, we will find ways to open dialogues with a spectrum of new audiences.

An Adequate Budget

Good public relations work doesn't come cheap. Paul and Taylor (1986) analyzed 101 of the nation's best performing businesses. They defined "best performing" as a combination of increased labor productivity, increased capital productivity, creation of new jobs and increased stock prices. Many of these companies deal in very specialized markets, like defense, health care and electric power. I chose 20 whose products and/or services were offered to the general public. The group was diverse, including computer and electronic firms, moving companies, breweries, grocery stores, convenience stores, newspapers, even a retailer of eye glasses. All showed excellent productivity and return on investment. And all made major commitments to promotion, sales, advertising and public relations—the sector we in conservation regard as "information/education."

Net sales of the 20 companies totaled $38.9 billion. Expenditures on sales, marketing and administration totaled $9.2 billion (Paul and Taylor 1986) or 23.7 percent of net sales.

A quick survey of information/education budgets in eight western and midwestern conservation agencies (Kansas, Montana, Colorado, Iowa, Arizona, South Dakota, Nebraska and Wyoming) shows a different pattern of public relations spending. These agencies had a total budget of $291.9 million. I&E budgets totaled $15.29 million or about 5.2 percent of total budget.

Iron-clad comparisons between the public and private sectors are difficult at best, but I find these data disturbing and revealing. Conservation agencies do not have to produce a product for sale; in spite of our best management efforts, wildlife populations are far more influenced by weather and federal agricultural policy than they are by biologists. It's not illogical to assume that we could afford to spend a larger proportion of our budget on public relations/marketing than most corporations can afford to spend. And, increasingly, we recognize the importance of good public relations. Most wildlife professionals readily admit that wildlife management contains a huge people-management component. But, when it comes right down to *funding* people management, we fall short.

I don't mean to suggest that a blind increase in public relations budgets would automatically improve conservation public relations, but the combination of regular survey work, a coherent plan and an adequate budget would work a revolution in I&E effectiveness. In the new era, the percentage of conservation department budgets spent on public relations will rival or exceed the percentage of budget spent for marketing, sales and advertising in the private sector.

Like any evolutionary process, the emergence of these approaches will take time. Other members of this panel will describe some of the first, halting steps that have been taken to develop a new style of public relations, a style that shows signs of succeeding in the complex times ahead. Conserving and managing wildlife is no longer enough; if we expect to hold onto the wildness we have left, we have to sell it to a nation that seems bent on forgetting is value. When we discover the way to make that sale to mainstream America, the new era in conservation will have arrived.

References

Barrows, P. and J. Holmes. 1990. Colorado's wildlife story. Colorado Div. Wildl., Denver. 450 pp.
Blair, N. 1987. The history of wildlife management in Wyoming. Wyoming Game and Fish Dept., Cheyenne. 295 pp.

Crowe, D. M. 1983. Comprehensive planning for wildlife resources. Wyoming Game and Fish Dept., Cheyenne. 143 pp.

Keefe, J. 1987. Missouri Department of Conservation: The first fifty years. Missouri Dept. Conservation, Jefferson City. 446 pp.

Paul, R. N. and J. W. Taylor. 1986. The 101 Best-performing companies in America. Probus Publ. Co., Chicago, IL. 382 pp.

U.S. Fish and Wildlife Service. 1988. 1985 national survey of fishing, hunting, and wildlife-associated recreation. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C.

Evaluating Citizen Participation: Creating Communication Partnerships That Work

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In this new era of conservation information, natural resource agencies have the opportunity to create new programs and ensure their success. Over the past 20 years, many natural resource agencies have adopted citizen participation strategies. Such strategies have helped agencies address public concerns about management policies and greater agency accountability (Hendee et al. 1974, Blahna and Yonts-Shepard 1989). They also enhance decision making by improving information exchange between agencies and the public (New York State Department of Environmental Conservation 1989, McMullin and Nielsen 1991). Renewed attention is being focused on citizen participation strategies in synchrony with increased public interest in environmental issues and resource management activities. Agencies that implement citizen participation strategies to meet the challenges of resource management can improve these programs through critical, comprehensive evaluation.

Our purpose is to discuss an evaluation strategy that can be used to develop successful citizen participation programs to improve not only the agency's information about the public, but also the public's understanding of the diversity of viewpoints about natural resources in the community. First, we describe the evaluation strategy in general, then illustrate its application in a citizen participation effort that was undertaken in New York to involve the public in deer management decisions.

Framework for Evaluation

Various evaluation methods have been implemented to assess the utility of citizen participation programs (Sewell and Phillips 1979, Mazmanian and Nienaber 1979, Blahna and Yonts-Shepard 1989, Landre et al. 1990). Most commonly, evaluations of citizen participation programs have emphasized documentation of program impacts. A summative evaluation examines the success or failure of programs by determining if the stated objectives have been achieved (Kraus and Allen 1987). However, a summative evaluation strategy that focuses on program outcomes might not uncover reasons for program failure or success. This strategy cannot determine if the outcomes occurred because the prescribed plan was followed or not, or if other unexpected circumstances arose during program implementation. In addition, summative evaluations of citizen participation efforts do little to improve the information exchange process as it occurs during the effort.

A more interactive, comprehensive evaluation examines program content and the implementation process, in addition to the impacts of the program. A formative evaluation that examines the program in progress (Kraus and Allen 1987) provides constant review and assessment of implementation effectiveness and feedback that can be used to modify or develop new strategies during implementation. When applied to citizen participation, the evaluation facilitates communication between multiple parties. A combination of formative and summative evaluation fosters program success, rather than merely judging success or failure upon completion of the citizen participation effort.

Evaluation of Citizen Task Forces

We used a comprehensive strategy (Decker 1988) to evaluate a citizen participation program for making decisions about deer management in New York. USDA-APHIS-ADC funded this evaluation as a part of a larger study of deer policy formulation to address problems with deer damage in agriculture. We conducted an evaluation throughout the process from the early stages of planning, through design and implementation (formative) and after program outcomes were produced (summative).

Citizen participation offers a forum for wildlife agencies to receive information from a variety of stakeholders[1] who are interested in the various alternatives for and consequences of different wildlife population levels. Decisions about desirable wildlife population objectives have direct implications for the degree of both negative and positive human-wildlife interactions (such as property damage or recreation opportunities) that will occur in a region. As a result, citizen participation efforts targeted toward discussing wildlife population objectives are of interest to a variety of stakeholders in the local community.

We evaluated a Citizen Task Force (CTF) program implemented jointly by the New York State Department of Environmental Conservation (NYSDEC) and Cornell Cooperative Extension (CCE) "to establish acceptable deer population objectives with the assistance of a constituent task force for each of several selected deer management units," (W. Jones personal communication: 1990). CTFs were a collaborative effort of NYSDEC, CCE and CTF members. NYSDEC and CCE conceptualized the CTF process. NYSDEC financed and attended CTF meetings. CCE invited CTF members and facilitated the CTF meetings. NYSDEC selected four Central New York deer management units (DMUs) to pilot-test the CTF citizen participation program. NYSDEC and CCE selected for each CTF approximately 10 stakeholders who reflected a variety of deer-related interests (e.g., agriculture, deer hunting, deer/car accidents, businesses, environmental education) present in each DMU.

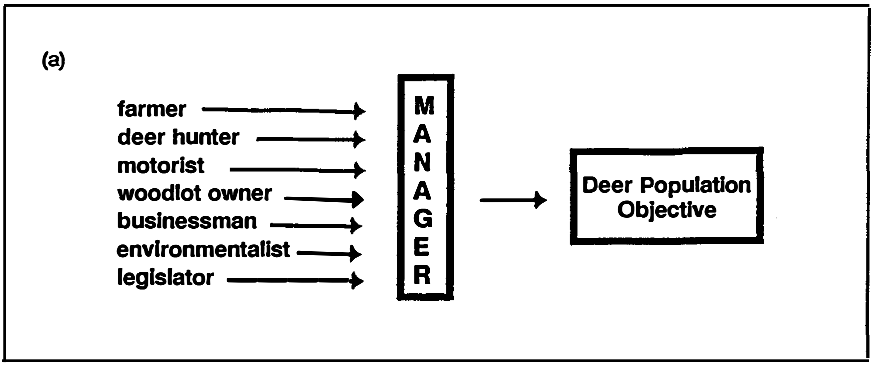
The purpose of the CTF was accomplished via a series of two or three meetings, with CTF members contacting stakeholders in the DMU between meetings. At the first meeting, NYSDEC communicated the current status of the deer population and management in the DMU. Following the initial meeting, CTF members gathered input from stakeholders in the DMU; they discussed their findings at subsequent meetings. CCE facilitated discussions and directed the CTF toward a unanimous agreement for recommending a particular deer population objective to the deer manager. If consensus could not be reached, the manager would set the deer population objective based on the variety of recommendations produced by the CTF.

[1]The term stakeholders encompasses supportive constituencies, organized interest groups and individuals affected by deer management who may not be affiliated with an organization. Stakeholders are those individuals who are affected by deer positively or negatively, including people who do not recognize their stake in decision making about deer.

Program Theory and Context

As evaluators, we were involved at the inception of the CTF program. We met with NYSDEC staff to identify the theories, concepts, assumptions and decision-making context within which CTFs would operate in the deer management system. With input from NYSDEC, we articulated the goals and objectives of the citizen participation effort.

We used two models (Figure 1) to describe the specific context of CTFs in relation to a standard method of deer management decision making. With the standard model, deer managers assess and weigh inputs from a variety of stakeholders who have no interaction among themselves. With the CTF model, informed stakeholders interact



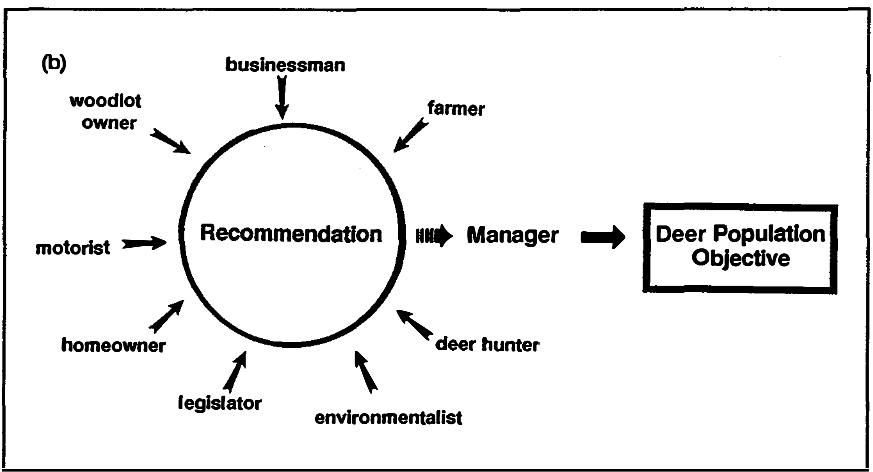


Figure 1. (a) Example of a standard model of citizen participation for setting a deer population objective that demonstrates the communication of each stakeholder with the deer manager individually. The manager must synthesize all individual comments when setting a deer population objective. (b) Example of the Citizen Task Force model, demonstrating communication among a group of stakeholders who recommend a deer population size for the deer manager to consider.

with each other and recommend a deer population objective to the deer manager. The deer manager's role changes to one of providing technical information to a group of stakeholders and receiving a recommendation while retaining authority to manage deer, rather than having to interpret many individual stakeholder comments in lieu of a group recommendation.

Program Design

We examined the proposed program design prior to implementation to determine if the design reflected the CTF model and the goals and objectives articulated earlier. We participated as evaluators in organizational meetings, discussed alternative citizen participation methods (e.g., public hearing, citizen advisory committee) with the NYSDEC deer managers, reviewed documents describing the pilot CTFs, clarified the process for selecting stakeholder participants and proposed concerns for program developers to address. Failure to evaluate the program design relative to goals and objectives might narrow the context of the program and reduce the capability of the deer managers and CCE facilitators to identify problems in advance of implementation.

Program Implementation

We evaluated program implementation using a variety of personal interview, mail questionnaire and observation techniques as CTFs were underway. NYSDEC and CCE used results from evaluating program implementation to improve the program as it occurred in the pilot sites. Following is a brief description of the strategies used to evaluate program implementation.

1. Evaluators conducted a personal interview with CCE facilitators prior to the first meeting. CCE assessed the program idea, expressed concerns and suggested improvements for implementing CTFs. The interview also motivated facilitators to reflect about the CTF process and improved communications between CCE and NYSDEC.
2. CTF members were mailed questionnaires before the first meeting. Members' information needs (other than the materials they received), and opinions about deer and deer management were reported to NYSDEC and CCE.
3. CTF members were interviewed by telephone after the first and second CTF meetings. Evaluators asked CTF members their impressions of the meeting, how representative the members were of the DMU, and suggestions for improving the meetings. This feedback was synthesized and communicated immediately to NYSDEC and CCE to create awareness of members' satisfactions and dissatisfactions with the process so that organizers could prepare for or make adjustments to the CTF before the next meeting.
4. Evaluators attended and observed the pilot CTF meetings, and provided a critical assessment at a debriefing session immediately after each CTF meeting.

Program Outcomes

The summative evaluation was an assessment of the program's effectiveness that compared objectives developed at the theory stage with program outcomes. After the four pilot CTFs concluded the formative evaluation, 11 additional CTFs were implemented statewide and were included in the summative evaluation. CTF members completed questionnaires before and after the CTF meetings, and NYSDEC and CCE were interviewed by telephone to assess the usefulness, benefits and liabilities of the process. Changes in CTF members' opinions were analyzed by comparing responses to items replicated in pre- and post-meeting questionnaires.

We also assessed the opinions of DMU stakeholders who were not members of CTFs to compare with the views of CTF members. We mailed questionnaires to representative samples of five or six stakeholder groups in each of four DMUs. The CTF recommendation about the preferred size of the deer population was compared to responses from non-member stakeholders in the DMU.

Results from the Comprehensive Evaluation

The comprehensive evaluation assisted the wildlife management agency in conducting an effective CTF citizen participation program. Findings from the evaluation resulted in adjustments to CTFs during development and implementation. For example, before implementing CTFs, the evaluators and CCE alerted NYSDEC that CTF members may have difficulty translating a concrete situation (e.g., stakeholders want to see more deer) to an abstract numerical representation of the deer population level, (e.g., stakeholders want a 3.2 buck take index). The agency decided to ask CTF members to base their perceptions on a percent increase, percent decrease or no change of the current size of the deer population, from which deer managers could translate the CTF recommendation into a buck take index.

As the four pilot CTFs were in progress, interviews with CTF members revealed some were skeptical of NYSDEC's sincerity in applying the CTF recommendation, but the majority were impressed by the agency's willingness to listen to the public. At the next meeting, NYSDEC restated how the recommendation would be used in the decision-making process to alleviate the skepticism. Interviews also indicated many members learned about deer biology and management, with several gaining a new appreciation for the complexity of techniques and human dimensions of deer management. Members commented about learning firsthand from discussions with other CTF members and people in the community about the diversity of viewpoints related to deer in the DMU.

Summative evaluation findings determined if CTFs were effective and worthwhile for continued implementation. Of the 15 CTFs held throughout the state, 90 percent of the CTF members and all CCE and NYSDEC participants thought CTFs should continue to be used in the future. Many CTF members who did not hold a position prior to attending the CTF changed their opinions about management policies and techniques, agency personnel and communication efforts to view NYSDEC and deer management in a more positive manner. Non-member stakeholders were more critical of CTFs, implying a need to familiarize stakeholders in the DMUs about CTFs to improve acceptability of the CTF citizen participation process and its deer population recommendations.

Implications for Improving Communication Partnerships

Citizen participation provides an opportunity for natural resource agencies to exchange conservation information with local community citizens, leaders, agencies and government officials. Inviting speakers, technical advisors, mediators and evaluators stimulates communication between agencies who then communicate with their constituencies about the natural resource program. A web of information exchange is created between the natural resource agency and partnership organizations, the agency and stakeholders, and stakeholder groups themselves.

Comprehensive evaluation is a vital element of this process. Comprehensive evaluation improves the odds of program success through critical assessment of the planning, development, implementation and outcome of programs. Potentially, a communication gap could develop between the agency and participants in the program. Evaluators as "linkers" (Pomerantz 1989) translate and communicate the opinions of program organizers, partners and participants before, during and after program implementation. A combination of citizen participation and comprehensive evaluation is a powerful approach for exchanging conservation information in managing natural resources.

Acknowledgments

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References

Blahna, D. J. and S. Yonts-Shepard. 1989. Public involvement in resource planning: Toward bridging the gap between policy and implementation. Society and Nat. Res. 2:209–227.

Decker, D. J. 1988. Analyzing program "failure:" Evaluating past failure for future improvements. J. Extension 28:19–20.

Hendee, J. C., R. N. Clark, and G. H. Stankey. 1974. A framework for agency use of public input in resource decision-making. J. Soil and Water Conserv. 29(2):60–66.

Kraus, R. and L. Allen. 1987. Research and evaluation in recreation, parks and leisure studies. Publishing Horizons, Inc., Columbus, OH. 315 pp.

Landre, B. K., B. A. Knuth, and C. R. O'Neill. 1990. Public participation in Great Lakes Remedial Action Planning. Dept. Nat. Resour., N.Y.S. Coll. Agric. and Life Sci., Cornell Univ., Ithaca, NY. 40 pp.

Mazmanian, D. A. and J. Nienaber. 1979. Can organizations change? Environmental protection, citizen participation and the Corps of Engineers. The Brookings Institution, Washington, D.C. 215 pp.

McMullin, S. L. and L. A. Nielsen. 1991. Resolution of natural resource allocation conflicts through effective public involvement. Policy Studies J. 19(3–4):553–559.

New York State Department of Environmental Conservation. 1989. Public involvement for better decisions. Off. Public Affairs, Albany, NY. 52 pp.

Pomerantz, G. A. 1989. Combining resource management and public education goals: Social scientists as mediators in inter- and intra-agency program development. Paper presented at Second Symp. on Social Science in Resour. Manage., Urbana-Champaign, IL. 22 pp.

Sewell, W. R. D. and S. D. Phillips. 1979. Models for the evaluation of public participation programmes. Nat. Res. J. 19:337–358.

Responsive Management: Finding the Right Tool for the Job

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On a hot, humid afternoon in Southeast Pennsylvania on July 3, 1863, Robert E. Lee, one of the most brilliant army commanders of our time, ordered 15,000 men to advance across open terrain toward an enemy battle line more than a mile away. Their goal was a clump of trees that marked the center of that battle line. As if on parade, and with star-crossed battle flags snapping in the breeze, they set out toward the clump of trees.

In front of the trees lay a stone wall and behind it several thousand other men waited, gun barrels and fixed bayonets gleaming in the sunlight. As the troops advanced on the enemy lines, thousands of muskets and dozens of cannons opened fire. Advancing battle lines wavered; thousands of men were killed and wounded. Although a hundred men made it to and over the stone wall, they were quickly shot, bayoneted or captured. The assault slowed and the remaining men retreated. Only half of the men returned. The other half—over 7,000—were captured or left wounded, dying or dead on the gently sloping ground in front of the stone wall.

This assault, ever after known as ''Pickett's Charge,'' was doomed to fail. Men advancing across open ground, attacking an enemy firmly entrenched behind a stone wall or log breastworks, were so vulnerable to enemy fire, they simply could not reach, let alone capture, the enemy position.

The sad part is that Pickett's Charge was only one of dozens of frontal assaults ordered during the American Civil War and, by war's end, 95 percent of all frontal assaults on stone walls or breastworks were complete failures (MacDonald 1988). These failures were not unknown to the man who sent down orders for General Pickett to assault the heavily fortified union lines at Gettysburg. Ironically, just seven months before, the roles were reversed: General Lee and his Army of Northern Virginia decimated union lines as the Union Army attacked confederates firmly entrenched behind their own stone wall on Marye's Heights at Fredericksburg. The frontal assaults at Fredericksburg cost the Union Army over 18,000 men. Almost 2,000 of those men lay dead in front of that stone wall. The slaughter continued until the end of the war where battle after battle the lesson was repeated. For example, at Spotsylvania Court House on May 12, 1864, 18,000 union men were killed or wounded during a bloody frontal assault on a salient now known as the Bloody Angle. At Cold Harbor, on June 3, 1864, 7,000 union men were killed or wounded in less than 30 minutes during another such assault, and finally, at Franklin, Tennessee on November 30, 1864, when over 17,000 confederates charged heavily fortified union lines. Because the lesson had not been learned, the butcher bill was even worse at Franklin. The number of dead was twice as high at Franklin than at Gettysburg. This attack at Franklin was ordered by a general who had witnessed the tragedy of Pickett's assault just 16 months before.

Today, thousands of Americans walk across the fields where these battles took place. Many wonder why supposedly intelligent, well-trained generals ordered these insane frontal assaults when they were doomed to fail. At the time, frontal assaults were not viewed as tactically insane. In fact, it was a well-accepted military tactic. In pre-Civil War battles, infantry tactics were based on the musket, the most advanced weapon of the time. The musket was inaccurate at any distance over 70 yards; therefore, generals massed their assaulting line 150 yards away from the defensive line and sent them on a running charge. The defense could only fire one shot as the enemy charged, and many of those shots were inaccurate. If the attackers had suitable advantages in numbers, they could take the defensive line.

But advances in weaponry changed that. Although the soldiers carried a muzzle loader, it was a rifled gun that had a range of almost half a mile. According to Civil War historian Bruce Catton (1981:127): ''One could no longer get in close and mass forces before making the critical assault. The elbow to elbow charging column that had proved so effective in Napoleonic Wars and in the American Revolution was simply out of date. It was a good way to commit suicide. One would come under fire at a distance of 700 or 800 yards, instead of 100 yards. . . . So the kind of attack that had carried the day before was not good in the Civil War because the defense was so much stronger. . . . The generals were using the old tried and true tactics, and those tactics were out of date.''

The generals were using the old tried-and-true tactics, and those tactics were out of date. The technology had changed, but the mindset of using that technology had not. The generals were fighting yesterday's battles.

With 130 years of hindsight, it is clear what was happening during those tragic frontal assaults, but it would be unfair to criticize those tactics. The lesson is one of applying technology, the difficulty of recognizing the way technology changes, and the relationship between technology and its use. New technology tends to be used in the same way the replaced technology was used. Yesterday's tactics are used over and over, despite the obvious failure of those tactics.

One facet of fish and wildlife management where yesterday's tactics are still employed is with people. Despite calls for fish and wildlife agencies to incorporate social science research into programs, most management decisions are still based on little factual information. Yet, management decisions based on assumption and speculation are not without cost. Examples abound of how decisions made in the absence of appropriate social information have cost fish and wildlife organizations greatly in terms of wasted time, money and credibility.

For example, one fish and wildlife agency recently experienced dramatic declines in fishing license sales after raising license fees. Concerned about the declines and loss of revenue, the agency developed an information and education (I&E) campaign in order to increase sales. The message to anglers who were not buying licenses was that a small increase in the cost of the license was necessary in order to keep up with inflation. After several thousands of dollars were spent on the campaign, license sales continued to decline. The campaign was not working. Careful analysis revealed that license sales were declining not because of a license fee increase but because of a contamination scare. Most anglers consumed their catch in this state and news of contaminated fish caused license sales to decline. Many anglers simply were not fishing because they could not consume their catch. The campaign failed because it was assumed there was a relationship between license fee increases and declines in license sales. Had the campaign been based on a solid foundation of fact, the real reasons for the decline would have been discovered, and an effective campaign could have been developed.

After 10 years of biological research on a large endangered predator, another fish and wildlife agency decided to determine the feasibility of reestablishing the predator to some of its former range through the trial establishment of a similar non-endangered predator. Additional populations of the endangered predator would safeguard the animal from catastrophe that might wipe out one lone population. The agency speculated that a lack of public support for the project might lead to public outcry against reestablishment efforts and would ultimately reach politicians and derail the entire project. Subsequently, and based on experiences from other similar projects in other states, the agency developed I&E and public relations (PR) strategies where agency staff would meet personally with high-ranking officials and proactively negate potential problems. With the I&E and PR aspects completed, the agency initiated introduction of the selected species. Contrary to the anticipated public reaction, the public supported the agency's efforts. The introduced animals were removed from the wild within a year of their release, several months earlier than planned. Several of the animals died during the study and at least two of these deaths were due to human activities. Attitude and opinion survey research would have revealed that the public indeed supported the reestablishment effort, but a small segment of the public feared that the introduced animals would seriously impact the quality of deer hunting. Thus, I&E and PR efforts should have been focused on targeting this segment's fears and the illegality of harming the reestablished predator. Twenty thousand dollars worth of survey research and an I&E and PR campaign based on a solid foundation of fact could very well have significantly improved the trial reestablishment effort, enhancing the agency's ability to proceed with reestablishment of the endangered predator as quickly as possible.

Many state fish and wildlife agencies rely on voluntary public donations through a tax checkoff or some other means to secure funding for nongame wildlife programs. For years, one nongame wildlife program attempted to solicit monetary donations from the state's residents on a state-wide basis, with little or no regard for regional differences. But, as other sources of program revenue began to decline, a study on the effectiveness of promotional strategies was commissioned. The study revealed that certain promotional items could increase donations, especially if strategies were targeted at counties that matched the demographics associated with higher than average donation rates, such as counties with high per capita personal income, a high percentage of college graduates, medium to high population densities, and medium to high total populations. In fact, donation rates could have been kept at past levels by targeting only a handful of the 60 plus counties that were canvassed; the same result with less than half of the effort. Information on the social and demographic parameters affecting nongame program contributions was available from other studies, but was not incorporated into fund raising strategies. Unfortunately, it took a crisis for the agency to turn to information that was readily available, information that should have been the very foundation of nongame wildlife program fund-raising efforts.

These examples of wasted I&E and PR efforts are not meant to criticize, but to illustrate the folly of not using the social science tools and resources available to increase program effectiveness. They are the fish and wildlife management profession's equivalent to the bloody Civil War frontal assaults.

Concerned by the lack of social science research in natural resource management agencies, the Western Association of Fish and Wildlife Agencies (WAFWA) initiated Responsive Management (RM). The mission of RM is to provide fish and wildlife agencies with the tools and training to develop and implement human dimensions programs based on a solid foundation of fact, and to monitor public attitudes and perceptions, anticipate change, and tailor their programs to meet these changes. RM was developed to meet the following needs: (1) to develop a practical, inexpensive, valid and timely means to gather and analyze socio-economic data that are necessary in making decisions and anticipating future opportunities; (2) to teach fish and wildlife managers the skills in identifying and understanding changing publics and to develop a way to monitor change in those publics over time; (3) to provide training for agency personnel in understanding "learning and behavioral styles" and how to incorporate this knowledge into a more effective way to communicate with specific target publics, as well as change within the agency; and (4) to provide the benefit of multi-state cooperation to develop and share the above skills and knowledge.

RM consists of three major inter-related parts. One part is public opinion and attitude survey technology, called the Constituent Inventory Package (CIP). A second part, the Applications Strategy Package (ASP), consists of three training workshops ("Marketing," "Change" and "Communication and Dispute Resolution"). A third portion of the project is a support system developed to assist agency personnel in implementing the CIP and the ASP.

The CIP was developed to help agencies understand various publics and constituents. The CIP is a standardized, technologically advanced and relatively easily administered procedure for surveying public attitudes, knowledge and behaviors toward fish and wildlife resources. A library of questions covering a wide range of subjects has been developed and organized into survey modules according to potential research objectives. Survey modules include: (1) a standard questionnaire; (2) socio-demographics; (3) participation in wildlife-oriented activities (hunting, fishing, non-consumptive activities); (4) economics (economic impact, travel cost, contingent valuation); (5) agency performance (perceptions, hunting, fishing, trapping, non-consumptive wildlife recreation and use, law enforcement, information and education, private landowner assistance, animal damage control, habitat protection, urban wildlife programs, endangered species); (6) critical wildlife issues; (7) knowledge of animals; (8) basic attitudes towards animals; and (9) species preference. The survey instruments were built as a microcomputer-based methodology for collecting and analyzing survey information, known as computer assisted telephone interviewing (CATI). This system was developed by Steve Kellert of Yale University, Bill Shaw, Ed Carpenter, and Lisa Harris of the University of Arizona. To date, almost 30 surveys have been conducted by or for fish and wildlife agencies using RM and RM technology.

The ASP consists of three training workshops for mid-to-upper level managers in fisheries and wildlife agencies. The workshops are designed as three-day workshops for 5–25 agency personnel. The workshops are interactive, with participants regularly involved in small group discussions, writing, thinking and problem-solving. The training emphasizes practical application of new skills to on-the-job situations. There are leader's manuals, videotapes and a participant's manual for each workshop. The goal of the ASP is to provide a synthesis of the best available materials for continuing education in the areas of marketing, change and dispute resolution as they relate to fisheries and wildlife management. The training module on marketing trains managers to adapt and then apply basic business marketing principles to fish and wildlife management. The change module examines the interactions between individual management style and agency characteristics, and provides managers with means to initiate positive changes in themselves and the agency. The communication and dispute resolution module first establishes the importance of an agency issue management program and then shifts to the personal communication and dispute resolution skills of the professional manager. To date, over 35 ASP workshops have been conducted successfully for a number of fish and wildlife agencies. The training workshops were developed by Ben Peyton and Roger Eberhardt of Michigan State University.

A Responsive Management National Office has been established to provide RM sponsors with technical assistance, additional informational resources, project coordination, survey research, workshop coordination and assistance with special projects. One special project recently completed was the production of the booklet "A Bridge to the Future: The Wildlife Diversity Funding Initiative." This booklet was developed to assist the International Association of Fish and Wildlife Agencies and the U.S. Fish and Wildlife Service educate Congress on the benefits and importance of funding the Fish and Wildlife Conservation Act of 1980. RM has also assisted agencies in hiring RM/human dimensions in wildlife specialists in Montana, Indiana, Washington and Arizona. RM is attempting to bring the social science tools, technology and training, so necessary to make sound and intelligent management decisions, directly to natural resource professionals.

Yesterday's tactics are not always appropriate to solve today's problems. As tools, technology and the social system in which they are used evolve, so, too, must their use. New problems require new solutions. The lesson is not an easy one to learn, and history is replete with this lesson being taught over and over, even when the stakes are at their highest. Each profession has its own stone wall—its own Pickett's Charge. Nothing in American history can match the tragic loss as a result of the bloody frontal assaults during the Civil War. But the tragic loss of America's priceless natural resources as a result of not utilizing the full range of tools and technology available to conserve those resources ranks quite high. For the fish and wildlife management profession, the lesson is clear. The integration of social science tools and technology into fish and wildlife management programs is no longer a luxury; it is a necessity.

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References

Catton, B. 1981. Reflections on the Civil War. Berkeley Books, NY. 246 pp.
MacDonald, J. 1988. Great battles of the Civil War. Macmillan Publ. Co., NY. 200 pp.

Reaching the New Constituency—One Agency's Approach

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Introduction

In the 1970s, the buzz word was "nongame," in the '80s it was "nonconsumptive use" and "watchable wildlife," and in the '90s the term "biodiversity" appears to be in vogue. Call it what you like, it's an attempt by fish and wildlife organizations and agencies to broaden management interests and responsibilities beyond traditional "game-oriented" or "single-species" programs and, in turn, reap the political and fiscal benefits of that much larger segment of the populace interested in "wildlife." But given the attention this initiative has garnered over the past 20-odd years, it's disheartening to see just how slowly, and oftentimes reluctantly, state wildlife agencies are moving toward this end. Some blame lack of legislative mandates; others blame powerful sporting lobbies. Most are quick to point to their evolution and status as dedicated-fund agencies, principally dependent on revenue from hunting and fishing licenses and federal excise taxes on equipment. Whether real or imagined, these factors have posed, and continue to pose, significant roadblocks to program expansion into this area. The traditionalists by choice notwithstanding, even those managers and administrators inclined to move forward oftentimes discover they have an inability or lack of understanding to attract this new-found base of wildlife support. The problem is exacerbated because there are no cure-all techniques, risks are inherent, and even under the best of circumstances, motives about this shift in focus will be suspect from both camps. That much is a given. So, too, is the alternative—unless change is forthcoming, it will be the death knell of the wildlife conservation movement as envisioned by Leopold and others.

In 1987, the Wyoming Game and Fish Commission adopted a statewide "nonconsumptive use of wildlife" plan for the state. In so doing, they also gave their stamp of approval to a number of strategies designed to accomplish very specific objectives. This program of the Wyoming Game and Fish Department (WGFD) goes under the monicker "Wyoming's Wildlife—Worth the Watching." The conceptual aspects of this program were the subject of a paper at the Fifty-third North American Wildlife and Natural Resources Conference (Kruckenberg 1988) and need not be discussed in detail here. Some of the fundamental operating philosophies of the program are worthy of a second mention, however, since they remain what largely distinguishes this program from others of its kind. For example: (1) it involves all 604 game and nongame species found in the state; (2) it acknowledges that wildlife is a valuable economic commodity for the state; (3) its underlying premise is that the future effectiveness of the WGFD and, indeed, the future of the wildlife resource in Wyoming itself, depends on broad-based public support; (4) its fiscal strategy is that "money will follow opportunity"; and (5) its success is largely dependent upon aggressive and innovative marketing and advertising.

While the experiences in Wyoming may not be representative of, or applicable to, all states, the "Worth the Watching" program, five years after its inception, continues to enjoy unprecedented growth and popularity. It is, in fact, one of the most visible and successful programs of its kind in the country. Perhaps some of what has been learned and how the program functions can be adopted by other states looking to bridge the gap between historical and new constituencies of the wildlife resource.

"Worth the Watching"—Five Years Later

Projects

Consistent with the "money will follow opportunity" fiscal strategy behind the program, getting projects on the ground and developing monitoring systems to measure progress and evaluate the "new constituency" have been high priorities since 1987. To date, no less than four WGFD visitor centers, seven viewing areas, three cooperative community nature areas, four WGFD nature areas, 32 highway rest area viewing sites and interpretive signs, six cooperative kiosks on national forests, one cooperative national forest wildlife viewing guide, two cooperative community wildlife viewing tour guides, a bird and a mammal checklist and numerous other publications have been completed.

The WGFD is currently involved in cooperative projects on every national forest in Wyoming, six state parks, four state travel information facilities, two inter-agency visitor centers, 14 communities, eight schools and two private land parcels. These efforts are in addition to WGFD projects which include eight new visitor centers at district offices and fish hatcheries, as well as several new publications and viewing sites.

A project to develop new mechanisms for involving citizens in wildlife management and environmental management learning experiences was implemented in 1990. Involvement with private landowners and agencies in the development of a statewide directory of areas demonstrating good wildlife management practices is a recent outgrowth of the program. So, too, are the grizzly bear and wetlands/riparian education packages being developed for distribution to schools statewide.

One of the biggest projects currently underway is development of the Wyoming Wildlife Viewing Guide. When completed in late 1992, it will be the medium for tying all the "Worth the Watching" facilities together and also will become an international promotional tool for the state's wildlife, wildlands and wildlife management system.

The list of projects under development is very extensive, currently numbering about 60. As people see results, momentum for the program gathers in Wyoming. Other agencies are also carrying the "Worth the Watching" banner, as evidenced by the Wyoming Transportation Department using a pronghorn buck photo and an inset of the program's logo on the cover panel of the 1992 official highway map, of which 1 million copies will be distributed this year. Even corporate America has joined forces with the WGFD to promote the program. Earlier this year, Coors Brewing Company of Golden, Colorado became the first corporate sponsor of the program by developing a three-poster wildlife series using a "legendary treasure" theme to bring customers for one of their products closer to a wildlife experience. The obvious benefits of these kinds of exposure is that the program is starting to increase people's awareness about wildlife, the role of the WGFD in it's management, and beginning the long-term process of forging a new, expanded constituency for the state's wildlife and wildland resources.

The rapid growth of "Worth the Watching" is a direct by-product of the marketing and advertising component of the program. Central to this effort are three words: (1) control; (2) quality; and (3) uniqueness.

Control began with the program's inception, when, in 1987, the logo was registered with the U.S. Department of Commerce, Patent and Trademark Office. That move guaranteed protection and exclusive use of that identifier to the WGFD and remains today, the single best thing that has been done to insure the long-term integrity of the program.

Quality is a very important concept. It may take on a lot of dimensions, but everything that surrounds the program, or is identified with it, either in terms of material items (i.e., products, publications, etc.) or experiences, is driven by this principle. Department officials are insistent that users consciously associate a positive wildlife experience with "Worth the Watching."

Finally, "uniqueness" can be described as broadly as the state's land features or her vast wildlife resources, or as narrow as the fact that program administrators work very hard to keep the program "one of a kind."

Given the close ties the program has to the state's tourism promotion activities, the end result of these three operating principles is to create a mind-set in the resident and nonresident traveller that Wyoming clearly is *the* place to be to enjoy wildlife.

Mediums used to conduct this campaign are many and varied, and range from logos on saleable products, which in turn double as advertising agents, to outdoor billboards, to paid advertising in airline publications. "Packaging" is always done under a consistent look designed for maximum exposure and impact.

Since 1987, the Wildlife Trust Fund (Kruckenberg 1988) has provided about $650,000 toward past and ongoing projects. The fund balance currently stands at $11.4 million. Another $415,000 has been obligated toward visitor center facility development and $86,000 has been made available through other ongoing Maintenance and Operations budgets. An additional $450,000 of funding assistance has come from sources outside the WGFD including, but not limited to, advocacy groups, community volunteer services and federal grants. Beginning in July, the total FY '93 operating budget for the program will be approximately $400,000, excluding salaries, of which $132,000 will go toward cooperative projects and the remainder to projects funded solely by the WGFD.

In addition to the Wildlife Trust Fund, the sale of products continues to show promise as a means to help fund this new initiative. Sales income has nearly doubled during each of the past four years, most recently grossing $81,165 during fiscal year 1991.

Program Administration, Planning and Development

The "Worth the Watching" program is administered by the Information and Education Services Division (IES), one of five major administrative units of the WGFD. The marketing, advertising, promotion and revenue generating aspects of the program are handled through the office of the division chief, specifically a function entitled "Alternative Enterprises." Three permanent personnel are involved in this effort to varying degrees, with the actual amount of personnel time specifically devoted to this program approximately 2.3 full-time equivalents (FTEs).

Interpretive services, education, project planning and development, and day-to-day program coordination is conducted by the Education Section of IES. There currently are three permanent (education supervisor and two education specialists) and two full-time temporary interpretive services personnel working on this program. In addition, three to five temporary personnel with backgrounds in education, interpretation and wildlife are hired seasonally to man visitor centers and conduct tours. All totalled, approximately 5.6 FTEs are dedicated exclusively for this purpose from the Education Section.

In reality, all department divisions and personnel at all levels are involved at the project level of planning and development. In 1991, that involvement amounted to approximately 1,000 hours of personnel time, or approximately 0.5 FTEs, over and above that of IES personnel who are directly involved with the program.

From 1987 to the present, the "Worth the Watching" program has been guided by two planning documents. The first (Wyoming Game and Fish Department 1986) provided the background and basic framework from which the program was launched. The second (Wyoming Game and Fish Department 1988) dealt with the entire spectrum of interpretive and visitor services which the WGFD utilizes under the "Worth the Watching" program.

Beginning in 1992, all aspects of the program have been incorporated into a comprehensive "Master Plan" (Wyoming Game and Fish Department 1992). This plan updates the initiative based on what has been learned during the initial five years. It also more closely aligns the program to the overall mission and goals of the WGFD and reflects the program's scope being expanded beyond that envisioned in 1987. This expansion is a direct result of the program's success and popularity.

One aspect of the program has not changed, however, and that is its organizational relationship to the WGFD's "nongame" program. Unlike many other states, a conscious decision was made in the early planning process to segregate the "Worth the Watching" program, as previously indicated administered by IES, from the nongame management program which is administered by the Game Division. Even though there is frequent interaction between personnel of the two divisions, this distinction has been mutually beneficial to both programs. Foremost among them, however, is the fact that the "Worth the Watching" program has been allowed to mature without the negative connotations that unfortunately have plagued "nongame" programs nationwide since the 1970s. "Worth the Watching" is not about nongame, it's about wildlife. This is a factor worthy of consideration to others planning similar programs.

What Has Been Learned

The "Worth the Watching" initiative represented quite a change for the WGFD. Not surprising, however, until something tangible was on the ground that people could react to, the program was not taken all that seriously. Some traditional wildlife managers had difficulty visualizing how such an undertaking related to wildlife management. The public, on the other hand, wasn't sure what to make of this change or whether the agency's commitment to it was genuine. There was no real opposition, more of a pervasive skepticism, but it warranted constant vigilance to ensure it didn't get out of hand. In retrospect, it was the public who first demonstrated they were ready to move forward, even before all agency personnel had bought into the concept.

Because marketing and advertising was used to create an image for the program, even before it had much substance, the program literally vaulted into public prominence. Within just a few short months, it became very obvious to agency administrators that the point of no return had been reached. The response was immediate, it was positive and it was irreversible. During this embryonic stage, there was constant emphasis on coordination and public relations.

Perhaps even more important than the external publics, a very concerted effort has been made throughout the history of the program to garner internal support and keep personnel abreast of new developments. As a result, internal support for the "Worth the Watching" program has grown significantly since inception. This strengthened support can be attributed to several factors, most notably: (1) program emphasis on education outreach; (2) the involvement of field personnel in project planning and interpretive development; (3) intensive and extensive coordination with all divisions; (4) the development of interpretive educational materials which employees and the public can easily relate to sound wildlife and environmental management principles; and (5) structured workshops for employees which enable them to get more involved in agency and community communications efforts.

A concerted effort has been made not to alienate the consumptive and nonconsumptive user groups in Wyoming. Citizens interested in wildlife and wildlands are referred to as "wildlife enthusiasts." Likewise, the same principle applies to labelling the agency's management responsibility. It extends to "all free-ranging wildlife" and avoids the use of terms like "hunted" or "nonhunted," "game" or "nongame."

Some resident hunters and anglers have voiced concern about the fact that license revenue was being spent on what was originally referred to as a "nonconsumptive user" program. It was most noticeable in 1990, during a series of public meetings and legislative hearings on an across-the-board license fee increase. Closer examination revealed the concern was not over the "Worth the Watching" program *per se*, rather WGFD expenditures on threatened and endangered species like grizzly bears, bald eagles, black-footed ferrets and peregrine falcons. This never became a serious issue, although this concern is still occasionally expressed. It does, however, serve to remind everyone how critically important it is to identify a customer need or niche, develop a program image, stick by it, and bring along the internal and external publics every step of the way.

Helping the cause in Wyoming has been the strong support from businesses, communities and the legislature, because of the obvious benefits to the tourism industry and economic coffers of the state. This is not meant to imply the program is not without detractors, but rather that they are pale in comparison to supporters. Among the first, and still the most vocal, supporters are the license buyers themselves who see the strong ties to education, the positive light in which the program portrays the role of the hunter and angler, and the long-term benefits from a larger advocacy group for wildlife-associated recreation of all kinds.

The "Wyoming experience" may be nothing more than an anomaly, with the right people being at the right place at the right time. But, one cannot ignore that program architects also cleared three important hurdles that have plagued many other states, by first, identifying a clear need from the constituent, second, receiving strong support and commitment at the highest levels of the organization, and third, demonstrating to employees the program was relevant to the future of wildlife, wildlife management and their getting the job done.

About Interpretation

Maintaining good quality viewing and learning opportunities and services is an essential ingredient to reaching the new constituency. So, too, has been piggybacking ''Worth the Watching'' facilities and projects with other regular agency information and education outreach efforts to maximize public awareness. Even seemingly unrelated I&E efforts like habitat extension, Project WILD, hunter education and aquatic education have common ground that benefit when the ''Worth the Watching'' program identifier is used.

Perhaps the biggest surprise of all during this startup period has been the ability to disseminate basic wildlife management principles (i.e., hunting, habitat, game law enforcement, etc.) under the ''Worth the Watching'' banner. There's something about packaging a message in a recognizable and trusted medium that readily lends itself to consumption by the public. As such, five years after the fact, program personnel still are unsure what the outer limits of using this approach might be. The point is, what started out as a fairly narrowly focused program, targeting ''nonconsumptive users,'' has now blossomed into something quite unexpected that bears a direct relationship to virtually all programs of the agency and all users of the wildlife resource, both new and old.

Every sign, every exhibit and every facility of the ''Worth the Watching'' program attempts to provoke thought in a sincere and positive manner. Each theme and concept seeks to convey the interconnection of the visitor with the environment, wildlife and wildlife management. These might be considered analogous to spokes, which, when put into proper configuration, form a wheel or continuous circle that tells a complete story—in this instance, at over 100 locations throughout the state.

Any efforts to provide for wildlife viewing should also be regarded as a chance for an agency or organization to provide a learning opportunity. People not only like to view wildlife and wildlands, they also are anxious to learn as much as they can about them and welcome the opportunity to directly participate in wildlife management activities, such as volunteer programs.

The viewing opportunities provided under ''Worth the Watching'' are in more accessible areas and are developed to be compatible with, and not detrimental to, wildlife and wildlands. The WGFD policy is not to attract wildlife with feeding or to confine wildlife for the purpose of viewing, nor to locate projects in areas that cause undo disturbance to these resources. Each facility and project is located and conducted at sites where human activity levels are already high (e.g., near cities or along major roadways). The agency has declined involvement in many activities recommended by personnel or the public for one of the above reasons. Ethical conduct in viewing wildlife and using wildlands has, thus, become an important and regular interpretive element at all nature areas and viewing sites.

This practice of locating interpretive projects in areas already experiencing high human traffic can also have secondary benefits like increasing school and community involvement in wildlife conservation efforts in general, improving the networking between interested groups and individuals and the wildlife agency, and reducing the transition period between program initiation and public acceptance by insuring high visitation rates, and, hence, higher exposure to the program.

Relating the conservation story and the lessons the agency, and even society, has learned allows a degree of introspection which people are not accustomed to seeing in a wildlife management agency. It, therefore, is a powerful technique in interpretation. It helps create advocates by cultivating understanding and trust. Good interpretation, when done correctly, provokes thought in a non-intimidating way and in a non-intimidating environment. It is more than just dumping out facts.

About the New Constituent

Clearly, much of the success of the "Worth the Watching" program hinges on marketing. For the WGFD, marketing is defined as "building and maintaining a mutually beneficial relationship with customers or constituents." Without current information on constituents, their values, needs and preferences, the WGFD could not hope to build and maintain this sort of relationship. Since 1987, additional data has become available which has provided better information on these new constituents, both residents and nonresidents. From this information, much has been learned about their expectations regarding a wildlife experience in Wyoming. For example, the 1985 National Survey of Hunting, Fishing and Wildlife-associated Recreation (U.S. Fish and Wildlife Service 1989) reported the following:

- 283,500 Wyoming residents participated in primary nonconsumptive wildlife use. This totals approximately 76 percent of the total population.
- These residents were both male and female, typically less than 44 years of age, with household incomes over $25,000, and at least some college education.
- Residents totalled 1.9 million days of primary nonresidential nonconsumptive use.
- Nonresidents totalled 2.0 million days of primary nonresidential nonconsumptive use.

In 1988, visitors to the National Elk Refuge near Jackson, Wyoming were surveyed. From these data (Ward and Anderson 1989), it was learned that these nonconsumptive users, who were sampled while viewing wildlife in Wyoming during the winter months, were:

- Primarily urban nonresidents, both male and female, with above average education and income levels.
- Visiting Wyoming for about five days, with a primary purpose of skiing and observing wildlife.
- Spending approximately $177.00 per day during their stay.
- Interested in seeing large mammals and bald eagles.

In 1988 and 1989, visitors to WGFD fish hatcheries were surveyed. From this information (Ward and Anderson 1989), it was learned that:

- Over 10,000 individuals visited 10 fish hatcheries in Wyoming to view the fish and hatchery operations.
- Nonresidents made up approximately 40 percent of the total visitors.
- Hatchery visitors spent at least 20 minutes at the facility.
- Hatchery visitors were interested in feeding fish and learning more about the wildlife of the surrounding area.

In 1988 and 1989, visitors to Wyoming Travel Commission Information Centers, WGFD Wildlife Habitat Management Units and WGFD Hunter Information Stations were also surveyed (Ward and Anderson 1989). From these data, it was found that:

- Respondents were primarily nonresidents, between the ages of 25 and 44, with above average education and income.
- The species most preferred for observation were elk, grizzly bear, moose, deer, bighorn sheep, bald eagle, pronghorn, bison, mountain lion, mountain goat and wild horses.
- Unmarked, undeveloped areas were the most used for wildlife observation.
- Many nonconsumptive users were also hunters and anglers.

In 1989, residents were surveyed as a pilot test of the Responsive Management Project. In this survey (Wyoming Game and Fish Department 1990), random households in Wyoming were sampled to determine attitudes on a variety of subjects. A number of findings were relevant to the new constituent. For example:

- Pure nonconsumptive users were primarily females, aged 20–59, with household incomes between $30,000 and $50,000, and some college education.
- Over 70 percent of the hunters sampled were also nonconsumptive users. Over 35 percent of the nonconsumptive users sampled also were hunters.
- Respondents felt the most important programs managed by WGFD were the bald eagle, big game, elk, sport fish, general wildlife, moose, terrestrial wildlife, bighorn sheep, raptor and waterfowl.
- Respondents felt that the most important problems faced by the WGFD were those of law enforcement and habitat loss.

Finally, the most recent estimates of expenditures in Wyoming attributable to nonconsumptive use (Kohley and Buchanan 1990) suggest that nonconsumptive users spend over $245 million dollars annually. WGFD management costs associated with nongame and nonconsumptive use totaled about $4 million in 1990.

Where From Here

With a program like "Worth the Watching," or any others that have experienced such phenomenal growth, finding, or perhaps better stated, making time to do long-range planning can be difficult. Nonetheless, the WGFD has already identified several actions that will be pursued within the next five years that are designed to allow the program to achieve its full potential as the means by which the new constituency is reached and, in turn, yield their political and fiscal support toward the business of wildlife management in Wyoming. Among those items are:

1. Develop more effective and efficient methods of monitoring and surveying visitors to agency facilities and others engaged in non-traditional, wildlife-associated recreation in the state.
2. Develop new mechanisms to communicate with this new constituency on a continuing basis. This will include, but not necessarily be limited to, creating a database from registration rosters at agency facilities for follow-up information exchange using some type of specialty publication.
3. Evaluate the facilities, planning, operational and interpretive education aspects of the program, utilizing an outside team of experts.
4. Improve the staffing levels of permanent personnel directly associated with the program.
5. Develop new initiatives whereby the new constituency can directly help pay for wildlife management programs in the state, and also better facilitate their buying into existing methods of funding these programs.

In addition, the WGFD will continue to emphasize those program attributes which have proven so successful, including taking measures to insure strong support from hunters and anglers toward agency management programs aimed at *all* species of wildlife, placing high priority on getting projects on the ground, and relying on an aggressive marketing, advertising and promotion campaign to keep the program at the forefront of local, state, regional and national audiences.

Conclusion

Four years ago at this conference, "Wyoming's Wildlife—Worth the Watching" was described as a "substantial change in direction for the WGFD" (Kruckenberg 1988). Today, these authors would credit the program with literally changing the face of the agency and changing how the public views its operation and responsibilities. "Worth the Watching" is not a panacea and not without its problems. But five years after-the-fact, it appears to be doing exactly what it was intended to do by positioning the agency to best meet the needs of a changing society, and the challenges posed by a new era that undoubtedly will bring more, not less, pressure on Wyoming's wildlife and wildland resources. Only by moving in this direction is there hope for future generations.

References

Kohley, T. and T. Buchanan. 1990. Nonconsumptive wildlife use in Wyoming. Dept. of Geography, Univ. Wyoming, Laramie. 81 pp.

Kruckenberg, L. L. 1988. "Wyoming's Wildlife—Worth the Watching:" Management in transition. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 53:424–430.

U.S. Fish and Wildlife Service. 1989. 1985 national survey of fishing, hunting and wildlife-associated recreation—Wyoming. U.S. Dept. of Interior, Washington, D.C. 81 pp.

Ward, J. P. and S. H. Anderson. 1989. Nonconsumptive user survey and recommendation for activities in Wyoming. Coop. Fish and Wildl. Resear. Unit, Univ. Wyoming, Laramie. 85 pp.

Wyoming Game and Fish Department. 1986. A plan for the development of nonconsumptive use of wildlife in Wyoming. Unpubl. planning rept. 11. Cheyenne, WY.

———. 1988. A plan for interpretive and visitor services for nonconsumptive wildlife experiences in Wyoming. Unpubl. planning rept. 5A–4. Cheyenne, WY.

———. 1990. The Wyoming responsive management pilot test. Cheyenne, WY. 74 pp.

———. 1991. Annual report—1991. Cheyenne, WY. 158 pp.

———. 1992. Wildlife interpretive services program master plan. Unpubl. planning rept. 5A–5. Cheyenne, WY.

Successful Communication and Education Strategies for Wildlife Conservation

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Introduction

Many wildlife professionals have stressed the importance of education as an integral component of resource management (e.g., Leopold 1933, Lewis 1974, Giles 1978, Diamond and Filion 1987). Management programs that stem from an understanding of both biological and human factors and their interactions have, in exemplary situations, incorporated education and communication to complement research, law enforcement and management practices as relevant and meaningful components of a comprehensive management plan (Blanchard 1984, 1987, in press, Pamplin 1986). The role of education is often understood best through case studies that document the effectiveness of educational programs in helping to solve specific wildlife problems.

The impetus for this study was a project undertaken in the Autumn of 1991, by the senior author, under contract with the U.S. Fish and Wildlife Service (FWS), Office of Training and Education (*see* Pomerantz 1992 for complete details of the case studies and findings reported herein). The project analyzed case studies of successful environmental education programs that have helped advance resource management objectives. It identified key program elements of successful educational strategies that can be applied by the Service as it develops and implements its environmental education programs. In conjunction with that project, the Office of Training and Education conducted a national environmental education workshop for FWS employees. As keynote speaker at the workshop, this paper's second author drew from experience in developing successful educational strategies for wildlife conservation. The purpose of this paper is to identify, from an examination of successful education and communication programs, those strategies held in common and to make recommendations generalizable to solving wildlife conservation problems elsewhere.

Methods

An exhaustive literature search was conducted to identify examples of successful environmental education programs targeted at achieving resource management objectives related to fish and wildlife. The two criteria for selection of case studies for analysis were (1) that they helped achieve fish or wildlife management objectives and (2) were evaluated, either formally or informally, to provide evidence of success.

Numerous citations of environmental education strategies used in connection with wildlife were identified through the Biological Abstracts and ERIC literature searches, and a search of North American Association for Environmental Education proceedings. However, few of the cases identified included an evaluation component. From these searches, six documented cases were selected; five in which educational strategies proved effective at helping to solve wildlife management problems and one whose strategies, though not targeted, are applicable to solving wildlife problems.

Following the literature review, telephone interviews were conducted with the leaders of the selected environmental education programs. In some cases, comments by program leaders supplemented information already reported in the literature. In others, the interview served as the primary basis for information about the program, while printed literature was used to flesh out the case study.

Results

The six case studies were:

I. *Conservation of Seabirds on the North Shore of the Gulf of St. Lawrence.* A comprehensive array of educational strategies targeted a management goal of restoring depleted populations of seabirds and included strong research and evaluation components of socio-cultural change (Blanchard 1984, 1987, 1989, in press, Blanchard and Monroe 1990, Blanchard and Nettleship in press).

II. *The Information and Education Program of the Yukon-Kuskokwim Delta Goose Management Plan.* An integrated communication and education program designed to help reduce declines in populations of four species of geese and promote cooperative management (Ady 1989, Blanchard 1987, Case 1989, C. Hunt personal communication: 1991, Pamplin 1986).

III. *Wolf Recovery in Montana.* A strong communication and education program emphasizing local involvement with the goal of decreasing wolf mortality from humans so wolf numbers can increase to recovery objectives (FWS 1990, P. Tucker, E. Bangs personal communication: 1991).

IV. *Educational Strategies for Sandhill Cranes on the Platte River in Nebraska.* Formal school programs, outreach and ecotourism combined to raise awareness of the impact of human activities on Sandhill crane habitat and develop public support for the cranes (Faanes and Lingle 1991, C. Faanes personal communication: 1991).

V. *The Monday Group: A High School Environmental Action Program.* A high school seminar class program emphasizing political action for the achievement of fish and wildlife management objectives (Hammond 1986, 1987, personal communication: 1991).

VI. *Educational Strategies used by a National Park for Natural Resource Management and Conservation.* Comprehensive and locally grounded educational and outreach programs designed to increase environmental knowledge and foster favorable attitudes toward the park system and conservation (Jacobson 1987, 1988, 1989, 1990, 1991, personal communication: 1991).

Each of the six cases held features in common, and contributed to an understanding of the working features of effective communication and education programs. The key program elements were as follows:

Research

The management problem and its context were investigated before educational and management strategies were developed. This included human dimensions research into the culture and special interests of the people in closest contact with the species. The research described how much people knew about the management situation, what their vested interests were, their attitudes and values towards the wildlife species, and activities that impacted the species. Biological research also was conducted to ascertain the status of the populations of interest and their habitats. The information gained through ecological and human dimensions research was then used as the basis for the design and implementation of the educational program.

Planning

There were several important aspects shared by each of the programs in their approach to the management situation.

Comprehensive approach. Each communication and education program was one part of a comprehensive strategy that also included research, habitat management practices and law enforcement. This multifaceted approach was especially evident in the Quebec, Alaska and Montana case studies, where education was used as an effective resource management tool. Moreover, education, when used in concert with these other activities heightened the programs' impacts and gave them credibility.

Cooperative planning and shared responsibilities. In all of the successful case studies, responsibility for the planning, development and implementation of the educational programs was a cooperative effort. The advantage of coordinating input from all interested parties was ultimately realized in the public's acceptance of the resulting management plan. Giving relevant constituents a substantive role in the development of the program ensured their continuing participation and support of agency programs. Distributing responsibility also enabled the program implementation to proceed more smoothly.

Local involvement and responsibility. The involvement of local people in every stage of the program's development and implementation was paramount to the success of each of the educational programs. This was especially true if an outsider was trying to initiate change, as in the case involving Kinabalu Park, where the stakeholders needed to share the credit and view the program as their own (S. Jacobson personal communication: 1991). In the opinion of the director of the Monday Group, "Sound environmental education programs are built carefully, over time, with an openness to participation in determining what they are to be, and how they are to be implemented. In this manner an environmental education program grows from its context. It becomes the handiwork of the stakeholders and a part of their value system and territory" (Hammond 1987:82).

Long-term approach. Education was viewed as a long-term process whose results would be realized some time in the future. Educational programs were not viewed as a quick-fix solution to a management problem, but as a slow process that could work with other management strategies to achieve a long-lasting goal.

Responsive management. Most of the programs included in their long-term educational programs necessary, short-term management strategies that addressed specific problems in a timely fashion.

Implementation

The following were educational strategies common to each program.

Experiential education (Hands-on!). Over and over, experiential education has proven to be a key element to program success. As the leader of the Monday Group stated, ''Students must do, rather than simply be told'' (Hammond personal communication: 1991).

Program and materials developed with local input. Including local constituents in the development and implementation of educational programs has been an important element in program success. Advice from local residents helped guide the format of materials and the content of programs. By incorporating local dialects, addressing issues of prime importance to residents and listening to their concerns, it was possible to develop programs that were locally relevant and accepted by the communities.

Face-to-face contact. This was crucial between the management authority and citizens. Having direct contact with decision makers and program leaders gave people a sense that their concerns were being listened to and their problems addressed. When such contact ended, so, too, did trust between management authorities and the public (Case 1989, C. Hunt personal communication: 1991).

Internal education program. In a number of cases, educating the people who would conduct the program or be the primary contact for the public was important and necessary to the program success. This included ensuring their sensitivity to the educational backgrounds and cultural norms of the constituents and providing current biological information about the species of concern.

Local responsibility for leadership and conservation work. In addition to the involvement of local residents in the planning and design of education and management strategies, their assumption of responsibility for implementing various programs was very important. Empowering residents with leadership roles gave them a true stake in the outcome of conservation activities.

Mass media. Spreading the word of conservation issues and management activities through newspapers, television and radio was an important aspect of many of these programs. Using the mass media helped raise awareness and engender public support for education and management programs.

Printed materials and curricula. Printed materials were valuable and helped convey important concepts. When printed materials were presented personally or used in conjunction with another educational strategy, they were particularly effective.

Evaluation

Evaluation of program effectiveness made it possible to determine the relationship of educational programs to management objectives. In each of the programs, the function of evaluation was to measure the degree to which the educational objectives were being achieved and whether the education program was integrated with the overall management goals. Evaluation also suggested how the program might be modified, such as by targeting new audiences, changing particular strategies, conducting more research or enlarging the educational objectives. Long-term evaluation showed whether a program affected root causes or merely provided a "quick-fix" for certain symptoms. It identified trends in the social and ecological environments, and, thus, helped direct long-term planning and research.

Discussion

Based on the past successes of these communication and education programs, we recommend the following process in designing new educational programs. It is a generalized framework for an education program designed to help solve a wildlife problem. There are four basic phases to the process—research, planning, implementation and evaluation—each providing feedback to the system and allowing for modifications within each phase over several years (Figure 1). The process is adapted from a conceptual framework developed by Blanchard and Nettleship (in press) for educational programs relevant to seabird conservation.

The *research* phase provides information on the socio-cultural context that is necessary for developing the education strategies. The basic method is a regional appraisal that clarifies the relationship between the wildlife population and the people, uncovers root causes to the problem, and identifies target groups for the program. These groups may include not only persons whose actions pose direct threats to wildlife, but also persons who influence them and persons who are able to reduce the threat or enhance the resource. The appraisal yields answers to many questions, such as how vital are the activities to the regions's economy and culture? Are the technologies appropriate? What are the root causes of the problem? Who are the decision makers in the region? The outcome of the research phase is the identification of appropriate management goals that are shared by managers and the public.

During the *planning* phase, the educational goals and objectives are established, and appropriate educational strategies are planned. The goals may be cognitive, such as to increase public knowledge of regulations, affective, such as to increase public concern for species and their habitats, or behavioral, such as to decrease human disturbance. During this and every stage, it is wise to involve target audiences in the planning process. The selection of appropriate educational strategies requires an understanding of such factors as how much information is needed, who will deliver it and with what resources. It also requires clarity about the desired outcomes, such as whether they are long- or short-term. The participation of target audiences is crucial throughout this phase.

Important elements of the *implementation* phase include the style of presentation, timing of activities and persons chosen to conduct them. It is important to look for approaches that are interactive, help build trust with the constituencies, utilize local ideas and customs, and involve the participation of local opinion leaders. It helps to develop a manageable timeframe that focuses on a few strategies at a time.

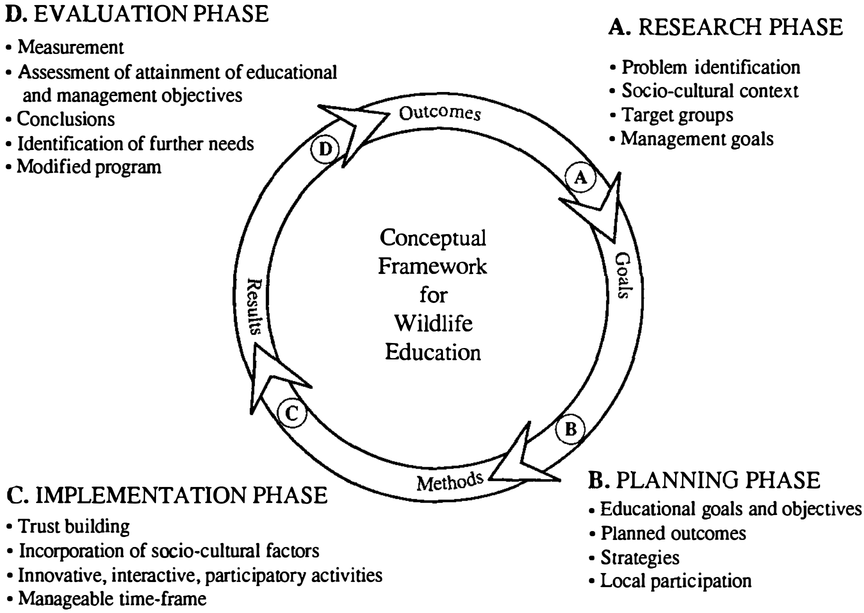

Figure 1. Conceptual framework for an education program designed to help achieve wildlife management objectives (adapted from Blanchard and Nettleship in press).

The last phase, *evaluation*, measures the degree to which the educational objectives and the overall management goals are achieved. It suggests how the program may be modified and helps direct long-term planning. Evaluation provides the essential data for decisionmakers and funding agencies who may control the program's future. It permits tough-minded decisions to be made based on qualitative and quantitative performance indicators. When programs are successful, evaluation provides the grist for publicity and promotion that leads to further support. Where outcomes are less than expected, the dynamics and knowledge base exist to make decisions and correct problems when and where required (Blanchard and Nettleship in press).

Conclusions and Recommendations

The analysis of successful conservation education programs contributed to an understanding of the working features of effective communication and education programs, and led to the following recommendations for designing new educational programs or modifying existing ones:

1. Investigate the problem and its context thoroughly, from both biological and human perspectives.
2. Use your investigative research and personal insights to determine the approach to management.
3. Integrate educational programs into the overall management plan, which includes research, law enforcement and habitat management.

4. Cooperate with all relevant constituents in program development. Share results of preliminary research.
5. Share responsibility for the program with relevant agencies, groups and individuals.
6. Involve local residents in program planning from the very beginning.
7. Be patient! Durable, long-lasting achievements take time.
8. Be responsive to immediate needs.
9. Select educational strategies appropriate to the educational background and cultural norms of the constituents.
10. Incorporate hands-on activities and techniques of experiential education.
11. Involve local residents in the development and implementation of programs. Share results of evaluation.
12. Make repeated face-to-face contact with your audience. Get out and meet your constituents one-on-one or in small groups, and in typical gathering places.
13. Conduct an internal education and training program so that managers and staff are equipped with the sensitivities, knowledge and skills needed.
14. Empower local residents with responsibility and capability for conservation activities by giving them leadership roles, skills and greater say in decision making. Offer training programs as appropriate.
15. Use printed materials that are locally relevant and introduce them through personal contact.
16. Inspire and motivate; this can be just as or more important than providing information.
17. Use the mass media: newspapers, television and radio.
18. Evaluate your programs from beginning to end!

The general framework for conservation education advocated can apply to many settings where communication and education programs are needed. Clearly though, the precise strategies used to advance wildlife management objectives will vary from one situation to another. By being alert and responsive to cultural differences, and involving local citizens in education programs, managers can increase their program's impact on wildlife conservation.

Managers need to apply their knowledge of the human dimensions of wildlife problems to educational programs designed to support management goals. More evaluation of programs is needed so that managers can identify those elements that are critical for program success. The contribution of these communication and education programs toward the successful attainment of management goals provides a glimpse of the efficacy of education when applied to wildlife management.

References

Ady, J. C. 1989. Teach about geese: Environmental education responds to a conservation issue in Alaska. Pages 111–115 *in* NAAEE proceedings.

Blanchard, K. A. 1984. Seabird harvest and the importance of education in seabird management on the North Shore of the Gulf of St. Lawrence. Ph.D. thesis. Cornell Univ., Ithaca, NY. 242 pp.

———. 1987. Strategies for the conservation of seabirds on Quebec's North Shore and Geese on Alaska's Yukon-Kuskokwin Delta: A comparison. Trans. N. Am. Wildl. and Nat. Resour. Conf. 52:399–407.

———. 1989. Working together for the conservation of seabirds on the North Shore of the Gulf of St. Lawrence. Pages 47–53 *in* NAAEE Proceedings 1989.

———. in press. Culture and seabird conservation: The North Shore of the Gulf of St. Lawrence, Canada. *In* D. N. Nettleship, J. Burger, and M. Gochfeld, eds., Seabirds on islands: Threats, case studies, and action plans. International Council for Bird Preservation Tech. Publ., Cambridge, U.K.

Blanchard, K. A. and M. C. Monroe. 1990. Effective educational strategies for reversing population declines in seabirds. Trans. N. Am. Wildl. and Nat. Resour. Conf. 55:108–117.

Blanchard, K. A. and D. N. Nettleship. In press. Education and seabird conservation: A conceptual framework. *In* D. A. McCullough and R. Barrett, eds., Wildlife 1001-Population. Science Publishers, The Hague.

Case, D. J. 1989. Yukon-Kuskokwim Delta goose management plan: An evaluation of the information and education program. Final Rept. to the USFES, Anchorage, AK (Order No. 70181–03348–88). 37 pp.

Diamond, A. W. and F. Filion, eds. 1987. The value of birds. International Council for Bird Preservation Tech. Publ. No. 6, Cambridge, U.K. 267 pp.

Faanes, C. A. and K. Lingle. 1991. Ecology of the Platte River: An elementary school curriculum. U.S. Fish and Wildlife Service, Grand Island, NE. 29 pp.

U.S. Fish and Wildlife Service. 1990 Annual report of the Montana Interagency Wolf Working Group. U.S. Fish and Wildlife Service, Helena, MT. 29 pp.

Giles, R. H., Jr. 1978. Wildlife management. W. H. Freeman, San Francisco, CA. 416 pp.

Hammond, W. 1986. The Monday Group: From awareness to action. Pages 264–271 *in* Project WILD, Elementary Activity Guide. Western Regional Environmental Education Council. 280 pp.

———. 1987. (How) Can interdisciplinarity be implemented? Pages 77–84 *in* Trends and issues in environmental education: EE in school curricula. J. F. Disinger, ed., ERIC Clearinghouse for Science, Mathematics, and EE, Columbus, OH. 152 pp.

Jacobson, S. K. 1987. Conservation education programmes: Evaluate and improve them. Environ. Cons. Vol. 14(3):201–206.

———. 1988. Media effectiveness in a Malaysian park system. Jour. Envir. Educ. Vol. 19(4):22–27.

———. Mass media and park management: Reaching the public beyond the park boundary. The Environmentalist Vol. 9(2):131–137.

———. 1990. A model for using a developing country's park system for conservation education. J. Envir. Educ. Vol. 22(1):19–25.

———. 1991. Evaluation model for developing, implementing, and assessing conservation education programs: Examples from Belize and Costa Rica. Environ. Manage. Vol. 15(2):143–150.

Leopold, A. 1933. Game management. Charles Scribner's Sons, NY. 481 pp.

Lewis, H. F. 1974. Lively: A history of the Canadian Wildlife Service. Canadian Wildl. Serv. manuscript rept., Ottawa. 255 pp.

Pamplin, W. L., Jr. 1986. Cooperative efforts to halt population declines of geese on Alaska's Yukon-Kuskokwim Delta. Trans. N. Am. Wildl. and Nat. Resour. Conf. 51:487–506.

Pomerantz, G. A. 1992. Educational strategies for conservation. Report submitted to the U.S. Fish and Wildlife Service, Office of Training and Education, May. 46 pp.

Market Information: Matching Management with Constituent Demands

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Wildlife agencies are struggling to understand how their conservation activities can meet the demands of an increasingly diverse clientele. Attempts to define the wildlife "product" in North America are not new (Scheffer 1976), but will become especially challenging as cultural diversification accelerates into the 21st century (Witter in press). Though frustrating for agencies, the dynamic struggle to understand wildlife's diverse clientele is essential. A company must seek a "balanced business cycle" in which the firm's products and services match its clientele's wants (Davis and Davidson 1991). Otherwise, it's time to change the organization or, at the extreme, eliminate it.

Public expectations for agency programs are widely varied (Witter 1990a). Most agencies satisfy the interests of harvest-oriented constituents. Many clients, however, expect nonconsumptive or aesthetic-oriented facilities and services like nature centers, hiking trails, birding guides, and special nonconsumptive events comparable to hunting seasons, such as Eagle Day (Witter et al. 1980), Prairie Day (Maupin et al. 1982), and Day on the River (Catlin 1984). Other citizens oppose harvest-oriented activities and seek to curtail or eliminate traditional folkways of hunting and fishing (Richards and Krannich 1991). Still others are simply uninterested. Research in Missouri suggests that one-fifth of the state's citizenry is generally unconcerned about wildlife (Witter 1992).

Agencies are trying to achieve a balance, responding to demands for innovation, while satisfying traditionalists who have provided the money and political base upon which modern wildlife conservation was founded. Somehow, resource agencies must match their organization and management activities to their current business cycle. How can this be accomplished? The Missouri Department of Conservation (MDC) uses market research to relate socioeconomic characteristics and outdoor interests of its constituencies to its conservation activities.

Market Information for Fish and Wildlife Agencies

Marketing begins with human needs, wants, and demands (Kotler 1984). Needs are defined as basic human requirements (food, water, air, shelter, social interaction, recreation); wants are specific requests for products and services to satisfy needs; and demands are wants for products or services that are backed up by an ability and willingness to pay for them. The process of marketing involves an exchange between two parties and is concerned with satisfying wants and demands. From a wildlife agency's perspective, marketing perhaps is best described as "the analysis, planning, implementation, and control of carefully formulated programs designed to bring about voluntary exchanges of values . . . for the purpose of achieving organizational objectives" (Kotler 1982:5).

Marketing should not be equated with selling, and certainly not confused with a coercive transaction, the "hard sell." Even for a profit-oriented business, selling is only one part of marketing and involves the actual exchange of goods or services of equivalent market value (Kotler and Andreasen 1987). Marketing is providing a product or service to a preexisting want or demand. "The aim of marketing is to make selling superfluous" (Drucker 1974) because the basis for exchange has already been established.

Marketing may threaten some wildlife professionals who see themselves on an undisputable mission not subject to market principles. Actually, wildlife managers should be comfortable with the definition of marketing—the process of carefully formulating programs to achieve specific exchanges. This definition practically paraphrases the classic description of wildlife management as "the art of making land produce sustained annual crops of wild game for recreational use" (Leopold 1933).

To successfully incorporate market principles into fish and wildlife management, the agency and manager must have fundamental market information. Successful fish and wildlife management starts with information about populations and habitats; market information is similar fundamental knowledge but is information about constituent wants and demands. The way to discover wants and demands is to collect facts and data about the characteristics, behaviors, perceptions, attitudes, and participation rates related to fish and wildlife recreation. Armed with information about current and prospective clients, the organization can tailor products and services to satisfy the desires of the clientele. Information can also be used by the agency to anticipate changes in customer needs, wants, and perceptions, permitting proactive strategies rather than crisis management (Kotler and Andreasen 1987).

Market research in government is not a new idea (Snavely 1991), nor is it new to fish and wildlife agencies. In government, market research has been used to promote education (Prasad and Murphy 1989), economic development (Watzke and Mindak 1987), election to public office (Mauser 1983), and recreation (Howard and Crompton 1980). Marketing by wildlife agencies to promote conservation was outlined no later than the mid-1970s (Schick et al. 1976), and detailed for agency managers as part of Responsive Management (1990). However, Leopold's (1930) prophetic call for agencies to build management programs on the financial and political resources of hunters and non-hunters is one of the earliest statements on the importance of serving a wide range of customer interests in wildlife management.

Marketing for fish and wildlife agencies has unique features when compared to traditional business marketing principles (Snavely 1991). First, agencies have limited control over their missions and target customers. In Missouri, MDC's responsibilities are constitutionally mandated (State of Missouri 1989:61–63). The mission statement of MDC responds to the constitutional responsibilities and defines the customer as "present and future citizens of Missouri" (Missouri Department of Conservation 1989:14). Unlike businesses, agencies are "told" for whom they will produce products and services. Second, though satisfying a public service role, an agency can and does regulate the wildlife services the citizenry is allowed to receive. Unlike businesses, agencies limit access to their products to conserve wildlife. Third, wildlife agencies must necessarily strive to provide services that benefit all citizens. Unlike businesses that might focus on selected market segments to maximize profits, agencies are civil service organizations. Fourth, ordinary markets do not exist for "public" amenities, such as outdoor recreation and environmental quality. Under public policy there is no charge for most natural resource amenities; rather, there is an arbitrarily determined charge which does not reflect the full cost of providing the service or its true market value. Unlike a business transaction, where a client receives a product or service and immediately pays the provider, some citizens may pay for fish, forest, and wildlife conservation but choose not to participate in related recreation nor expect to receive any benefits from the resources. Conversely, some citizens may pay only a portion of the value of their recreation participation or resource use. And, in some cases, such as birdwatching, a charge is not feasible because once the amenities are provided, people cannot be excluded from enjoying them.

Market Information for MDC

Recent studies of citizens' fish, forest, and wildlife-related interests illustrate how an agency can improve resource management through market information.

Case 1: Developing the Innovative and Maintaining the Traditional

Background. In 1979 and 1989, Fleishman-Hillard Research, Inc. of St. Louis was contracted by MDC to conduct surveys of urban Missourians' interests in conservation. One objective was to monitor outdoor participation between the 1979 study (Witter et al. 1981) and 1989 study (Witter 1990b). Another objective was to explore citizen attitudes toward hunting, fishing, trapping, and clear-cutting.

Selected results. Unchanged over the decade was nature-oriented TV viewing, with 80 percent of the population involved in both 1979 and 1989. Constant, too, was involvement in gathering nuts and greens (30 percent), and participation in hunting (20 percent). Angling increased slightly; 53 percent, up from 49 percent. Examples of activities in which substantial growth occurred over the decade were birdwatching near home, camping, boating, hiking, canoeing, and conservation group membership.

Approval of recreational angling was practically unanimous (94 percent), and hunting received majority approval as well (68 percent). Support for trapping (35 percent) fell short of a majority. Missouri urbanites expressed mixed sentiment on clear-cutting 10-acre forest parcels as practiced on MDC areas; roughly one-third approved, one-third disapproved, and one-third had no opinion.

Marketing implications. The major funding source for MDC is a dedicated one-eighth of one percent sales tax that has generated over $500 million for fish, forest, and wildlife programs since its start in 1977 (A. J. Brand Missouri Department of Conservation: unpublished data). Virtually all Missourians contribute to fish, forest, and wildlife conservation, and virtually all should expect some conservation benefits.

Urban Missourians' growing interest in aesthetic-oriented recreation helped justify development of innovative programming for urbanites. One such response was construction of nature centers targeted at urban residents. Located in St. Louis, Kansas City, Springfield and Jefferson City, these centers are focal points of a statewide network to serve the aesthetic-oriented wildlife interests of the large population of urban Missourians (Wallace and Witter 1991).

Wildlife agencies must be attentive to tradition as well as innovation. High urban approval of recreational fishing was not unexpected. Relatively strong approval of hunting was surprising. Conventional thinking suggests that the isolation of urban citizens from animal and plant husbandry has led to the development of anti-harvest sentiment. Perhaps helping to explain urbanites' support for hunting was the finding that 4 of 10 urban Missourians surveyed said they grew up in a small town or rural area, places where the folkways of fishing and hunting are well accepted.

Lack of support for trapping confirmed that this issue demanded special sensitivity on MDC's part. One proactive response by MDC was a feature article on trapping and Missouri furbearers in the *Missouri Conservationist* magazine (Childress and Cwynar 1992). The one-third of urbanites undecided about clear-cutting suggests that this standard practice within MDC Forestry Division warrants additional explanation. Ultimately, however, the public may reject agency explanations of management practices and conclude that agencies are preoccupied with selling rather than marketing these controversial practices. Agencies then will be compelled to end these practices or face the consequences of programs that are not matched to clientele's wants or are even offensive (Davis and Davidson 1991).

Case 2: Tailoring for a Racial Minority

Background. Black Missourians account for about 10 percent of the state's population, with most residing in St. Louis and Kansas City. The 1979 surveys of urban Missourians conducted by MDC revealed outdoor involvement by blacks substantially lower than whites, a finding not completely unanticipated (Washburne 1978). In 1990, the MDC conservatively estimated that black Missourians had contributed about $25 million to the conservation sales tax since its start in 1977. Based on their relatively low involvement in outdoor activities, MDC questioned whether black Missourians experienced comparable benefits.

The MDC contracted Fleishman-Hillard Research to conduct small group research (focus groups) to explore lack of black participation in nature-oriented activities. Focus groups were deemed best suited to explore potentially sensitive explanations for lack of black outdoor participation. Each group consisted of 14 black adults representative of middle income blacks, led in discussion by a group moderator from Fleishman-Hillard.

Selected results. Lack of black involvement in outdoor recreation was explained by three fears. First was fear of racial intimidation. The sobering revelation was that focus group participants recognized dramatic improvements in interracial relations in Missouri, but they were unwilling to test these changes on remote and rural MDC areas. MDC areas, in fact, represented the opposite of what most of them would seek in an outdoor setting. Many MDC lands promote individual involvement in remote areas in harvest-oriented activities, while focus group participants preferred secure areas affording opportunities for group interaction and conversation.

Second, focus group participants tended to be unfamiliar with or fearful of the outdoors. Participants generally lacked experience with the opportunities and services of MDC. They expressed misconceptions about dangers in the outdoors, and found little comfort in the idea of "being alone with nature."

Third, focus groups participants feared random violence on MDC lands—an unlikely possibility, but a real one that actually claimed one MDC employee and three visitors in nightmarish murders at an MDC area in 1986 (Mosley 1986). The threat of random violence might be heightened for urbanites painfully aware of crime, urban blight, gang warfare, homelessness, and drug abuse (McCormick and Turque 1991).

At the conclusion of the focus groups, participants were informed of MDC's responsibilities, services and facilities. Participants regretted to learn of the many MDC services they had never used, but were even more disappointed that their children were missing chances to learn about and appreciate nature.

Marketing implications. Cultural historians assert that white resource managers should not assume non-whites perceive nature as whites do (Meeker et al. 1973). Focus group findings confirmed this. But a persistent theme throughout the focus groups was that outdoor successes will build the confidence of blacks and encourage them to involve their families and friends.

The MDC hopes that nature centers provide the safe, group-oriented setting that focus group participants preferred for outdoor recreation. Centers offer an outdoor environment in or near the city limits where visitors can learn from indoor exhibits and can walk paved trails that are clearly mapped, signed and patrolled by staff. MDC also is seeking minority staff and actively recruiting minority volunteers. Moreover, MDC is making special effort to invite black visitors to nature centers. Focus group blacks wanted the extra assurance that they and their families would be welcomed and safe at MDC areas. Fostering black visitation at nature centers could take years, however. Overcoming pervasive social fears will not be an easy task.

Recognizing that the black population in Missouri is not one public, but many diverse publics (Waldrop 1990), and acknowledging that minority interest in the outdoors could be an issue of ethnicity as much as race, MDC is continuing research on black outdoor participation. A cooperative study with the University of Missouri is examining black visitation at the 7,000-acre August A. Busch Wildlife Area in suburban St. Louis. The area has a long history of black visitation. By understanding why the area appeals to black visitors, perhaps attractive management practices or site attributes can be enhanced even further to encourage more minority attendance, or the practices and attributes might be duplicated at other MDC sites not frequented by non-whites.

Case 3: If At First You Don't Succeed . . ."

Background. The MDC started a stream conservation program in 1986 to provide landowners assistance in managing their streams. Called "Streams for the Future," this initiative was expanded in 1989 to inform the general citizenry of the benefits of stream conservation in Missouri. The primary medium for contacting the public was the *Missouri Conservationist* magazine, MDC's publication sent free to Missouri adults requesting it, or about 400,000 households in the late-1980s. *Conservationist* coverage of streams was given in articles, as well as a 16-page feature on stream conservation in the August 1990 issue. However, dramatically expanded reporting on stream conservation came from TV and print coverage of the 1990 "Natural Streams Act." This Act was a citizen initiative that would have mandated numerous stream conservation measures. Public attention on stream issues seemed to reach a peak in early-November 1990, with the overwhelming defeat of the Natural Streams Act at Missouri polls.

The MDC was interested in citizen awareness of stream conservation after four years of seemingly sharp focus on the issues. Gallup Organization, Inc. was contracted by MDC to survey Missouri adults' perceptions of stream conservation. Telephone interviews were conducted with a random sample of 606 Missouri adults in January 1991 (Missouri Department of Conservation 1991).

Selected results. Awareness of specific stream and river conservation programs was extremely low. Five of six respondents could not name a stream conservation program by name. Only 7 percent mentioned the Natural Streams Act, and only 1 percent named "Streams for the Future." When asked a direct question, if they had heard of MDC's "Streams for the Future" program, 25 percent said yes. An encouraging 75 percent of respondents had heard of the *Missouri Conservationist* magazine, but only 28 percent of these were aware of "Streams for the Future," only slightly higher than the overall population.

Marketing implications. Despite a four-year streams initiative, punctuated by intense media coverage of the Natural Streams Act, citizen awareness of stream conservation issues was barely detectable. Wildlife agencies hoping to garner citizen support for conservation are, thus, well advised to follow the first rule of business—advertise, advertise, advertise, and then advertise some more. Such persistence might involve years, if not decades, of consistent messages before the public's consciousness is raised to an action level. However, there is always the possibility that the public will never be convinced of the need for action, despite the best publicity and educational efforts an agency can direct at a resource problem.

Case 4: "If You Build It They Will Come," But Will It Pay Off?

Background. A program promised to Missourians if the conservation sales tax passed in 1976 was "a system of Conservation Interpretive Centers . . . with informed personnel to interpret for visitors" (Missouri Department of Conservation 1975:15). Three centers have been constructed as a result, with another at Jefferson City scheduled for completion in 1993. Typical construction costs for an MDC nature center range from $2 million to $4 million, with annual operating costs (including salaries) about $250,000 for each. No entrance fees are charged.

A criticism of aesthetic-oriented wildlife users is their apparent unwillingness to help fund state programs of fish and wildlife conservation (McCloskey 1979). This criticism persists despite evidence that many nonconsumptive enthusiasts think most agencies do not respond to their fish and wildlife interests, and despite the scarcity of comprehensive funding mechanisms through which nonconsumptive users can contribute. As a result, they support private conservation organizations offering services and products to their liking (Witter and Shaw 1979).

A "chicken and egg" or "which comes first" stalemate now appears to characterize the relationship between agencies and nonconsumptive users: until agencies are convinced that aesthetic-oriented users will help pay, no special programs or services will be provided; until nonconsumptive users see programs or services, their funding and support probably will be withheld. A 1991 visitor survey at MDC's Burr Oak Woods Nature Center provided important clues to benefits of aesthetic-oriented programming.

Selected results. The stereotypical respondent was female (67 percent), age 25 to 44 (61 percent), with at least some college education (74 percent). Most respondents were urban or suburban dwellers (77 percent), married (81 percent), with children living at home (64 percent).

A plurality (42 percent) heard of Burr Oak Woods from a friend or neighbor. Visitors drove an average of one-half hour to reach the center, and most (69 percent) stayed at least one hour. Practically all (91 percent) said their visit to Burr Oaks was ''very enjoyable,'' with respondents willing to pay an average of about $1.50 if MDC were to request an entrance fee. After their visits, most respondents (83 percent) were able to report that Burr Oak Woods was managed by MDC.

Marketing implications. Among the most pressing needs facing fish and wildlife agencies is to broaden their political and financial support beyond the traditional base of sportsmen (Shaw and King 1980). Dedicating seed money to innovative programs such as nature centers could be a painful philosophical and fiscal process for many agencies. However, the benefits could be great.

Nature center visitors stand in stark contrast to the stereotypical Missouri hunter— a young to middle-aged male of rural background (Porath et al. 1980). And though anglers are more demographically diverse than hunters (Gallup 1990), variability in gender, education, and place of residence among nature center visitors brings a healthy mix of vital social characteristics into MDC's programming.

Not only does a diverse public represent the strongest potential base of financial support for innovative services, but such a base might have unexpected benefits for traditional programs. Animal rightists have been stereotyped as ''. . . highly educated, relatively well-to-do female professionals'' (Richards and Krannich 1991:370). Highly educated females drawn to aesthetic-oriented programming at nature centers could represent an important foil to animal activists.

Case 5: Dollars and Cents: Is It Worth It?

Background. Few tasks are more difficult than assigning dollar values to public services as enigmatic as increases in hunting opportunities or maintaining free flowing streams. Resource managers thus have been skeptical of economics in management decisions. However, fish and wildlife are scarce resources and conflicts over their use are escalating. Economic impact analysis, valuation, and modeling are now parts of most MDC public surveys. Biologists and managers use economic facts to determine the public benefits of fish, forest, and wildlife management.

Selected results. Fish and wildlife recreation expenditures in Missouri by state residents and nonresidents in 1985 totalled nearly $1.4 billion and accounted for over $2.7 billion in total business activity through the re-circulation of dollars within the economy (Brown 1991). These expenditures accounted for nearly one-third of all travel spending in Missouri (U.S. Travel Data Center 1988) and supported nearly 57,000 jobs in Missouri, about one-half of all travel-related employment in the state (U.S. Travel Data Center 1988). Nearly $50 million in sales tax revenue was generated from direct expenditures, while supported jobs generated $40 million in state income tax revenue. Additional state and federal tax revenue is also generated from supplemental taxes on gasoline, airline tickets, and corporate income.

Comparison of values among Missouri wildlife management areas, river systems, (Brown 1991) and a Kansas City nature center revealed great variability in the values Missouri citizens place on conservation-oriented amenities (Table 1). Values per one-day trip varied from a high of $16 at a wetland area managed intensively for waterfowl hunting to $1.50 at the Burr Oak Woods Nature Center in suburban Kansas City. Variation in day values was observed among different clientele, with recreationists participating in specialized activities such as big game and waterfowl hunting valuing sites more highly. However, specialized activities had fewer participants, so that areas offering less specialized opportunities, such as hiking and viewing, had higher participation with more visitors of local origin, but lower day values. Thus, annual benefits and benefit-cost ratios were often similar for disparate areas (Table 1).

Marketing implications. The economic impacts of consumer spending have powerful political influence and often determine government support for specific industries and public trust resources. The media frequently highlights the positive impacts of fishing and hunting on local communities, and administrators and legislators argue the merits of various fish and wildlife-related resource uses based on their contributions to employment, state revenues, and economic development. In 1985, sales tax revenue accruing from fish and wildlife-associated recreation spending in Missouri was nearly equal to revenue generated by the conservation sales tax (Brown 1991). Conservation of fish and wildlife pays big public benefits; a point emphasized by conservation advocates whenever the Missouri legislature debates the rare proposal for alternative uses of the conservation sales tax.

Missouri's urban centers are spheres of influence for a variety of public programs, including fish and wildlife recreation. Values of one-day trips indicate that specialized recreation activities, like waterfowl and big-game hunting, are higher quality experiences in remoter natural settings distant from urban sprawl. Visitors to rural

Table 1. Comparison of values among Missouri wildlife management areas, river systems, and a Kansas City nature center. Dollar values are for one-day recreation trips estimated by travel cost and contingent valuation methods.

	Wildlife management areas			River systems		Burr Oak Woods Nature Center
	Whetstone Creek	Ted Shanks	Weldon Spring	Gasconade River	Pool 24 Miss. River	
$ value per trip[a]	10.25	16.20	5.35	5.80	4.80	1.50
Percentage of local trips[b]	35	36	98	75	78	97
Annual trips	15,190	32,660	43,940	457,000	68,490	95,000
Annual $ benefits	155,850	528,765	235,079	2,650,600	326,700	143,450
Annual B/C ratio[c]	3.0:1	2.2:1	24.6:1			1.7:1

[a]One-day trip value is for survey year.
[b]Percent of local trips was determined by defining a 1 to 4 county region for the resource area surveyed.
[c]The annual benefit/cost ratio is based on per trip value times annual value divided by the annual operating costs, excluding salaries and development costs, for the survey year. Operating costs for river systems were not available.

wildlife areas travel farther and value their opportunities for these activities more than urban visitors who engage in aesthetic-oriented activities, such as hiking and bicycling, at nearby wildlife areas. However, sites near urban centers attract more visitors, so that annual benefits at these areas are equivalent to those at rural areas. These areas satisfy a variety of wants while providing equal benefits to a diverse clientele. Economic evidence of the benefits of diverse recreational programming compels managers to serve many different clientele and provides accountability for diverse agency programs.

New Era of Conservation Service

Market information is the way for wildlife agencies to enter a new era of conservation service. These data will not tell an agency what management decisions to make, but will provide clues to guide decisions in an increasingly complex society.

Collecting market information should be an ongoing part of an agency's research program. Leopold's (1948:45–48) observation on the benefits of continuity and commitment in biological research applies to market research: "once in a blue moon research will, by accident, hit upon a discovery of practical value without any preliminary work on fundamentals, but when pursued as a policy, such accidental hits are a losing game"; "What I am asking for is a balanced program, which recognizes that some research jobs are short while others are long, and that the neglect of either is poor policy"; and "If we fail to reduce this fumbling today, the well-springs of funds will dry up tomorrow."

No resource agency can do everything for everyone. Market information helps resource managers determine who should be served and in what ways, allowing agencies to allocate scarce resources across many public wants, and perhaps, stimulating support for broadened programming.

References

Brown, E. K. 1991. Putting economics to work in fish and wildlife management. Publ. Profile 7-91. Missouri Dept. Conserv., Jefferson City. 38 pp.

Catlin, D. 1984. A day on the river. Missouri Conservationist 45(8):32.

Childress, P. and T. Cwynar. 1992. Talking about trapping. Missouri Conservationist 53(1):11–14.

Crompton, J. L. and C. W. Lamb. 1986. Marketing government and social services. John Wiley & Sons, NY. 485 pp.

Davis, S. M. and W. H. Davidson. 1991. Is it time to kill your organization? Modern Office Technology 36:12–14.

Drucker, P. F. 1974. Management: Tasks, responsibilities, practices. Harper and Row, NY. 839 pp.

Gallup, G., Jr. and F. Newport. 1990. 1989 Gallup leisure audit. The Gallup Poll Monthly April:27–30.

Howard, D. and J. Crompton. 1980. Financing, managing, and marketing recreation and park services. William C. Brown Publishers, IA. 490 pp.

Hueber, G. 1991. Americans report high levels of environmental concern, activity. The Gallup Poll Monthly 307:6–12.

Kotler, P. 1982. Marketing for nonprofit organizations. Prentice-Hall, Englewood Cliffs, NJ. 528 pp.

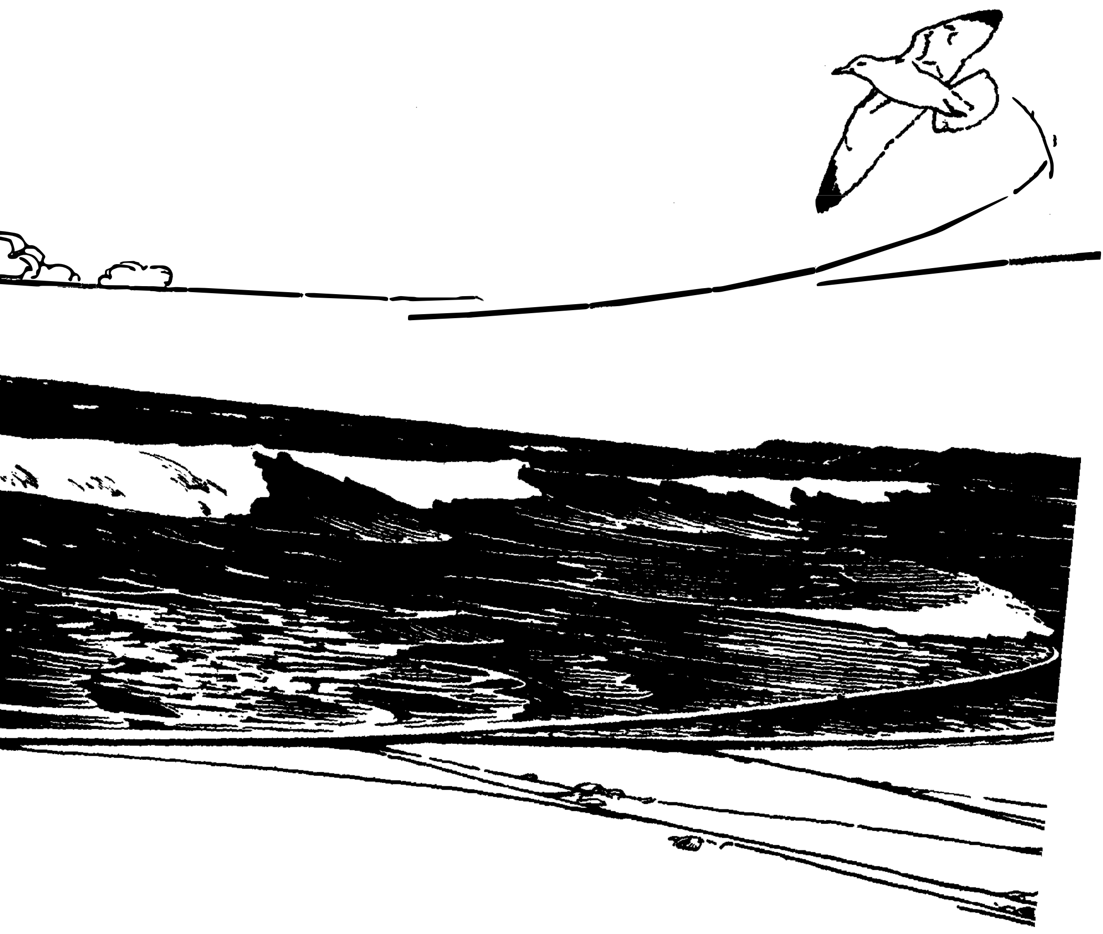
———. 1984. Marketing management: Analysis, planning, and control. Prentice-Hall, Englewood Cliffs, NJ. 794 pp.

Kotler, P. and A. R. Andreasen. 1987. Strategic marketing for nonprofit organizations. Prentice-Hall, Englewood Cliffs, NJ. 670 pp.

Leopold, A. 1930. The American game policy in a nutshell. Trans. Am. Game Conf. 17:284–309.

———. 1933. Game management. Charles Scribner's Sons, NY. 481 pp.

———. 1948. Why and how research? Trans. N. Am. Wildl. Conf. 13:44–48.
Mauser, G. 1983. Political marketing: An approach to campaign strategy. Praeger, NY. 304 pp.
Maupin, G. T., B. K. Bassett, D. T. Catlin, and D. J. Witter. 1982. Missouri's prairie day: Methods and evaluation of an interpretive extravaganza. J. Interpretation 7:31–39.
McCloskey, M. 1979. Nongame wildlife. Sierra March–April:8–13.
McCormick, J. and B. Turque. 1991. Big crimes, small cities. Newsweek 10 June: 16–19.
Meeker, J. W., W. K. Woods, and W. Lucas. 1973. Red, white, and black in the national parks. The N. Am. Review Fall:3–7.
Missouri Department of Conservation. 1975. The new design for conservation. Missouri Conservationist 36(8):1–20.
———. 1989. Strategic plan: Fiscal years 1990–1994. Missouri Dept. Conserv., Jefferson City. 56 pp.
———. 1991. Missourians' perceptions of streams and stream conservation. Publ. Profile 4–91. Missouri Dept. Conserv., Jefferson City. 26 pp.
Mosley, J. 1986. Few clues in murder of four. St. Louis Post Dispatch, 11 September:A1–3.
Porath, W. R., S. L. Sheriff, D. J. Witter, and O. Torgerson. 1980. Deer hunters: A traditional constituency in a time of change. Proc. Internat. Assoc. Fish and Wildl. Agen. 70:41–53.
Prasad, S. and M. Murphy. 1989. Marketing higher educational institutions to academically talented students. Pages 575–580 *in* J. M. Hawes and J. Thanopoulos, eds., Developments in Marketing Science, Volume XII. Academy of Marketing Science, Akron, OH.
Responsive Management. 1990. Marketing in a fisheries and wildlife agency. Western Assoc. Fish and Wildlife Agen., Tallahassee, FL. 32 pp.
Richards, R. T. and R. S. Krannich. 1991. The ideology of the animal rights movement and activists' attitudes toward wildlife. Trans. N. Am. Wildl. and Nat. Resour. Conf. 56:363–371.
Scheffer, V. B. 1976. The future of wildlife management. Wildl. Soc. Bull. 4:51–54.
Schick, B. A., T. A. More, R. M. DeGraaf, and D. E. Samuel. 1976. Marketing wildlife management. Wildl. Soc. Bull. 4:64–68.
Shaw, W. W. and D. A. King. 1980. Wildlife management and nonhunting wildlife enthusiasts. Trans. N. Am. Wildl. and Nat. Resour. Conf. 45:219–225.
Snavely, K. 1991. Marketing in the government sector: A public policy model. Amer. Rev. Publ. Admin. 21:311–326.
State of Missouri. 1989. Constitution of Missouri. Office of Secretary of State, Jefferson City. 175 pp.
U.S. Department of Interior. 1988. 1985 National survey of fishing, hunting, and wildlife-associated recreation. U.S. Govt. Print. Off., Washington, D.C. 167 pp.
U.S. Travel Data Center. 1988. The economic impact of travel on Missouri counties, 1986. U.S. Travel Data Center, Washington, D.C. 28 pp.
Waldrop, J. 1990. Shades of black. Am. Demographics 12(9):30–34.
Wallace, V. and D. J. Witter. 1991. Urban nature centers: What do our constituents want and how can we give it to them? Legacy 2:20–24.
Washburne, R. F. 1978. Black underparticipation in wildland recreation: Alternative explanations. Leisure Sciences, 1:175–189.
Watzke, G. E. and W. A. Mindak. 1987. Marketing-oriented planning in public administration: The case of the state development agency. Internat. J. of Publ. Admin. 9:153–192.
Witter, D. J. 1990a. Wildlife management and public sentiment. Pages 161–172 *in* J. M. Sweeney, ed., Management of Dynamic Ecosystems. N. Central Sec., The Wildl. Soc., West Lafayette, IN. 180 pp.
———. 1990b. Cityscape. Missouri Conservationist 51(6):22–25.
———. 1992. City mouse, country mouse. Missouri Conservationist 53(2):4–9.
———. In press. Wildlife-related recreation in a "new age." 2020 vision: Meeting the fish and wildlife conservation challenges of the 21st Century. Proc. Midwest Fish and Wildl. Conf. Symp. Des Moines, IA., December 1991.
Witter, D. J. and W. W. Shaw. 1979. Beliefs of birders, hunters, and wildlife professionals about wildlife management. Trans. N. Am. Wildl. and Nat. Resour. Conf. 44:298–305.
Witter, D. J., D. L. Tylka, and J. E. Werner. 1981. Values of urban wildlife in Missouri. Trans. N. Am. Wildl. and Nat. Resour. Conf. 46:424–431.
Witter, D. J., J. D. Wilson, and G. T. Maupin. 1980. "Eagle Days" in Missouri: Characteristics and enjoyment ratings of participants. Wildl. Soc. Bull. 8:64–65.



Special Session 3. *Conservation Education: Investing in the Future*

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An Evaluation of Volunteerism in Selected Conservation Education Programs

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Introduction

Successful environmental education (EE) programs depend on appropriate evaluation of curriculum materials, goals, utilization (Hart 1981) and implementation system. Limited budgets for many natural resource agencies (Adams et al. 1988) and other organizations force reliance on volunteers to conduct training workshops and implement classroom activities. Because organizations need volunteers, many volunteer programs avoid evaluation (Allen 1987). Nevertheless, evaluation is needed to make informed decisions concerning effective use of volunteers in EE programs.

Volunteers are characterized as high in assertiveness or dominance, achievement, affiliation, extroversion, sociability, and autonomy (Reddy and Smith 1972, Guyatt 1974, Athey 1987). The motivation to become involved as a volunteer usually is multi-dimensional (King 1984), including a desire for personal development, altruistic characteristics (Guyatt 1974), personal convictions about the purposes of the program, interpersonal attachments to the program or group (Knoke and Prensky 1984), and other background characteristics (King 1984, Rohs 1986). However, background characteristics may not be good indicators of volunteerism (Rodriguez 1984).

Knowledge of volunteer commitment and retention also should be examined for proper evaluation of a volunteer program. Highly committed volunteers identify with the goals of the organization (Hirschman 1970). Participation in the decision-making process of the organization increases commitment and decreases apathy (Smith and Reddy 1973, Knoke 1981). However, when participation in decision making is not provided, extensive communication between the policy makers and the volunteers can compensate for the lack of direct participation (Knoke 1981). Support and feedback from paid staff, minimal administrative responsibilities and interaction among volunteers are relatively more important to commitment than personal variables, according to Pierucci and Noel (1980) and Rodriguez (1984).

Project Learning Tree (PLT) and Project WILD (WILD) are multidisciplinary educational programs that rely heavily on volunteers. Both follow a tiered system of training and implementation, from national and state directors, to trainers (i.e., facilitators), to users (i.e., educators), and ultimately to students. Individuals interested in becoming facilitators must attend a two-day training workshop, and educators interested in using the materials in either classrooms or the community must attend a six-hour training workshop (Adams et al. 1985).

PLT and WILD were adopted by sponsoring agencies in Texas in 1985 and essentially rely on volunteers at the facilitator and educator level. Over 4,000 people have gone through PLT training and 145 have participated in facilitator training. Of the trained facilitators, less than 50 percent are considered active (M. J. Walterscheidt personal communication: 1991). Over 18,000 teachers have participated in WILD training workshops; 360 people have become trained facilitators, but only 230 are currently on the active list (I. Hiller personal communication: 1991).

The purpose of this study was to determine if there were measurable characteristics that distinguish "active" and "inactive" facilitators and educators. "Actives" had conducted at least one training workshop or used PLT/WILD materials in the classroom. The results of this study may help national and state directors of EE programs better identify the type of individuals to select as volunteer facilitators and educators.

Methods

This study examined differences between active and inactive facilitators and educators in: (1) educational background; (2) environmental attitude and action; (3) personal values; (4) commitment; and (5) situational variables. One hundred and sixty-four PLT and 191 WILD facilitators, and 400 PLT and 600 WILD educators were sent a self-administered questionnaire.

Respondents reported the approximate number of credit hours taken in selected academic fields. Environmental attitudes and actions were examined with modified versions of the Environmental Concern Scale (Weigel and Weigel 1978) and the Actual Commitment section of the Ecology Scale (Maloney et al. 1975). Questions on the environmental attitude scale were rated from 1 (least) to 5 (most environmentally concerned). Each positive environmental action received a score of 1, and no action received a 0.

Personal values were tested with portions of the Values Scale (Nevill and Super 1986) for ability utilization, achievement, altruism, autonomy, creativity and social interaction. Each value was represented by 5 statements rated using a 4-choice Likert scale (4 being very important). Responses to the statements for each personal value were summed.

Commitment to PLT and WILD was examined using statements proposed by Knoke (1981) and by ranking reasons for attending a training workshop. Commitment and importance of reasons for attending a workshop were measured with a 5-point Likert scale (5 representing "very important").

Situational variables were examined by ranking possible barriers to activity. Respondents ranked the top three reasons why they would not conduct a workshop or why they had not used the materials after training. The most important reason was given a 3; those not ranked were given a 0.

This study examined whether active facilitators and educators would have: (1) more educational background in the life sciences than inactive facilitators or educators; (2) higher environmental attitude and action scores than inactives; (3) higher personal value scores than inactives; and (4) higher commitment scores than inactives. Student's *t*-tests, contingency table analysis or analysis of variance (ANOVA) were used where appropriate to test hypotheses.

Results

The adjusted response rate was 114 (79 percent) for PLT facilitators, 225 (64 percent) for PLT educators, 147 (79 percent) for WILD facilitators and 332 (65 percent) for WILD educators. Sixty-six percent ($n = 181$) and 73 percent ($n = 259$) of the responding facilitators and educators, respectively, were active.

Overall, facilitators had more background in education and life sciences than in other academic areas. Life science hours were significantly higher ($p = 0.016$) and education hours were significantly lower ($p = 0.047$) in active versus inactive facilitators (Figure 1a).

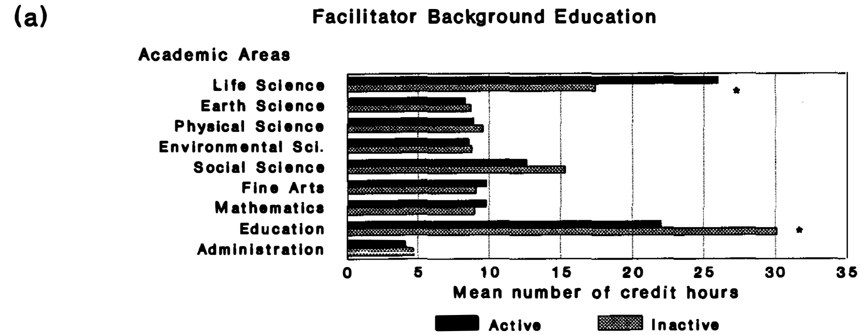
Educators had a higher average number of education hours than any other academic area (Figure 1b). Active educators had more credit hours in all academic areas than inactives; however, significant differences occurred only in education ($p < 0.02$) and earth science ($p < 0.001$) hours.

The average total environmental attitude score for active and inactive facilitators was 62.6 out of 75. Total environmental action scores (range = 0 to 10) for active and inactive facilitators were 7.6 and 7.2, respectively. The differences were not significant for either attitude ($p > 0.94$) or action scores ($p > 0.25$).

The mean environmental attitude score for active educators was 62.0 compared to 58.4 for inactives. The mean environmental action scores (range = 0 to 10) for active and inactives were 6.6 and 4.8, respectively. Differences were significant ($p < 0.001$) for both attitude and action scores.

Respondents rated all personal values as important (figures 2a and 2b). No significant differences occurred. However, differences in altruism and creativity between active and inactive educators approached significance ($p < 0.06$ and $p < 0.09$, respectively).

Commitment-oriented responses concerning levels of communication and interaction were significantly ($p < 0.05$) different between active and inactive facilitators (Table 1). Although active facilitators' scores were higher than inactives on their perceived influence on workshop format and contact with other facilitators, their scores were still low.



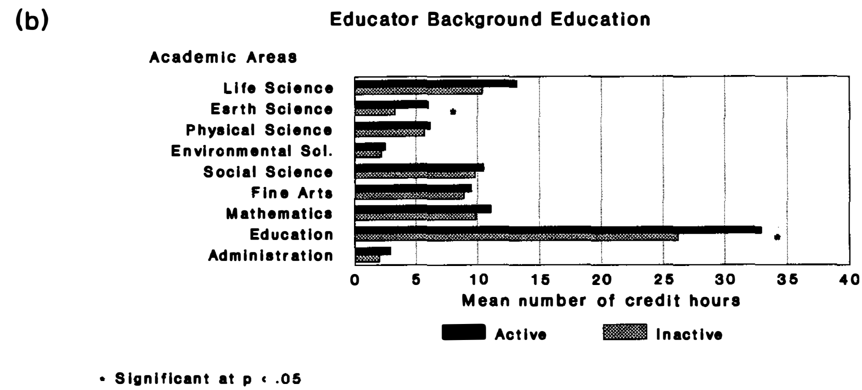


Figure 1. Mean number of academic credits of Project Learning Tree and Project WILD facilitators (a) and educators (b).

Active and inactive educators had significant ($p < 0.05$) differences on four of five statements (Table 1). Although actives scored higher than inactives, actives were generally in the middle range, indicating they were not sure of sufficient communication or support.

The two most important reasons for attending facilitator training were a professional interest in the environment and to have access to PLT or WILD materials in order to share them with others. The least important reason was career advancement or Advanced Academic Training credit (Table 2). No significant differences occurred between active and inactive facilitators.

The most important reasons for educators to attend a training workshop were an interest in environmental issues and to receive additional natural resource materials. The least important reason was being required to attend. There were significant differences ($p < 0.01$) between active and inactive educators on seven reasons (Table 2).

The most important reason for not conducting a training workshop for active and inactive facilitators was a lack of time (Table 3). Active facilitators also ranked the

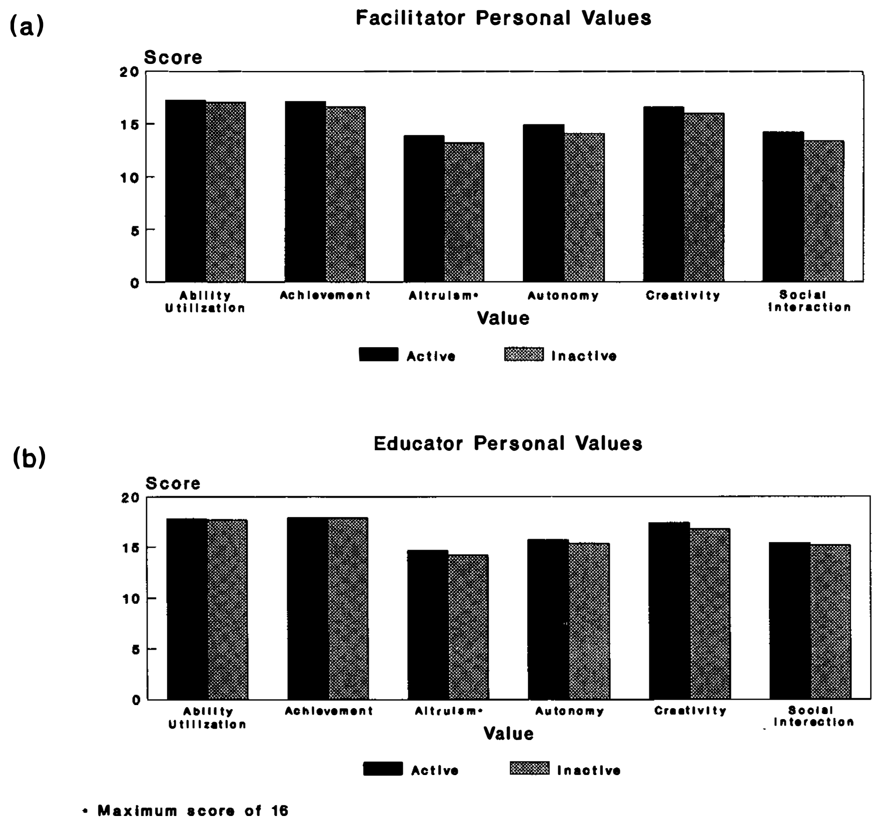


Figure 2. Personal value scores for Project Learning Tree and Project WILD facilitators (a) and educators (b).

availability of people to participate as an important reason for not conducting workshops (Table 3).

The most important reason educators had not used activities was a lack of time to fit them into the curriculum. The second reason differed according to which measure of importance was evaluated with time to plan activities being more important by raw score and not being in a teaching situation by mean score (Table 4).

Discussion

The success of PLT, WILD and other EE programs is grounded in the continued involvement and support of volunteers as facilitators or educators. Organizations can save personnel time and money through active volunteer programs. However, to get the greatest benefit from a volunteer program and to keep satisfied volunteers, organizations need to identify potentially active volunteers and retain them.

Table 1. Project Learning Tree and Project WILD facilitator and educator scores on commitment questions. Scores range from 1 (least) to 5 (most commitment).

Question	Facilitators			Educators		
	Active		Inactive	Active		Inactive
Role in the way workshops are run in Texas	3.51	*	3.21			
Importance in leading workshops	4.27	*	3.95			
Play an important part in PLT/WILD	4.31	*	3.99			
Enough information state director	4.22	*	3.83	3.38		3.25
Enough support from state director	4.31	*	3.87	3.42	*	3.08
Contacts with others to discuss ideas	3.34	*	2.74	3.13	*	2.61
Strong commitment to PLT/WILD	4.09	*	3.50	3.82	*	2.88
Support of administration				3.74	*	2.98

*Significant at $p \leq 0.05$.

Volunteer values were important to both active and inactive facilitators and educators. Participation in PLT or WILD workshops already indicated volunteerism, unless they were required to attend. This study reinforces the multi-dimensional motivation of volunteers through achievement, altruism and different reasons for attending training workshops (King 1984). Reasons for attending training workshops agreed with Knoke and Prensky (1984) that similar goals and interests (i.e., interest in the environment) were important motivators for involvement.

Table 2. Project Learning Tree and Project WILD participants' reasons for attending training workshops. Scores range from 1 (least) to 5 (most important).

Reason	Facilitators		Educators		
	Active	Inactive	Active		Inactive
Receive additional materials	4.04	4.27	4.49	*	3.62
Career advancement or Advanced Academic Training credit	2.27	2.39	3.31		3.41
Interest in environmental issues	4.64	4.54	4.53	*	3.99
Job responsibilities/mandatory attendance	3.19	2.97	1.68	*	2.54
Access to materials to share them with others	4.35	4.15			
Show how environmental materials could be integrated into non-science areas	4.09	4.13			
Interest in science education	4.32	4.19			
Recommendation from colleague			3.37	*	2.65
Lack of training in environmental education			3.62	*	3.24
Meet new curriculum objectives			3.58	*	2.92
Personal advancement			3.94	*	3.61

*$p < 0.05$

Table 3. Reasons Project Learning Tree and Project WILD facilitators have not, or would not, conduct training workshops. Scores are totals of ratings.

	Scores	
Reasons	Actives	Inactives
Time to plan a workshop	270	138
Time to conduct a workshop	251	140
Availability of participants for workshops	232	79
Support from the state director	12	2
Support from administrators or supervisors	75	50
Money for materials	67	12
Change of job		85
Recently trained		45

Interest in the environment was reinforced by high environmental attitude and action scores. All facilitators scored high in environmental concern and environmental action. Active educators scored higher than inactive educators but were still slightly lower than facilitators in both areas. Apparently, an active facilitator can be identified by a higher interest and involvement in the environment.

Even if educators have favorable attitudes toward the environment, they may not have the skills or knowledge to teach about it (Johnson 1980, Adams et al. 1988, Zosel 1988). Many non-science educators perceive EE as science-related, and our respondents did use the materials most in life and earth science classes. This finding agreed with a national and Ohio study in which most respondents used WILD in the science area (Cantrell 1987, Natl WILD Survey of Use 1990). This prevailing attitude may make non-science educators uncomfortable teaching about the environment through PLT and WILD activities.

A background in science can increase teacher use of EE materials (Bandelier 1967). Active facilitators had significantly more background in life science and active ed-

Table 4. Reasons educators have not used Project Learning Tree or Project WILD materials after the training workshop. Scores are totals of ratings.

Reason	Score	Mean
Time to fit activities into curriculum	376	0.90
Time to plan activities	212	0.52
Materials are not appropriate for subjects currently teaching	140	0.49
Training is not adequate preparation to use materials	34	0.12
Not enough materials or money	75	0.17
Class size is too large	68	0.13
Lack knowledge to teach environmental materials	53	0.18
Job has changed	162	0.46
PLT or WILD does not express the proper way to address environmental issues	4	0.02
Not currently in a teaching situation	186	0.81

ucators had significantly more in earth science than inactives. However, activities were used by less than half of the educators in physical sciences. This indicated that life and/or earth science training, not science in general, was an important indicator of active facilitators and educators. In-service training may need to include activities that help alleviate the volunteer's feeling of inadequacy toward teaching science-related materials and increase voluntary use of EE materials.

Facilitators, as a whole, were motivated by altruism (e.g., helping others or sharing materials) and rated personal development as least important. Comparatively, educators participated because of a personal interest in new activity ideas and personal advancement. These results correspond to a previous study by Zosel (1988).

Voluntary participation in an organization positively affects use of the EE program (Cantrell 1987, Zosel 1988). Although inactive educators rated the importance of mandatory attendance significantly higher than actives, this reason was given a low overall rating (Table 2). Required attendance did not discriminate between active and inactive facilitators.

Active facilitators felt they were an important part of PLT/WILD, and were getting support and information from the state directors. They were less certain about their role in the decision-making process concerning conduct of workshops or having contact with other facilitators. However, as long as the communication and support are adequate, the facilitator's role in the decision-making process becomes less important (Knoke 1981, Rodriguez 1984). Increasing opportunities to interact with other facilitators needs to be considered (Rodriguez 1984). Lower scores on communication, support and interaction may not indicate a causal relationship with inactive facilitators. However, it may be a contributing factor to inactivity. The majority of facilitators ($n = 176$) wanted follow-up training indicating that both actives and inactives desired more information and reinforcement.

All educators were either not sure of or disagreed with adequate communication, support and a general commitment to the programs. Cantrell (1991) also found that educators wanted more reinforcement and training. These results indicated that on-going communication and support are important considerations in a volunteer program. Cantrell (1987) and Zosel (1988) disagreed on the effect of administrative support in EE implementation. In this study, the value of administrative support was uncertain (Table 1).

Time was the most important reason for not conducting a workshop or using the materials (tables 3 and 4). Active facilitators also reported that the lack of interested participants was an important reason for not conducting workshops. If facilitators have been giving workshops, it may become more difficult for them to find interested educators, which increases time constraints.

Lack of a teaching situation was the second most important reason preventing use of activities for some educators. Lack of opportunity in their job was a major reason educators had not used WILD materials in Ohio (Cantrell 1986, 1991). A change of job position or job responsibilities can be a major contributor to drop-out of volunteers in EE programs.

In summary, EE programs which use volunteers as part of their implementation system need to recruit people who have high achievement and altruistic values, identify with program goals, and have a high interest in and concern for the environment. However, these characteristics may not be enough; proper training is essential (Zosel 1988). Training should stress that EE is not just science-related but that it is multidisciplinary.

Volunteer retention will require high levels of communication and support from paid staff, opportunities for interaction between volunteers, and follow-up training or advanced mini-workshops. Directors of EE programs may have to examine their communication and training network. Finally, if program directors have other administrative responsibilities, communication with facilitators and teachers may suffer. Sponsoring organizations will need to examine the possibility of hiring full-time state directors in order for these EE programs to sustain volunteer involvement.

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References

Adams, C. E., C. Charles, J. Greene, and M. Swan. 1985. New designs in conservation/ecology education. Am. Biol. Teach. 47:463–469.

Adams, C. E., R. A. Stone, and J. K. Thomas. 1988. Conservation education within information and education divisions of state natural resource agencies. Wildl. Soc. Bull. 16:329–333.

Allen, N. J. 1987. The role of social and organizational factors in the evaluation of volunteer programs. Eval. and Prog. Plan. 10:257–262.

Athey, T. R. 1987. The dynamics of volunteer participation in futures research. Futures. April:168–183.

Bandelier, K. J. 1967. Community resources in teaching secondary biological concepts in Indiana. Ph.D. dissertation, Univ. Montana. Diss. Abs. Internatl. 28:1,724.

Cantrell, D.C. 1986. A statewide survey of Project WILD in Ohio. Ohio Dept. Education, Division of Inservice Education, Columbus. 16 pp.

———. 1987. A case study analysis of curriculum implementation as exemplified by Project WILD in one midwestern state. Abstract, Ph.D. dissertation, Ohio St. Univ. 430 pp.

———. 1991. A longitudinal study of the implementation of Project WILD. A presentation at annual meeting of the North American Association for Environmental Education. St. Paul, Minnesota.

Guyatt, D. E. 1974. The volunteer centre. Ministry of Community and Social Services, Toronto. 150 pp.

Hart, E. P. 1981. Identification of key characteristics of environmental education. J. Environ. Educ. 13(1):12–16.

Hirschman, A. O. 1970. Exit, voice, and loyalty. Cambridge: Harvard Univ. Press, Boston. 230 pp.

Johnson, W. D. 1980. Teachers' perceptions and circumstances that influence willingness to teach environmental studies. Univ. Illinois, Urbana-Champaign. Diss. Abs. 41(2):616–A.

King, A. E. 1984. Volunteer participation: An analysis of the reasons people give for volunteering. Diss. Abs. Internatl. 45(5):1,528–A.

Knoke, D. 1981. Commitment and detachment in voluntary associations. Am. Soci. Rev. 46:141–158.

Knoke, D. and D. Prensky. 1984. What relevance do organization theories have for voluntary organizations? Soci. Sci. Qtr. 65(1):3–20.

Maloney, M. P., M. P. Ward, and G. N. Braucht. 1975. Psychology in action: A revised scale for the measurement of ecological attitudes and knowledge. Am. Psyc. 7:787–790.

National Project WILD Survey of Use. 1990. Preliminary results. Project WILD. Boulder, Colorado. 8 pp.

Nevill, D. D. and D. E. Super. 1986. The Values Scale: Theory application, and research. Consulting Psychologists Press, Palo Alto, CA. 54 pp.

Pierucci, J. and R. C. Noel. 1980. Duration of participation of correctional volunteers as a function of personal and situational variables. J. Comm. Psyc. 8:245–250.

Reddy, R. and D. Smith. 1972. Personality and capacity determinants of individual participation in organized voluntary action. *In* D. Smith, R. Reddy, and B. Baldwin, eds., Voluntary Action Research. Lexington Books, Lexington, MA.

Rodriguez, M. C. 1984. A study and analysis of the variables determining the retention behavior of volunteers. Diss. Abs. Internatl. 44(11):3516–A.

Rohs, F. R. 1986. Social background, personality, and attitudinal factors influencing the decision to volunteer and level of involvement among adult 4-H leaders. J. Vol. Action Res. 15(1):87–99.

Smith, D. H. and R. D. Reddy. 1973. The impact of voluntary action upon the volunteer/participant. *In* D. H. Smith, ed., Voluntary Action Research. Heath, Lexington, MA.

Weigel, R., and J. Weigel. 1978. Environmental concern: The development of a measure. Envir. and Behav. 10(1):3–15.

Zosel, D. 1988. Teacher use of Project WILD. M.S. thesis, Univ. Wisconsin, Madison. 144 pp.

New York's Sportfishing and Aquatic Resources Education Program: What We've Learned About Working with Volunteers

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Introduction

Wildlife and natural resources management agencies wishing to conduct educational programs have a number of options available to them, including using agency staff to develop and deliver the programs, and working through existing networks of schools or informal education programs, such as 4-H, scouts and nature centers. There are several aspects of 4-H that make it particularly attractive to those wishing to conduct youth natural resources education programs. Perhaps most important, 4-H has a well-established tradition of using trained volunteer leaders to carry out educational programs with youths. Nationwide, there are approximately 1.25 million 4-H volunteer leaders working with over 20 million youths in 4-H clubs, camps, conservation field days and other settings. It is relatively easy to reach these volunteers with new materials through the network of professional youth educators, i.e., 4-H agents, in over 3,000 counties across the United States. In addition, 4-H educational materials are developed by highly-trained educators and scientists at land-grant universities in each of the 50 states. Finally, 4-H has proven its ability to conduct youth natural resources education programs, including shooting sports and national wildlife habitat and forestry contests. It was primarily for these reasons that the Chief of the

Bureau of Fisheries at the New York State Department of Environmental Conservation (DEC) chose the Cornell Cooperative Extension 4-H Program to carry out New York's Wallop-Breaux sportfishing education program.

In 1988, DEC entered into a cooperative agreement with Cornell Cooperative Extension to develop the New York State Sportfishing and Aquatic Resources Education Program (SAREP). The overall goal of SAREP is to use adults' and youths' interest in fishing to involve them in a program through which they: (1) learn about fishery management, biology and ecology; (2) develop an understanding of New York's aquatic resources and threats to those resources; (3) develop a sense of stewardship toward our aquatic resources; and (4) improve their angling skills. This goal was to be accomplished by training adult volunteers to conduct in-depth educational programs with youths, focusing on fishing, angling ethics, and aquatic sampling and ecology. The adult leaders would be active anglers recruited through sportsmen's organizations from throughout New York State and would be supported in their volunteer activities by their local county 4-H agent.

The purpose of this paper is first to briefly describe SAREP and then to present the results of evaluations of various components of the program. The implications of the results of these evaluations for natural resources education programs using volunteers also will be discussed.

New York's Sportfishing and Aquatic Resources Education Program

The major components of SAREP are: volunteer instructor certification trainings; volunteer recruitment and support; the SAREP Leaders' and Members' Manuals; and youth education programs. Each of these is described below.

Volunteer Trainings

Starting in 1989, we have conducted four to six regional trainings annually for volunteer instructors. The trainings run from Friday evening until Sunday afternoon, and cover such topics as angling ethics, aquatic sampling and ecology, working with youths, and organizing SAREP youth programs. There is no formal fishing skills instruction because most of the participants already are skilled anglers, although much sharing of techniques occurs informally. At the end of the training, participants are required to conduct a short lesson on some aspect of sportfishing, aquatic ecology or angling ethics. They are then certified as SAREP Instructors.

Volunteer Recruitment and Support

During the first two years of the program, volunteers were recruited primarily through letters explaining the program to county 4-H agents and sportsmen's clubs, and through news releases to outdoor writers. Starting in 1991, we expanded our recruiting strategy to include letters and newsletters to scouts, nature centers, camps, recreation centers, and boys and girls clubs.

County 4-H agents provide support for SAREP instructors in a number of ways, including organizing meetings of instructors in their county, helping instructors recruit youth and organize 4-H clubs, and providing recognition and awards. The Cornell SAREP staff also have supported the instructors through a quarterly newsletter, inviting existing instructors to attend additional trainings, conducting instructors skills weekends (e.g, an ice-fishing workshop), and being available to answer questions, provide educational resources and discuss problems as they arise.

SAREP Leaders' and Members' Manuals

The core of SAREP Leaders' Manual is 20 separately bound activity chapters focusing on specific fishing trips, e.g., pond, stream, salt water and ice fishing, or on activities such as rod building and developing public presentations on fishing and aquatic resources. Incorporated into each of the fishing trip chapters are one or more aquatic sampling activities, such as measuring water temperature or using a D-net, and informational sheets describing important concepts, such as acid rain or wave action. The Leaders' Manual also includes an introductory chapter and supplemental materials, such as guides to fish, aquatic invertebrates and plants, and bulletins on fish contaminants. The Members' Manual includes a short introduction to each activity in the Leaders' Manual, record sheets for youth to record what they learn during the activities, and pictures of common fish and aquatic invertebrates.

Youth Education Programs

SAREP emphasizes long-term, in-depth educational programs, rather than short-term exposure. Initially, our expectations were that, at a minimum, certified instructors would work with youth in a 4-H sportfishing club, conducting 12 activities from the SAREP Manual over a period of one year. In addition to running their SAREP club, we encouraged instructors to conduct shorter-term educational activities, including giving fishing lessons to youths participating in other (non-SAREP) 4-H clubs, giving presentations in schools and organizing fishing derbies.

Evaluation Methods

The evaluations have focused on volunteer instructor follow-through with activities for youth and reasons for volunteering. We have conducted formal written and phone surveys, as well as made a number of observations during trainings and through discussions with 4-H agents and volunteer instructors. The methods for the various evaluations are described below.

Follow-through with Activities for Youth

In spring 1991, a written survey was developed to determine the extent and nature of SAREP activities with youths on the part of all instructors trained during 1989 and 1990. Question wording, format and order were based on survey research theory and successful research applications (Dillman 1978, Brown et al. 1989). The survey was pre-tested with a small group of volunteer instructors. The questionnaire implementation plan (i.e., cover letter content, timing of second and third mailings) was based on Dillman's (1978) total design method. The survey included questions about whether the instructor followed-up with activities for youths, the types of activities conducted, the number and demographics of youths reached through a variety of activities, intentions for continued involvement with SAREP, the reasons for not following-up, and satisfaction and frustrations experienced through involvement with SAREP.

The survey was sent to a list of 170 individuals who records show attended SAREP trainings during 1989 and 1990. A total of 12 surveys were returned indicating the individual had moved and left no forwarding address or had not actually attended the training. In addition, seven of the individuals were members of couples who worked together with one group of youth, and five attended the trainings as representatives from DEC. Therefore, the actual number of potential respondents to the survey was 146. Ninety-nine instructors responded to the written survey for a 70-percent adjusted response rate. All non-respondents who were reachable by phone were contacted through a phone survey which included questions about whether or not the individual followed-up and how many youth he or she reached through a SAREP club and other delivery methods. A total of 132 instructors responded to the written or telephone follow-up survey.

During the winter of 1992, a phone survey was designed following the methods of Dillman (1978) to determine the follow-through activities of the SAREP instructors certified during 1991. The survey included questions about whether the individual followed-up with activities for youth, the types of activities conducted, intentions for continued involvement with SAREP and satisfaction gained through involvement with SAREP. We were able to reach 56 of the total 78 new instructors, for a response rate of 72 percent.

In addition to the actual surveys of volunteer instructors, we had information about the 1990 (n = 72) and 1991 (n = 78) instructors collected as part of the application process. This information included occupation, extent of volunteer activities with youth, involvement in sportsmen's clubs and fishing experience.

Reasons for Volunteering

This assessment consisted of two separate surveys. The first survey was directed at a stratified random sample of 80 individuals selected from current volunteers on mailing lists for county 4-H Natural Resources programs in New York, and was conducted using a phone interview. The second survey, using a written questionnaire, was directed at a stratified random sample of 499 individuals who were members of the Southtowns, New York, Walleye Association. All 80 individuals were reached via the pone survey, whereas the response rate to the written survey was 35.5 percent. Both surveys asked respondents about the nature and extent of their volunteer activities and the reasons for volunteering. More details about this study can be found in Greene and Applebee (1991).

Evaluation Results and Implications

Recruitment and Support of Volunteer Leaders

Our original recruitment plan focused heavily on sportsmen's groups. However, we experienced difficulty in garnering the support of the organized sportsmen's community in New York State. Although recruitment materials were sent to the state and regional contacts for sportsmen's organizations, when asked how they heard about SAREP at the trainings, only 3 percent of the volunteers indicated organized sportsmen's groups as opposed to 36 percent indicating Cooperative Extension sources and 30 percent indicating outdoor press. In addition, when asked to rate the support for their activities that various groups had offered, volunteers rated sportsmen's groups lower than any other group (2.7 on a scale of 1–4, with 4 being excellent support; approximately 40 percent of our volunteer leaders are members of sportsmen's groups). Part of this lack of support can be attributed to organizational problems the sportsmen's groups in New York have been facing over the past several years. However, it is possible that even in the absence of these problems, recruiting through sportsmen's groups would not have been the best strategy.

The results of the reasons for volunteering study shed some light on the differences between 4-H volunteers active in natural resources programs and sportsmen participating in a local walleye association. Only 15 percent of the sportsmen indicated that they were volunteering with youths; their volunteer activities included youth sports, taking youngsters fishing and conducting hunter/trapper training courses. Twenty percent of the sportsmen indicated that they volunteer with groups other than youth, including civic groups (e.g., Kiwanis) and church. In contrast, 65 percent of the 4-H volunteers serve as volunteers for other groups (45 percent with other community organizations, 9 percent with church groups and 8 percent with other youth organizations). The primary reasons the 4-H leaders cited for volunteering were commitment to the 4-H program (51 percent) and commitment to the natural resources subject area (48 percent). These results are supported by a nationwide study showing the importance of the personal and social development aspects of volunteer work to 4-H volunteer leaders. When asked how they benefited from their involvement with 4-H, 88 percent of the volunteers responded they gained satisfaction from helping others, 79 percent from making new friends, 76 percent from increased self-worth and 75 percent from working with people. In contrast, 66 percent benefited from using their talents, 60 percent from gaining useful knowledge and 36 percent from continuing their education, responses that may indicate interest in a particular subject matter (University of Wisconsin 1986).

What emerges from these studies is a picture of a "4-H volunteer type." This individual volunteers for a number of activities and is more committed to 4-H and personal and youth development than to a particular subject matter, such as natural resources. Our problem in garnering the support of organized sportsmen's groups may be that sportsmen are not, as a general rule, the "4-H volunteer type." Their involvement with a sportsmen's group would indicate that their primary interest is in fishing or hunting, and the fishery or wildlife resource, and while they may see the importance of passing that interest on to young people, they may not have a desire to actually work with youth themselves.

In light of these findings, we expanded our recruiting strategy during the third year of SAREP to include more people who already volunteer with youths or whose jobs entail working with youth. Because most of these people enjoy youth work, and because SAREP would fit into their on-going volunteer and work activities, we hypothesized they would be less likely not to follow-up due to lack of time, or to not being able to find other volunteers or interested youths. The groups we targeted included scout leaders and youth professionals working at boys and girls clubs, camps, recreation centers and nature centers.

Follow-up by Certified SAREP Instructors

As of spring 1991, 73 percent of the instructors trained during 1989 and 1990 had followed-up with SAREP programs for youth in their communities and 27 percent had not. Of the individuals who did follow-up, 85 percent were still actively engaged in SAREP programs at the time of the survey and 71 percent of those currently active planned to continue with SAREP for more than two years. The greatest benefits of their follow-up activities with youths generally had something to do with sharing knowledge with kids. For example, one volunteer wrote, "observing wonderment on the faces of youth after learning something new."

The primary reasons for not following-up included not enough time (44 percent of volunteers who did not follow-up), personal problems (e.g., illness, 17 percent), could not find other volunteers to work with (11 percent), could not find interested kids (11 percent) and did not get enough support from county 4-H agent (8 percent). A few responses had to do with feeling unable to organize a club. However, a number of those who were interested in teaching sportfishing to kids, but not in organizing a 4-H sportfishing club, worked in conjunction with existing 4-H clubs, classrooms or other youth education programs where they did not have to assume responsibility for organization.

About half of those who did not follow-up indicated an interest in continuing with the SAREP program when they had more time or overcame personal problems, or in a limited capacity (e.g., as a helper but not an organizer). A quarter would be interested in becoming involved if their 4-H agent or a fellow instructor were to give them a call and offer to help. Only about one-quarter of those who did not follow-up after the training were no longer interested in any involvement in SAREP.

Compared to instructors certified in 1989–90, a much higher percentage of the instructors certified during 1991 followed-up with programs for youth. Eighty-two percent of the 1991 instructors had followed-up and another 14 percent planned to (the survey was conducted in the winter and half of the instructors had just been certified the previous fall), leaving only 4 percent with no plans for following-through. Of those who followed-up after the trainings, 93 percent intended to continue their involvement in SAREP for two or more years.

Why did more instructors trained in the third year follow-up than did instructors trained in the first two years of the program? We have several hypotheses to explain this difference, all of which directly relate to the reasons cited by volunteers for not following-up. These hypotheses include improved support from fellow instructors and 4-H agents, recruiting instructors whose SAREP activities fit into their on-going volunteer and work activities, and allowing more flexibility in commitment following the training. Although we currently do not have the data to directly prove or disprove these hypotheses, we have some ancillary evidence. Additionally, we present these possibilities as interesting areas of inquiry for further research.

Possibly the most critical factor influencing instructors trained during the third year to follow-through with youth programs was the fact that there were existing active instructors with whom they were able to interact. These existing instructors served as role models and informal mentors, as well as demonstrated enthusiasm for SAREP and provided a sense of community for the new instructors. Many of the existing instructors actually attended the later trainings, providing "living proof" that it was not only possible to conduct SAREP programs with youths, but that conducting these programs was fun and rewarding. Other new instructors had contact with existing instructors in their communities prior to or after the trainings, sometimes cooperating with them in conducting the youth programs.

Similar to the support of fellow instructors, the support of the 4-H agent is essential for volunteers carrying out activities with youth. In general, volunteers from the first two years who followed-through rated highly the support they received from 4-H agents (3.2 on a scale of 1–4, with 4 being excellent support). In several counties where the agent did not show an interest in SAREP, there was very poor follow-through on the part of the instructors. The improved follow-up during the third year may be due in part to the increasing support of 4-H agents over the past several years, as SAREP has demonstrated its success and become a more established and accepted program in the 4-H system in New York.

A third possible explanation for the increased follow-up is that, during 1991, we recruited individuals with more interest and experience in working with youth. In 1990, approximately 90 percent of the new instructors attending the trainings had experience working or volunteering with youth compared to 95 percent in 1991. There was a larger increase in the percent of instructors whose jobs involved working with youth between 1990 (18 percent) and 1991 (35 percent). In addition to the possibility of higher follow-up rates among individuals with youth experience, having such individuals present could have resulted in a more positive attitude towards conducting youth programs at the trainings. As mentioned above, there also were previously trained instructors at the 1991 trainings who had positive attitudes towards working with youth in SAREP programs.

A fourth important difference between the first two and third years of SAREP was that, during the third year, we defined our expectations for the instructors more clearly, both through literature the instructors saw prior to the training and through discussions at the trainings. We also were more realistic in our expectations, drawing on our two years of experience with instructors. In particular, although we still emphasized long-term, in-depth educational programs during the third year, we encouraged instructors to become involved through a number of channels, including shorter-term activities. This gave the instructors the opportunity to design their SAREP experience to fit their own needs, abilities, and on-going work and volunteer commitments.

Programs for Youth

SAREP instructors have worked with youth in a number of settings, including 4-H SAREP clubs (88 percent of the 1989–90 instructors and 42 percent of the 1991 instructors who followed-up); 4-H general interest clubs (28 percent and 17 percent for 1989–90 and 1991, respectively); after-school clubs (21 percent and 14 percent for 1989–90 and 1991, respectively); school classrooms (13 percent and 17 percent for 1989–90 and 1991, respectively); fishing derbies (36 percent and 10 percent for 1989–90 and 1991, respectively); conservation field days (17 percent and 0 percent 1989–90 and 1991, respectively); camps (35 percent and 8 percent for 1989–90 and 1991, respectively), scouts (5 percent and 17 percent for 1989–90 and 1991, respectively) and other (e.g., displays at county fair or National Hunting and Fishing Day events; 26 percent and 29 percent for 1989–90 and 1991, respectively). In light of the decrease in percentage of instructors trained during 1991 who have worked in SAREP 4-H clubs, it is important to ask whether the increased follow-up for the 1991 instructors has been accompanied by a decreased involvement with long-term, in-depth youth education programs. However, it is too early to determine whether this is the case for two reasons: (1) there was a very limited time period between the training and the survey for the 1991 instructors; and (2) the 1991 instructors showed an increase in school classroom, scout and other activities which also could have been long-term educational programs. Future evaluations will focus on the nature of the youth programs in various educational settings.

The total number of youth reached through the program during 1990 was estimated at 11,700, 92 percent of whom were Caucasian, 6 percent black and 2 percent other minority ethnic groups. Just over half (52 percent) of the youths were 9–12 years old, and another third (32 percent) were 12–18 years old. Eighty-one percent were male and 19 percent were female. In general, we are meeting or exceeding our original goals in terms of number of youths involved in the program. However, because of the near universal appeal of fishing among different ethnic groups, there is a potential for recruiting minorities into a program such as SAREP that we have not met. We currently are developing a plan to increase minority participation, through working with recreation centers in urban areas, and the 4-H staff in New York City and other major urban centers.

In addition to fishing, the instructors have incorporated stewardship (angling ethics) and science (aquatic ecology) education into their programs with youth. During 1990, an average of 43 percent of the time in SAREP youth programs was spent on sportfishing, 19 percent on angling ethics, 17 percent on aquatic sampling and ecology, 9 percent on public service, and 12 percent on other activities. Ninety-five percent of the instructors included angling ethics in their programs and 71 percent included aquatic sampling and ecology. Another 26 percent wanted to include aquatic ecology, but did not feel confident teaching this subject matter. Based on these results, the aquatic ecology component of the trainings was changed from an emphasis on aquatic invertebrate identification to more discussion of how instructors could get youths involved in having fun doing sampling activities without worrying about knowing the names of the organisms.

Preliminary results from a survey of youth involved in SAREP clubs indicate that not only are the SAREP youth engaged in a variety of fishing, stewardship and aquatic ecology activities in their clubs, they also are enjoying and learning from these activities. The instructors appear to have effectively transferred their knowledge and enthusiasm for our fishery resources to the youth with whom they are working.

Conclusions

What have we learned from our work with SAREP over the past three years? Perhaps most importantly, we have learned that is is possible to successfully conduct a Wallop-Breaux education program, with an emphasis on in-depth involvement of youths and volunteer leaders, through a state's Cooperative Extension network of faculty and county 4-H agents. The program may include an array of educational activities, including fishing, angling ethics, and aquatic sampling and ecology. Building support for such a program among networks of volunteer leaders (e.g., 4-H, scouts, churches) and professional educators (e.g., nature centers, camps) is just as important as working through networks of sportsmen's groups. In addition, provision must be made for building support for the program among the county Cooperative Extension associations; this will be a particular challenge as the number of SAREP instructors increases and the financial situation for county extension programs deteriorates. We also learned that incorporating a diversity of volunteers into our program requires being flexible in the commitment we ask of them. Therefore, even though we and our DEC cooperators are committed to our goal of providing in-depth educational experiences for youth, we welcome volunteers who choose to conduct a variety of youth educational activities.

References

Brown, T. L., D. J. Decker, and N. A. Connelly. 1989. Response to mail surveys on resource-based recreation topics: A behavioral model and an empirical analysis. Leisure Sci. 11:99–110.

Dillman, D. A. 1978. Mail and telephone surveys. John Wiley & Sons, Inc., New York. 325 pp.

Greene, H. D. and G. J. Applebee. 1991. Volunteer needs assessment data analysis project. Cornell Cooperative Extension, Sea Grant Program. Youth Education. 6 pp.

University of Wisconsin—Madison. 1986. Volunteers and extension agents: Partners in action. Phase II: summary of 4-H volunteer responses. Cooperative Extension, Univ. Wisconsin, Madison. 21 pp.

What Teachers Want from Agencies

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Introduction

Teachers attending wildlife conservation/ecology workshops were asked to list types of assistance they wanted from their state wildlife conservation agencies. The workshops were held at the Granite Creek Ranch facilities of the Safari Club International's American Wilderness Leadership School during July and August 1991. The ranch is located south of Jackson, Wyoming in the Bridger-Teton National Forest.

Most of the teachers attending the four 10-day sessions involved in the study were from throughout the United States (Table 1) and involved various grade levels (Table 2). A total of 142 educators participated in the study.

Methodology

During an evening meeting at each session, the participants were randomly divided into groups of five to six persons. Each group was asked to list four types of assistance they most desired from their state wildlife conservation agencies for their education programs. A recorder was selected by each group to list suggestions and then the final four were agreed upon. After 30 minutes, a spokesperson for each group presented their list to all the participants and the list was submitted to us. All the suggestions were regarded equally, as no priority was given to ranking or to any groups' list.

Results

From the lists submitted, 116 items were usable and were arranged into categories (Table 3).

The educators listed participation by agency personnel with classes as the most requested activity (39 percent of the items listed). Such participation was desired mainly for classrooms, with only 7 percent listing field trips. Written and verbal comments at the discussions emphasized a desire for hands-on types of activities in the classroom.

Providing educational materials received the next highest total of items (31 percent). The types of materials requested were:

1. biological specimens; furs, bones, skulls, feathers, etc. (28 percent of materials listed);

Table 1. Number of participants by state or country.

State or country	Number
Florida	22
Pennsylvania	21
Wisconsin	17
Michigan	11
Minnesota	8
Louisiana	7
Nebraska	6
Maryland	4
New Jersey	3
California	3
Illinois	3
Arizona	3
Georgia	3
Colorado	3
Washington	3
Texas	1–2
New York	1–2
Idaho	1–2
Wyoming	1–2
Missouri	1–2
Alabama	1–2
Canada	3–4
South Africa	3–4
Mexico	3–4

Table 2. Number of participants by grade level taught or educational role.

Grade level taught or role	Number
Elementary	45
Secondary	62
Administrators	11
College	6
Other	18
Total	142

Table 3. Teachers' requests, in percentage, for assistance from agencies (116 items).

Participation by agency personnel with classes	39 percent
Providing education materials	31 percent
Conducting workshops for teachers	10 percent
Assisting schools in establishing outdoor classrooms and nature areas	9 percent
Miscellaneous	11 percent

2. current lists of materials available, i.e., publications, speakers, sites for field trips, AV materials (28 percent).
3. other listings, including a variety of items, AV programs, posters, handouts, newsletters, etc. (44 percent).

Other requests by the educators were for conducting workshops for teachers (10 percent), and assisting schools with establishing outdoor classrooms and local nature areas (9 percent). The remaining suggestions included a variety of items, i.e., providing transportation, volunteer/intern programs for students, hunter safety courses, community awareness programs and career guidance.

Discussion

This small survey of teachers from across the country and from all grade levels provides insight as to what teachers want from agencies. Although the major request was for an agency person to visit their classes, this can be difficult on a regular basis due to limited personnel and time involved. However, our perception is that teachers desire such visits to give credibility to their own conservation education programs, and to provide an opportunity for both the teacher and students to learn from an "expert."

We feel such visits by professionals provide an excellent opportunity to bring the "real world" into the classroom and should be encouraged for most agency personnel, especially at the local level. State-wide or regional education staff persons cannot visit all schools, but our experience indicates that other agency personnel would like to work with schools and have much to share. However, they may be hesitant to become involved, as they wish to know more about how to work with schools and how to be effective in the classroom. Such training has not been a part of most professionals' education.

In-service training sessions for interested personnel can assist them with development and presentation of effective programs with classroom teachers. The establishment and coordination of such training would logically be the responsibility of education/information staff personnel. Effective programs to address this situation have been initiated by several agencies including the Wyoming Game and Fish Department and the Denver Regional Office of the U.S. Fish and Wildlife Service (Scientists in the School program).

Our study indicates that teachers want qualified agency personnel to assist them in their classrooms. Presentation by qualified personnel with good communication skills can be an effective means of increasing the awareness of both teachers and students about wildlife conservation and management. Teachers can then continue such programs using educational materials supplied.

Many agencies provide or support teacher training workshops, but our survey indicates that periodic visits to classrooms by conservation professionals may enhance the programs in our schools.

Effects of Wildlife Cartoons on Children's Perceptions of Wildlife and Their Use of Conservation Education Material

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Introduction

The public's primary contact with wildlife today is the media (More 1977, Pomerantz 1977, Pomerantz and Hair 1988, Kellert 1980, Kellert and Westervelt 1983). One form—comic material—enjoys a higher readership than any other print-oriented medium except the daily newspaper (Ball 1983), and cartoons are young children's favorite television programs (Lyle and Hoffman 1972, Liebert and Schwartzberg 1977, Forge and Phemister 1987, Huston et al. 1987). Conservation education organizations often incorporate wildlife cartoons to present ecological ideas and make messages more interesting. Using unrealistic human-like creatures, however, raises the question of whether learners develop humanistic and moralistic values of wildlife at the expense of ecological and/or utilitarian perspectives. The complexity of present and future resource management requires participation by citizens who have developed a balanced attitude toward resources. This study examined the effects of anthropomorphic wildlife cartoons on children's perceptions of wildlife and use of conservation education material. Through written surveys and oral interviews children's responses to two video presentations (photographs versus cartoons) were measured. Differences due to age, sex and past direct contact with wildlife were also compared, but are not addressed in this paper.

Findings apply strictly to children ages 7–9 and 12–14 years living in Michigan. However, because childhood experiences strongly influence adult attitudes and activities, as suggested by More (1977) and Pomerantz (1977), study implications may be applicable to other ages.

Methodology

This study, conducted in spring 1990, examined whether an anthropomorphic wildlife cartoon experience modified the physical, anthropomorphic and moral attributes ascribed to real animals by Michigan school children in two age groups (grades 1–3 and 6–8). Two age ranges were studied to assess whether developmental changes influence youngsters' responses to an anthropomorphic wildlife cartoon. Further, children between the ages of 7–9 years are exposed to more animated cartoons than any other age group (Lyle and Hoffman 1972, Liebert and Schwartzberg

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1977), and youngsters 12–14 years of age are the greatest consumers of comic books (Wright 1983).

An anthropomorphic wildlife cartoon *experience* refers here to the combination of visual and verbal information provided by an anthropomorphic cartoon with character dialogue. *Physical attributes* refer to the morphology, physiology, behavior and habitat needs of wild animals. *Anthropomorphic attributes* refer to any human characteristic given to animals—e.g., worrying, loneliness, long-term planning, hatred, etc. *Moral attributes* reflected the subject's perception of right and wrong treatment of an animal. Measures of moral attributes did not differentiate between animal rights and animal welfare perspectives.

Subjects (N=2,200: grades 1–3 = 838; grades 6–8 = 1,362) attended public or private schools in Michigan. All regions of the state were represented in the sample (e.g., northwest, southeast), including rural and urban areas of the lower and upper peninsulas. Subjects in each age group were randomly placed into six experimental groups involving various combinations of viewing a natural history video (NH) and a fantasy (F) video (Figure 1.). The NH video presented the habitat requirements of three unfamiliar species (pine marten, belted kingfisher and shrew). Unfamiliar species were selected based on the assumption that the impact of anthropomorphism decreases as familiarity with an object increases (Blanchard 1982). Although the NH message described several habitat needs and behaviors of each of these species, certain characteristics were emphasized because the F video presented variations of them: The marten is arboreal and solitary; the kingfisher is piscivorous and has a loud "rattling" call; and the shrew has a voracious appetite, always eating and

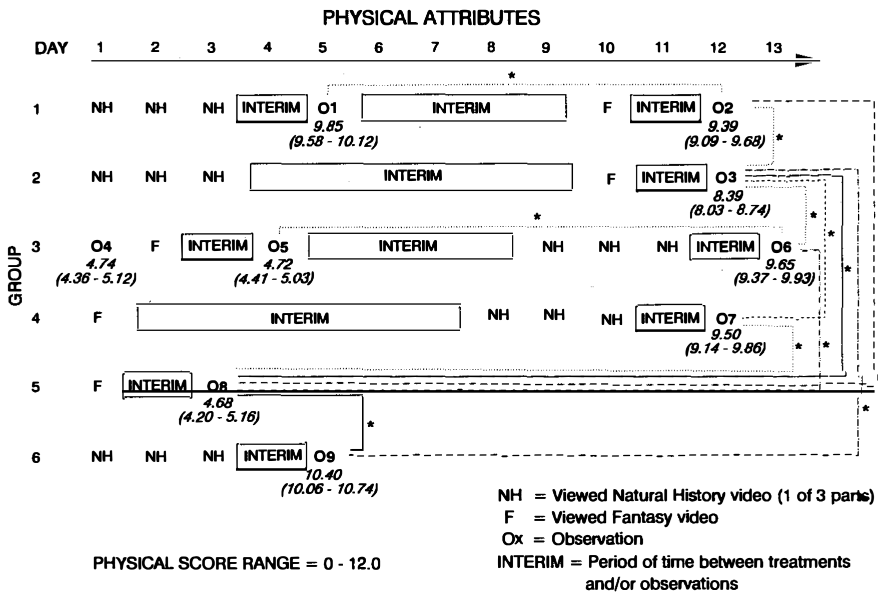

Figure 1. Research designs and results for the six grade 1–3 experimental groups. Higher Physical Attributes score means and confidence intervals (italicized) indicate greater number of correct responses. Line and asterisk between 2 means denote a significant difference (P≤0.05).

moving quickly. These animals were presented in a video format using actual still photographs.

The cartoon presentation introduced a message promoting environmental respect using a video format with still characters. Time and budget limitations prevented the use of animation; plus a simple still presentation would provide basic information on the impacts of anthropomorphism without the confounding effects of animation (i.e., movement). The grade 1–3 script focused on respecting others, their possessions and time, and the environment. The grade 6–8 script emphasized the impact human activities have on the environment through all their activities. Caricatures of the three species dialogued these messages. Max and Mindy represented martens; Kurt and Kerry symbolized kingfishers; and Stu and Sandy characterized shrews. Although these characters looked like their real-life counterparts, some of their natural characteristics were purposely distorted. For example, the shrews were depicted as being slow creatures with picky appetites, the martens were afraid of heights and desirous of friendships, and the kingfishers were soft-spoken, shy vegetarians.

Two close-ended surveys—NH and Cartoon—were developed to measure changes in subject perception of the physical, anthropomorphic and moral attributes of real wildlife. The questionnaires were identical except for a few items related to the accompanying video, e.g., the Cartoon Survey referred to the presented environmental message. Items assessing changes in subject perception of the physical attributes of wildlife asked about behavioral characteristics of the three species—e.g., if you saw a wild marten, would it be alone? Do shrews move slowly? The questions evaluating modifications in anthropomorphic tendencies referred to human-like characteristics in the three species—e.g., do you think a marten knows the difference between right and wrong? Do you think a shrew cares about how pretty it looks? Do you think a kingfisher makes plans for what it will be doing three weeks from now? The Moral Attributes items measured changes in subject concern for the humane treatment of animals by inquiring whether certain actions were "right" or "wrong"—e.g., is it right or wrong when someone keeps a shrew in a cage at home as a pet, when someone catches a marten in a trap and uses it fur for warm gloves, when someone kills a kingfisher to have it stuffed to show in a museum?. Each student received a Physical, Anthropomorphic and Moral Attributes composite score, and the mean scores for these three factors in each observation (O_x) were compared. All instruments underwent validity and reliability analyses. Both the surveys and videos were pilot-tested with 388 students in grades 1–3 and 6–8 in Michigan, and revised accordingly.

To explore further youngsters' cognitive processes related to their perceptions of cartoons, 210 of the subjects were personally interviewed. Questions evaluated whether subjects saw the cartoon characters as symbols of the real animals or simply characters in a story, their television cartoon consumption patterns (e.g., types of syndicated TV cartoons watched and favored), and subject perceptions of TV cartoons and their educational value.

Results and Discussion

Mean scores for the Physical, Anthropomorphic and Moral Attributes factors in each observation (O_x) were compared using a repeated measures t-test, t-test for independent groups, 1-way analysis of variance across six groups, and Tukey's test (figures 1–3). Only the grade 1–3 results are primarily presented here. Findings for the grade 6–8 students were similar except for the Moral Attributes factor, discussed subsequently.

Results showed that for both age groups, the anthropomorphic wildlife cartoon experience modified the children's ascription of physical attributes to real animals. Subjects were willing to accept the distorted physical characteristics of the cartooned wildlife as reality (inferred from comparisons O_8 versus O_9, O_1 versus O_2, O_3 versus O_9). Further, viewing the NH video containing accurate information failed to totally prevent or reverse the influence of the fantasy video (O_1 versus O_2, O_3 versus O_9). These findings contradict Wilson and Shaffer (1965), Snow (1974) and Dorr (1983) who proposed that children associate cartoon material or animation exclusively with fantasy, distortions of reality and caprice. Results agree with studies emphasizing the educational effectiveness of cartoons (e.g., Caldwell 1973, Kauffman and Dwyer 1974) because the children readily learned the content of the F presentation. Both age groups were also willing to accept the NH video information as reality (O_4 versus O_9). A "test effect" occurred, i.e., taking the test after watching the NH video reinforced its content (O_2 versus O_3). Thus, the students' perception of the physical attributes of the animals were less affected by the subsequent cartoon experience. An "order effect" also emerged; the last video presented had the greater effect on subject response (O_3 versus O_7).

Orthogonal contrasts for mean comparisons O_4 versus O_5 versus O_6 (−1, −1, +2) suggested that the physical attributes information in the NH video had a stronger impact on the children than the opposing material in the F educational experience.

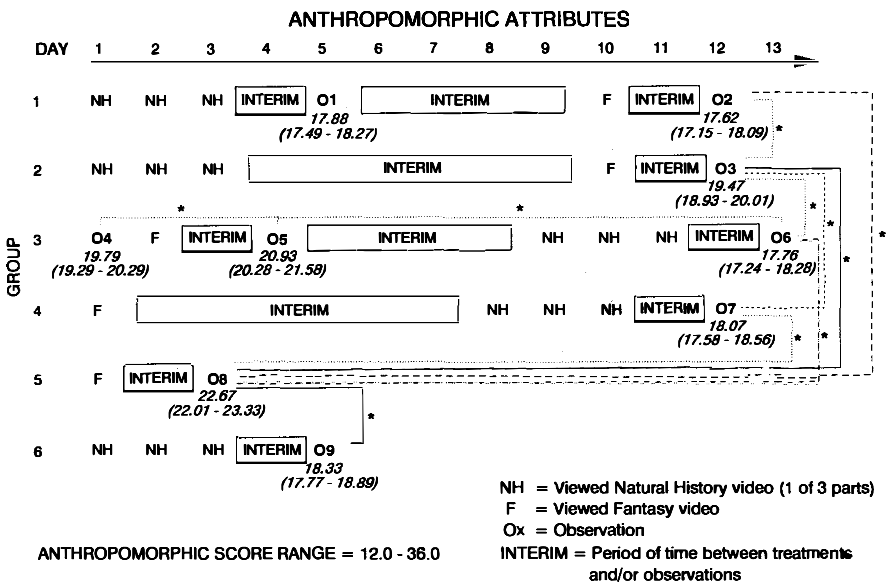

Figure 2. Anthropomorphic Attributes score means and confidence intervals (italicized) for the six grade 1–3 experimental groups. Higher means score indicated greater anthropomorphism. Line and asterisk between 2 means denote a significant difference (P≤0.05).

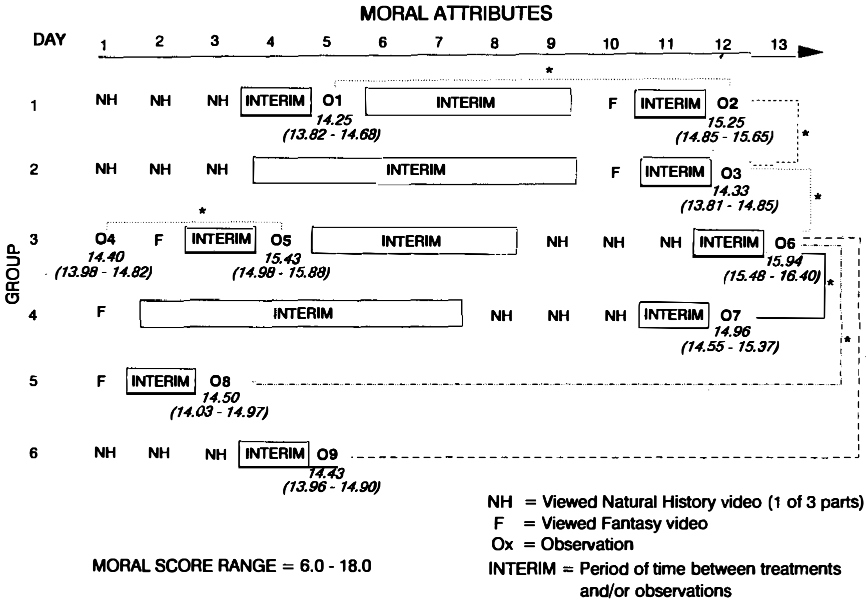

Figure 3. Moral Attributes score means and confidence intervals (italicized) for the six grade 1–3 experimental groups. Higher mean score indicates greater concern for the right and wrong treatment of animals. Line and asterisk between 2 means denote a significant difference ($P \leq 0.05$).

Other comparisons supported this: O_7 versus O_8, O_3 versus O_8. Thus, even though the F video produced erroneous perceptions of the creatures' physical attributes, the NH video had a stronger influence. It was able to "correct" some of the misconceptions fostered by the cartoon. Eta^2 (grades 1–3 = 0.68; grades 6–8 = 0.64) suggested that the effect of the physical attribute information in both videos for both age groups was strong. (Eta^2 ranges from 0–1 and estimates strength of effect.)

Findings for the effects of the cartoon video on students' ascription of anthropomorphic attributes showed similar patterns. Both age groups gave more anthropomorphic attributes to the species after viewing the cartoon (O_4 versus O_5, O_4 versus O_8, and O_8 versus O_9). This finding supports research by Wong (1985), but may contradict the Pomerantz and Hair (1988) analysis. Pomerantz and Hair reported that children who read *Ranger Rick*, a conservation education magazine featuring anthropomorphic wildlife cartoon characters, showed less anthropomorphism than did non-readers.

Test and order effects occurred (O_2 versus O_3, O_5 versus O_8, and O_3 and O_7). Subjects taking a test after the NH video had lower anthropomorphic scores (for reasons unknown—perhaps taking the test or its wording reinforced the NH information somehow). The last video viewed had the greater impact on anthropomorphic scores.

The NH video's negative impact on children's ascriptions of anthropomorphic attributes was stronger than the positive effect of the cartoon (O_7 versus O_8, O_3 versus O_8, and orthogonal contrasts for O_4 versus O_5 versus O_6: 0, +1, −1).

However, eta^2 revealed that neither experience had a very strong effect (eta^2_{1-3rd} = 0.29, eta^2_{6-8th} = 0.15). The anthropomorphism influence was much weaker than that for the Physical Attributes information—especially with the grade 6–8 students. This may have partially been due to the subjects' strong anthropomorphic tendencies before the experiment. Pretest (O_4) results showed high Anthropomorphic scores in both age groups. Past research agrees (Pomerantz 1977, LaHart 1978, Jungwirth 1979, Bartov 1981, Kellert and Westervelt 1983, Bowd 1984, Westervelt and Llewellyn 1985): youngsters from preschool through high school readily give human attributes to animals and interpret biological processes in anthropomorphic terms.

An age difference appeared for the effects of the cartoon on students' ascription of moral attributes. There was no treatment effect for the grade 1–3 students, i.e., this cartoon experience did not affect their concern for the right and wrong treatment of animals (O_8 versus O_9). However, a test effect occurred (O_2 versus O_3, O_2 versus O_6, O_4 versus O_5). Subjects taking the survey more than once had higher moral scores (i.e., expressed more concern for humane or moral treatment of an animal). Repeatedly encountering questions about the moral treatment of the three species may have helped the children interpret the questions and decide their positions on such difficult issues.

For the grade 6–8 students, there was neither a treatment or test effect on Moral Attributes scores. However, the majority scored consistently high on the Moral items. The mean Moral score for all observation means was 23.5 out of a possible high of 30.0. Hence, even at 12 years of age, the students were very concerned about the right and wrong treatment of animals. The developmental characteristic of the subjects' responses to moral questions about wildlife agrees with past research and theories (Pomerantz 1986).

The interviewing process revealed that for both age groups, the wildlife cartoon was a symbol of the real animal. It appeared that children did not see the cartoon as a character in the story, but as a representative of the species portrayed. Several different approaches suggested this. For example, at least 75 percent of both age groups said that people camping in Michigan could see Max in the woods if the looked hard enough. When asked how they would know that it was Max, more than 72 percent of the grade 1–3 students and more than 92 percent of the grade 6–8 students referred to the marten, giving some behavior characteristic of the species (e.g., he would be on all fours, he would make some animal sounds, he would be up in a tree, etc.).

Another approach to this symbol-versus-story character question involved a sequence of three slides with two of the cartoon characters: (1) Kurt sees smoke; (2) he flies toward it and sees trees afire; and (3) he sees Stu on the ground amidst burning flora. The students were first posed the question "Do you think Kurt would help Stu if Stu were in trouble?" Over 95 percent of the grade 1–3 students and 50 percent of the grade 6–8 students responded affirmatively. Next they were asked, "Do you think *you* would help Stu if Stu were in trouble?" Over 70 percent of the grade 1–3 students and about 85 percent of the grade 6–8 students gave a response indicating that they perceived him as a real animal—e.g., "Yes, I would help Stu because I like animals."

The interviews also revealed that both age groups displayed strong anthropomorphic orientations; however, this tendency appeared less frequently in the grade 6–8 students. For example, when asked whether a wild kingfisher would help a wild shrew in the midst of a forest fire, about 70 percent of the grade 1–3 students gave an anthropomorphic justification for whether or not it would. Only 47 percent of the grade 6–8 students provided such an explanation.

Both age groups also regularly watched TV cartoons at home (grades 1–3 = 77 percent; grades 6–8 = 82 percent), and animal characters comprised most of their favorite cartoons (grades 1–3 = 84 percent; grades 6–8 = 68 percent). Further, when asked if people are supposed to learn things when they watch cartoons at home, the children answered "Yes" or "Sometimes" (grades 1–3 = 74 percent; grades 6–8 = 89 percent). When probed, the "Sometimes" subjects indicated that people are supposed to learn when the cartoon had a moral or lesson in it. Potter (1988) found that certain TV viewing motives seemed to consistently correspond to higher perceptions of reality—to learn about things or information and to become aroused. Thus, if children expect to learn from cartoons, the first motive, they may perceive them as reality and accept the morals presented in them. The finding that over half of each age group remembered and described specific lessons they had learned from TV cartoons supports this hypothesis. Further, these lessons or morals could modify youngsters' future related behaviors. Past research by Forge and Phemister (1987) reported that prosocial cartoons influenced young children's behavior.

Recommendations

This study suggests the following recommendations for use of anthropomorphic wildlife cartoons. First, if designers of conservation education material wish to incorporate anthropomorphic wildlife cartoons for their appeal and effectiveness, they should do so only for that reason—i.e., to stimulate interest. They should avoid using them to represent actual species because children will likely perceive the characters as symbols of real animals and transfer fallacious information to the species. Designers should also choose cartoon characters that are very anthropomorphic or human-like, not closely resembling the representative species. Cartoons such as Mickey Mouse or Woody Woodpecker illustrate this level of anthropomorphism; they are actually humans "in fur." Semi-anthropomorphic characters—e.g., Bambi—should be avoided because their more realistic appearance will more likely encourage children to see them as symbols of real wildlife and take any of their human-like qualities as reality.

Because information from the NH video corrected some of the misconceptions fostered by the cartoon video, all conservation education experiences involving anthropomorphic cartoons should also include realistic information about the presented species. There should always be a balance of realism and fantasy to counter any fallacies prompted by the cartoon.

Educators incorporating anthropomorphic wildlife cartoons should use them with caution. They should review the material for any inaccuracies and balance them with realistic, accurate information. This is very important. Since children see the cartoon as a symbol of the real animal, they will learn and accept its information until truth replaces it.

The finding that children expect and accept morals or lessons of syndicated TV cartoon exposes the possible impacts of anti-hunting and anti-trapping cartoons such as *Seabert the Seal*. Past *Seabert* episodes contained definite morals or lessons usually detrimental to wildlife management—e.g., "Many wild animals are disappearing from the earth because man is hunting them and destroying their natural habitats''; and ''I was a fool. I didn't know. I thought animals were useless; that they were idiots, but they are kinder than humans.'' Further, concepts presented in these cartoons were erroneous, e.g., ''Once upon a time civilized man and beasts of the wild lived together in harmony, neither threatening the other's future existence.'' If children accept and integrate such information and values into their value and belief systems, they will most likely develop biased and inaccurate views of wildlife management, and misconceptions about the role of consumptive activities. Misinformed and biased future citizens will not be able to respond effectively to the ever-increasing challenges and complexities of present and future resource management.

Pomerantz (1977), Richmond and Morgan (1977) and Gilbert (1982) proposed that TV may be the greatest influence on children's attitudes toward wildlife. This study supports their supposition. Cartoons were still a part of the subjects' TV-viewing habits even at 14 years of age. Further, their favorite cartoons included animal characters, the children considered the cartoon characters a symbol of the real species, and they expected and readily accepted morals presented in the programs. These findings, plus the growing popularity of videos, computers and other forms of visual media in our society, hold important implications for wildlife managers and conservation educators. Professionals must be aware of what is being taught through television and other media, and seriously consider how they are shaping public attitudes and perceptions of wildlife and its management. Cartoons like *Seabert the Seal* stress the humanistic and moralistic values of wildlife, and encourage individual action. Managers and educators must provide realistic information on populations and species to balance these concerns, so that motivated citizens have a full understanding of ecological principles and relationships when working through value choices.

Future Research

This study provides strong evidence that children are susceptible to erroneous information and anthropomorphic messages conveyed unintentionally or incidentally through cartoons. The full extent of these influences remains to be determined and provides many opportunities for further research. First, since this study used still cartoons, the consequences of enhancing cartoon images through animation or other means need to be established. Animism research has shown that movement greatly affects how children process and perceive visual presentations.

Second, use of cartoons in various ways may influence how children respond. For example, do cartoon characters used to narrate an otherwise realistic educational message have undesired effects on student perceptions of animals? Or, do cartoon educational experiences not intending to increase anthropomorphism or moralistic attitudes—e.g., solely has an ecological message—increase the anthropomorphic tendencies in the viewers, or their moralistic concern for animals?

Third, this study measured influences of cartoons in an educational setting. Are children as readily influenced by anthropomorphic cartoons in a clearly recreational or entertainment setting? Further, the moral attributes defined in this study should be refined and researched to explore differences in welfare versus animal rights concerns. Finally, given the results of this study, it appears useful to assess the extent of public exposure to and full impacts of selected popular cartoon features which may impact public attitudes regarding wildlife and wildlife management (e.g., *Seabert the Seal, Smokey Bear, Ranger Rick, Captain Planet*). Possible opportunities to intercept or counter such information should be investigated, and appropriate material provided.

References

Ball, H. G. 1983. Who is Snoopy? Pages 14–20 *in* J. L. Thomas, ed., Cartoons and comics in the classroom. A reference for teachers and librarians. Libraries Unlimited, Inc., Littleton, CO.

Bartov, H. 1981. Teaching students to understand the advantages and disadvantages of teleological and anthropomorphic statements in biology. J. Res. in Sci. Teaching 18:79–86.

Blanchard, J. S. 1982. Anthropomorphism in beginning readers. Reading Teacher 35:586–591.

Bowd, A. D. 1984. Fears and understanding of animals in middle childhood. J. Genet. Psychol. 145:143–144.

Caldwell, K. S. 1973. Guidelines and principles for the utilization of animation in instructional films and videotapes. Ph.D. diss., Univ. Southern California, Los Angeles. 436 pp.

Dorr, A. 1983. No shortcuts to judging reality. Pages 199–220 *in* J. Bryant and D. R. Anderson, eds., Children's Understanding of Television, Academic Press, NY.

Forge, K. L. S. and S. Phemister. 1987. Effect of prosocial cartoons on preschool children. Child Study J. 17:83–87.

Gilbert, F. F. 1982. Public attitudes toward urban wildlife: A pilot study in Guelph, Ontario. Wildl. Soc. Bull. 10:245–253.

Huston, A. C., J. C. Wright, M. L. Rice, D. Kerkman, and M. St. Peters. 1987. The development of television viewing patterns in early childhood: A longitudinal investigation. ERIC ED 281673. 29 pp.

Jungwirth, E. 1979. Do students accept anthropomorphic and teleological formulations as scientific explanations? J. Coll. Sci. Teaching 8:152–155.

Kauffman, S. P. and F. M. Dwyer. 1974. Effectiveness of cartoons and photographs in in-service training. Calif. J. Educ. Res. 25:197–204.

Kellert, S. R. 1980. Attitudes of the American public relating to animals—Phase II. U.S. Fish and Wildl. Serv., Washington, D.C. 162 pp.

Kellert, S. R. and M. O. Westervelt. 1983. Children's attitudes, knowledge, and behaviors toward animals—Phase V. U.S. Fish and Wildl. Serv., Washington, D.C. 201 pp.

LaHart, D. E. 1978. The influence of knowledge on young people's perception about wildlife. Final Project Rept. to Natl. Wildl. Fed., Coll. of Educ. Florida St. Univ. 101 pp.

Liebert, R. M. and N. S. Schwartzberg. 1977. Effects of mass media. Ann. Rev. Psychol. 28:141–173.

Lyle, J. and H. R. Hoffman. 1972. Children's use of television and other media. Pages 129–256 *in* E. A. Rubinstein, G. A. Comstock, and J. P. Murray, eds. Television and social behavior. Reports and Papers, Volume IV: Television in day-to-day life: Patterns of use. Govt Print. Off., Washington, D.C.

More, T. A. 1977. An analysis of wildlife in children's stories. Pages 89–92 *in* Children, nature, and the urban environment: A symposium fair. USDA For. Serv., Northeast For. Exp. Stn. Gen. Tech. Rept. NE-30.

Pomerantz, G. A. 1977. Young people's attitudes toward wildlife. Michigan Dept. Nat. Resour. Rept. 2781. 79 pp.

———. 1986. Children and wildlife: Research implications for recreation resource management. Paper presented at First Natl. Symposium on Social Sci. and Resour. Manage., May 12–16, 1986, Corvallis, OR. 19 pp.

Pomerantz, G. A. and J. D. Hair. 1988. Effective conservation education by a private wildlife organization: Teaching children with *Ranger Rick*. Trans. N. Am. Wildl. and Natl. Resour. Conf. 53:542–551.

Potter, W. J. 1988. Perceived reality in television effects research. J. Broadcasting and Electronic Media 32:23–41.

Richmond, J. M. and R. F. Morgan. 1977. A national survey of the environmental knowledge and attitudes of fifth year pupils in England. ERIC ED 134 478. 201 pp.

Snow, R. P. 1974. How children interpret TV violence in play context. Journalism Q. 51:13–21.

Westervelt, M. O. and L. G. Llewellyn. 1985. Youth and wildlife: The beliefs and behaviors of fifth- and sixth-grade students regarding non-domestic animals. U.S. Fish and Wildl. Serv., Washington, D.C. 78 pp.

Wilson, R. C. and E. J. Shaffer. 1965. Reading comics to learn. The Elem. School J. 66:81–82.

Wong, C. J. 1985. The effect of cartoons on children's perceptions of wildlife. M.S. thesis, Colorado St. Univ., Fort Collins. 61 pp.

Wright, G. 1983. The comic book—a forgotten medium in the classroom. Pages 21–25 *in* J. L. Thomas, ed., Cartoons and comics in the classroom. A reference for teachers and librarians, Libraries Unlimited, Littleton, CO.

Youths Communicating With Youths: The Outdoor Writers Association of America's Youth Writing Contest

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If Men and Women are to understand each other, to enter into each other's nature with mutual sympathy, and to become capable of genuine comradeship, the foundation must be laid in youth (Ellis 1884).

The Outdoor Writers Association of America, Inc.—commonly referred to as OWAA—is a professional organization comprised of almost 2,000 individual active and associate members who professionally communicate about outdoor recreation, natural resources and conservation. Realizing that it was in the organization's best interests, as well as that of the subjects on which its members focus in their communications, to replace youths' apathy with an awareness and appreciation of the outdoors, OWAA initiated a Youth Writing Contest in 1987. The association offered first-, second- and third-place prizes of plaques and $500, $300 and $200, as well as plaques for honorable mentions (OWAA Planning for Tomorrow Committee files 1986). The annual contest has grown, spawning local youth writing contests across the continent and becoming part of the writing program of high schools. Most important, because the competition, designed for high school students, requires that entries must have been published, youths are creating forums for communicating an outdoor awareness to their peers.

Purposes

Stated Purpose

The introductory words of the press release issued by OWAA on February 28, 1991 to publicize the sixth annual competition stated the organization was presenting three cash awards "To encourage high school students to sharpen their ability to communicate the outdoor experience" (OWAA 1991). That is the stated purpose of the competition. However, it's worth exploring the motivating factors that led to the creation of the OWAA Youth Writing Contest and, thus, the unstated purposes of the competition.

Unstated Purposes

The vast majority of members of OWAA—whether their communication encompasses writing, editing, photographing, broadcasting, telecasting, illustrating, lecturing or other aspects of outdoor communications, and whether their medium is newspapers, magazines, books, radio, television, videotapes, audiotapes etc.—have a vested interest in wildlife management. Their subjects frequently are fishing- and hunting-related—sports that have experienced declines in participation (Harrington Market Research, Inc. 1991, Selection Research, Inc. 1991). Furthermore, they are sports attacked by special-interest groups in the name of animal rights or environmental impact.

Many of these special-interest groups have been particularly effective in instilling their philosophies in school curricula and clubs. In addition, much of the general-interest media has been perceived as sympathetic to their causes.

It was with those realizations that OWAA created its writing contest. The goal was to inspire impressionable youths to think and communicate about the outdoors. The topic was broad: "outdoors." A slant was not required; it needn't be pro-hunting, pro-fishing or pro-wildlife management. The hope, of course, as with all journalistic endeavors, was that truth and sound information leading to the determination of what is right would be communicated (OWAA Planning for Tomorrow Committee files 1985). The criterion for judging was "excellent writing" (OWAA 1991).

The organization recognized that the message youths frequently deliver to other youths carries a convincing relevance that no older person could convey in the classroom. It was OWAA's intention that high school youths would avail themselves of the journalistic options open to them to communicate their messages and, thus, be eligible to enter their printed words in OWAA's competition. School newspapers and literary magazines, club newsletters, articles and letters to the editor in local newspapers, and scholastic magazines, as well as the broad spectrum of other magazines, including local sporting and conservation magazines, were all avenues of publication (OWAA Planning for Tomorrow Committee files 1985).

Those publications directed at youths were of particular interest to the contest's founders, and it was their hope that the announcement of the contest might even motivate some students to initiate regularly appearing "outdoor" columns in their school or club publications (OWAA Planning for Tomorrow Committee files 1985).

The most important goal was to provide an avenue for youths to communicate with youths about the outdoors, but OWAA realized that the contest could produce positive byproducts.

For one, OWAA could receive favorable exposure. Simply by virtue of the announcement of the contest, which in 1991 included a mailing list of nearly 1,200 publicity outlets, the organization's name would become known to thousands, if not millions, of students and adults unfamiliar with the group (OWAA correspondence to G. Sapir: 1991). That exposure, in turn, could lead to: elevating the prestige associated with membership in OWAA; informing youths and adults of OWAA's purpose; and, perhaps, inspiring and guiding people into an outdoor communications career and, eventually, membership in OWAA (The OWAA Planning for Tomorrow Committee files 1985).

Exposure could benefit OWAA in other ways, including attracting industry appreciative of the organization's goals to its supporting member roster (OWAA Planning for Tomorrow Committee files 1985).

The contest would also generate story material for its members. Announcing it could serve as the subject of a column or broadcast. Following up with the winners could serve as another interesting topic (OWAA Planning for Tomorrow Committee files 1985).

Results

By most measurable criteria, OWAA's Youth Writing Contest is a success. Its principal purpose—to interest high school youths in writing about the outdoors—is being achieved. The number of contest entries has grown from 28 in 1987 to 72 in 1992 (OWAA correspondence to G. Sapir: 1992). Considering that the publications in which these articles originally appeared varied from high school literary magazines to city newspapers as widely circulated as the *San Francisco Examiner*, it is safe to estimate that, collectively, these youths' words have been read by millions of people, many of whom are youths themselves.

Not only have professional communicators been provided with story material by announcing the contest, but many communicators have taken it upon themselves to begin local contests in their own publications. Two impressive examples are the *San Francisco Examiner* and Spokane, Washington's *The Spokesman Review*.

"My outdoor writing began when I was 8," explained the *Examiner's* Outdoor Editor Tom Stienstra (personal communication: 1992), an OWAA member. "The paper I wrote for the class was meant to be 'Striper Fever,' but I misspelled the title and called it 'Stripper Fever.' I suppose the teacher had no idea what to expect.

"That's how I got started, and I felt if kids were given a similar opportunity, it might not only start someone on a budding career," Stienstra continued, "but it would give kids the opportunity to focus on the environmental ethic."

The newspaper invited school-age children, not just high school students, to write up to 500 words on the outdoors. Winners would receive a library of outdoor books, valued at $60–80. Eight hundred children, from ages 4 to 18, responded, many entries arriving in groups of 30 or 40, obviously the result of class efforts. A winning entry, along with the winner's photograph, was printed weekly for about three months (T. Stienstra personal communication: 1992).

Philosophically, the contest was a success: "The theme [of the entries] consistently was on environmental ethics and the yearning for an outdoor place," reported T. Stienstra.

From a marketing perspective, it was a success too. The winning entries were run weekly in the Saturday paper, which had circulation problems in comparison to the 750,000 Sunday edition. During the run of the contest, Stienstra reports that the Saturday circulation rose by about 12,000. After the newspaper ceased publishing contest winners, the Saturday circulation returned to its lower level.

Rich Landers, Outdoors Editor of *The Spokesman Review*, was one of the early supporters of a local contest. His paper published many of the articles that subsequently won top honors in OWAA's Youth Writing Contest. Not only has the Spokane publication's contest attracted the attention of youths, but it also has gained the approval of their teachers (Landers 1990). At least 12 local high school teachers have brought the theme of the outdoors into their classroom as a writing assignment (R. Landers personal communication: 1992).

"If there's a secret to good outdoor writing, Georgia Toppe and Mary Ann Waters must know it," wrote Landers in the October 1990 edition of *Outdoors Unlimited*, the official newsletter of OWAA. "These two Spokane English teachers have produced all 11 of the winners in the *Spokesman-Review* and *Spokane Chronicle* youth writing contest in the past three years," Landers continued. "Nine of those entries went on to win awards in OWAA's national outdoor writing competition."

''Both Toppe and Waters emphasize rewriting,'' wrote Landers (1990).

He quoted Waters: ''I use a workshop format. The kids themselves do most of the critiquing. They learn the art of critiquing as they learn the art of writing. Once they get over the fear of getting their feelings hurt, they become interested in hearing what others have to say.''

So, in this case, the writing contest has brought youths together to discuss the outdoors and ''outdoor writing'' with classmates, as they work toward ''sharpening their ability to communicate the outdoor experience''—the purpose stated in the OWAA press release announcing the contest (OWAA 1991).

''A lot of kids are turned off to writing because of the emphasis on grammar and punctuation,'' Toppe told Landers (1990). ''I think most English teachers are encouraging kids to write for the fun of writing, just as you would play tennis for the sake of playing tennis. Once you have fun and enter the arena, you start caring about the other things automatically. They start asking questions because they want to improve their game.''

Again, the contest is helping classes of students to improve their writing skills while focusing their attention on the outdoors.

Children across the country are being encouraged to write about the outdoors. In 1990, 183 entries were submitted to Montana's *Great Falls Tribune*. Most entries were assignments by English teachers (B. Linder personal correspondence: 1991). One went on to take first place in the OWAA Youth Writing Contest. Laurie Lee Dovey (personal correspondence: 1991), an OWAA member and columnist for the Johnstown, Pennsylvania, *Tribune-Democrat*, received 112 entries in 1990, the first year she ran a local contest. Three teachers made the contest part of their assignment log.

For 1991–92, the New York State Outdoor Writers Association, one of many state and regional professional outdoor writers groups across the continent, has organized a writing contest for children from kindergarten through 12th grade. The topic must focus on the outdoors and/or activities and experiences in the outdoors. The award will be a plaque and publication of the winning entries, thus making them eligible for entry in the OWAA competition.

In announcing its contest, the New York State Outdoor Writers Association (1991) wrote: ''Research has documented the importance of connecting with the outdoors as a child. Youth who are introduced to the outdoor world at a younger age are much more likely as adults to demonstrate a sustained commitment to the conservation of natural resources. It is important to find ways to encourage and enable youth to have positive experiences in the natural world.

''The New York State Outdoor Writers Association is recognizing its responsibility in this area through sponsoring an annual youth writing contest. The NYSOWA believes that writing about outdoor experiences will further reinforce this connection. The group hopes to offer some incentive for this effort through recognizing student writing about the outdoors and outdoor experiences.''

The success of the OWAA Youth Writing Contest can be measured by increased entries and by the large number of local contests it has inspired. In announcing many of these local contests, the sponsors have referred to the fact that winning entries will be published and submitted to the OWAA Youth Writing Contest. So, along with articles and press releases announcing the OWAA competition, familiarity with the OWAA Writing Contest grows as local contest mushroom.

More difficult to measure is how the prestige of membership in OWAA may have grown as the writing contest has grown. One example of this growth in prestige, however, may be that the Izaak Walton League of America asked and was allowed to co-sponsor the contest in its inaugural year. The next year, the League was turned down in its request to be a co-sponsor, for OWAA chose to sponsor the contest by itself (OWAA files 1987).

The Future

Local contests continue to spring up and prosper across the country, prompting more and more children to communicate about the outdoors and producing more and more eligible entries for the OWAA contest. The number of newspapers across the country that are potential sponsors of local contests is phenomenal. Furthermore, sportsmen's groups that publish a newsletter, state wildlife departments that publish magazines and civic groups that circulate their messages via the printed word are untapped sources of writing contests that could funnel published entries into the OWAA Youth Writing Contest.

As the national and local contests are embraced by more and more teachers, an ever-increasing number of youths will improve their writing skills while making the outdoors the focus of their attention and classroom discussion.

As the rewards of the OWAA Youth Writing Contest become better known to high school students across the country, youths will better utilize the means of becoming published available to them. Then, other youths in their impressionable teens will be able to read their peers' ideas—words that, to them, ring with an inherent credibility simply because of the age of the author and, perhaps, the reader's familiarity with the author or topic.

Consider the amount of untapped publications that can serve as contest sponsors and publishing grounds. Ponder the number of North American school systems that can breed entries and stir discussions in the classroom. Understand that the contest's recognition will increase as the annual contest unfolds each year. Grasp these notions and you have an appreciation of the tremendous potential of the OWAA Youth Writing Contest—a concept that already has achieved much that its creators foresaw.

Good, the more communicated, more abundant grows (Milton 1667).

References

Ellis, H. 1884. The task of social hygiene. Page 689 *in* Bartlett's Familiar Quotations, 15th ed. Little, Brown and Company, Boston, MA. 1,540 pp.

Harrington Research, Inc. 1991. Fishing motivation study. American Fishing Tackle Manufacturers Association, Barrington, IL. 43 pp.

Landers, R. 1990. The write stuff for youth. Pages 8–10 *in* Outdoors Unlimited. Oct. Outdoor Writers Association of America, State College, Pennsylvania. 52 pp.

Milton, J. 1667. Paradise lost. Page 286 *in* Bartlett's Familiar Quotations, 15th ed., page 286. Little, Brown and Company, Boston, MA. 1,540 pp.

New York State Outdoor Writers Association. 1991. NYSOWA to sponsor youth writing contest. Page 8 *in* New York Outdoors. Dec. New York State Outdoor Writers Association, Lockport, NY. 12 pp.

Outdoor Writers Association of America. 1991. Press release—youth writing contest. February 28. Outdoor Writers Association of America, Inc., State College, PA. 1 p.

Selection Research, Inc. 1991. The 1990 hunting frequency and participation study. National Shooting Sports Foundation, Inc., Wilton, CT. 523 pp.

Evolution of the 4-H Wildlife Habitat Evaluation Program into a National Tool for Integrated Learning

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Introduction

Purpose of the Wildlife Habitat Evaluation Program

An objective of 4-H programs is to promote an individual's appreciation of nature, understanding of conservation, and wise use of natural resources (Croft et al. 1970). A growing activity is the National Wildlife Habitat Evaluation Program where senior 4-Hers ages 14 through 19, learn about wildlife and management techniques, then demonstrate their knowledge, skills and attitudes through competitive wildlife habitat evaluation contests. Five activities are performed at county, state and national contests: identifying common wildlife foods; interpreting wildlife habitat from aerial photographs; on-site habitat management recommendations; and wildlife management plans for Rural and Urban areas.

The program develops skills for older youth to transfer abstract knowledge and attitudes gained from books to concrete problem solving in urban and rural landscape situations. Research of developmental stages suggests that grades 8 through 11 provide the best opportunity to promote abstract concepts such as those of ecology and wildlife management (Kellert and Westervelt 1983). Lahart (1978) and Dyar (1975) suggested that attitudes towards wildlife are strongly influenced during grades 5 through 8, and emphasized the value of factual learning at this stage. Activity-based curricula affects knowledge and skills of youth, and it can also change their attitudes. Race (1990) and Lahart (1978) suggested that participation in wildlife-oriented activities can affect attitudes as much as knowledge learned through more traditional methods. Kellert and Westervelt (1983) cited Baird (1982) as reporting, "if one were to try to change attitudes, education without an experiential component might not be very effective."

History of the Wildlife Habitat Evaluation Program

The program began in 1977 by Jim Byford and Tom Hill of the Tennessee Agricultural Extension Service. The first state judging contest was held in 1978. The program grew from approximately 200 participants in Tennessee in 1978 to over 12,000 from 17 states in 1991.

The first southern regional event was held in 1987. The second southern regional competition in 1988 was sponsored by the International Association of Fish and Wildlife Agencies, and a conference was held concurrently to discuss the possibility of a national event. In 1989 the first national event was held and state extension wildlife and 4-H specialists met to discuss ways to expand the program.

Three actions were initiated to increase interest by non-participating states and to promote uniformity in the national program. First, a handbook was developed applicable to all landscape regions in the United States. It included basic concepts and procedures of the original program with expansion to include urban and rural sites and game and non-game wildlife. Second, leader training workshops were key to the success of expanding the program. Four workshops were given to 50 participants from 8 states that included 28 4-H leaders during 1991. A paper reporting on the effectiveness of workshops to change participants knowledge of habitat evaluation and how to use the handbook is in preparation. Third, the national event was moved to different states each year so new habitats could be experienced by state winners.

In 1990, Colorado State University was given the charge to write the new national handbook. Extension wildlife employees from several states and the national office assisted with the manual. This paper reports on the developmental stages of the handbook and performance of youth at state and national events.

Methods

Handbook Development and Formative Evaluation

Gay (1980), Duby (1987), and Stout and Peyton (1988) discussed the importance of evaluating curricula as a mechanism for improvement. The handbook underwent two evaluations before final publication. First, a preliminary draft was presented for comment to the National Wildlife Judging Manual Development Committee, several 4-H wildlife project leaders, representatives from sponsoring organizations and educators. Recommendations received were combined with ideas from handbooks published in North Dakota, Tennessee and Mississippi to develop a complete prototype that was published in June 1990. Copies were distributed to 4-H Leaders with natural resource responsibility, state Extension Wildlife Specialists in each state, members of the 4-H Wildlife Habitat Judging Committee and program sponsors. The prototype was used to prepare judging teams who participated in the national event held in Weston, West Virginia, July 30–August 3, 1990.

The second handbook evaluation involved sending 180 survey questionnaires to all recipients of the prototype requesting comments on format, organization, content, readability and technical accuracy. The questionnaire was 10 pages long and included 29 Likert-scaled questions with a scale of 1–4, a question for rating each judging activity on a scale of 1–5, a section for respondents to indicate the youngest age they felt youth could comprehend the various sections of the handbook, and four open-ended questions. Likert-scaled questions did not offer an impartial or mid-point selection, as neutral responses were not considered valuable in identifying strong and weak aspects of the handbook.

Leaders of all 4-H teams attending the 1990 national event were brought together at a coaches session where the prototype was reviewed, and leaders commented on difficulties encountered while using the prototype to prepare participants for the national event. Documentation was made of comments and observations on how participants used the handbook during the contest. Information obtained at the 1990 national event and responses to the questionnaire were used to develop the final handbook.

Learner Achievement Evaluation

A third evaluation was conducted to determine achievement of senior 4-Hers in the activities. A survey was sent to Extension Wildlife Specialists in 26 states that had been active or shown interest in the program seeking scores achieved by 4-Hers on judging activities at state competitions. Scores were converted to a percentage scale of 0–100, and mean scores were compared with the following learner objectives:

1. Senior 4-Hers (14–19 years old) will be able to identify food items and list wildlife groups that utilize the item for food correctly 70 percent of the time in state or national judging events.
2. Senior 4-Hers will exhibit ability to apply knowledge of wildlife and wildlife habitat by scoring over 60 percent in the wildlife management plan activity.
3. Senior 4-Hers will demonstrate ability to apply knowledge of wildlife and wildlife habitat by scoring over 70 percent in the aerial photograph activity (not including oral reasons).
4. Senior 4-Hers will demonstrate knowledge about wildlife and wildlife habitat by scoring over 70 percent in the on-site habitat management recommendations activity.

Paired scores achieved by the same individuals on similar activities at state and national events were compared to determine if 4-Hers could transfer learned knowledge and skills to an ecological region that was different from the regions of their state.

Results

Handbook Evaluations

Response rate of survey forms was 15 percent, and 10.5 percent was used in calculations. Of 28 returns, only 19 answered questions sufficiently to be used in computations. There were 21 Lickert-scaled questions on the organization and format, readability and comprehension and technical content of the prototype. Numerical values were 1 for strongly agree, 2 for agree, 3 for disagree and 4 for strongly disagree. Responses were summed and mean scores were recorded for each question. Scores were highest for organization and format ($\overline{X}=1.9$) and lowest for technical content ($\overline{X}=2.1$), but all were on the positive side of the scale. Responses indicated that the following aspects of the prototype should be reviewed and modified:

1. the number of regions, how they were delineated and accuracy of information provided about each region;
2. clarification of activities in which 4-Hers were expected to participate in national judging events;
3. comprehension of the region and activity sections of the handbook;
4. appropriateness and detail of the wildlife management concepts;
5. appropriateness of wildlife species recommended for use at judging events in the various regions; and
6. the type and number of management practices.

Respondents were asked to identify at which age youth could comprehend material in the prototype. Results indicated that 13 years old was the youngest that youth could comprehend the overall handbook. Five of 19 respondents rated readability of the handbook as difficult or extremely difficult; 13 rated readability as appropriate; and one did not respond.

Respondents rated the content and usefulness of each activity with values of very good 1, good 2, fair 3, poor 4 and very poor 5. Results suggested that content was lacking in the wildlife management plan ($\overline{X}=2.4$), aerial photograph interpretation ($\overline{X}=2.4$) and urban landscape management plan ($\overline{X}=2.5$) sections. These sections were later expanded and examples of activities were added. The mean usefulness ratings were less than 2.1 for all activities except the wildlife management plan activity which received the lowest usefulness rating ($\overline{X}=2.3$).

Additional comments were written and subsequent changes made to the following aspects of the prototype:

1. The recommended maximum acreage of land treatment practices, such as clear-cut timber harvest, chaining and brush chopping, was changed from 100 acres to 40 acres.
2. The Chaparral region title was changed to Mediterranean Zone, and an area of Woodland was added in California. A new region titled Prairie Brushland was developed for southern Texas, and boundaries for Woodland and Great Plains Grassland regions were changed in Texas.
3. A section briefly describing how to prepare participants for events was developed.
4. Indexes were developed for each section.
5. Wildlife that can be pests were identified and reasons they are occasionally labeled pests were briefly explained.

The final handbook (Neilson and Benson 1991) contains information about 14 different landscape regions, 63 wildlife species, 43 habitat management practices and the five judging activities. Bailey's (1980) ecoregions of the United States were used as a guide to divide the U.S. into 12 regions with similar climate, vegetation and wildlife. Wetland and urban landscape regions were described and considered appropriate for use nationwide. An average of 11 wildlife species are recommended for management considerations in each region. Species were selected that are common to many regions, that occupy similar niches in different regions, that were a mix of game and non-game birds and mammals, that inhabit urban and rural landscapes and that require special habitats such as wetlands or expanses of vegetation in or near climax successional stages.

Learner Achievement Evaluation

The mean percentage score achieved by senior 4-Hers on identifying wildlife foods (65 percent) and on-site habitat management recommendations (65 percent) activities were significantly lower than the hypothesized mean of 70 percent. Interpreting wildlife habitat from aerial photograph activity percentage scores (79 percent) were significantly higher than the hypothesized mean of 70 percent. The mean score of 58 percent on the wildlife management plan was not significantly different than the hypothesized mean of 60 percent (Table 1).

The students' t-test for dependent variables indicated no significant differences in scores achieved at state and national events by the same individuals on identifying

Table 1. Two-tailed t-test comparing desired scores and actual scores achieved by senior 4-Hers on judging activities at state events.

Activity	H_0	N	$\bar{X}$ percentage	df	t	P
Identifying common wildlife foods	$\bar{X}=70\%$	226	65	225	3.57	<0.01
Interpreting wildlife habitat from aerial photographs	$\bar{X}=70\%$	226	79	225	8.11	<0.01
On-site habitat management recommendations	$\bar{X}=70\%$	190	65	189	3.89	<0.01
Wildlife management plan	$\bar{X}=60\%$	56	58	55	0.414	0.68

common wildlife foods, on-site habitat management recommendations and wildlife management plan activities (Table 2). Significantly higher scores were achieved at state events on the aerial photographs activity.

Discussion

The importance of evaluating educational curriculum is widely documented. Gay (1980) and Stout and Peyton (1988) indicated rigorous evaluation is essential to reveal strengths and weaknesses in curriculum. Continued evaluation is needed of the Habitat Evaluation Handbook and the program's effectiveness as a tool to educate youth and to promote positive attitudes towards wildlife and wildlife habitat. Results should be used to modify and improve future program delivery.

The low response rate in the handbook evaluation confounds validity of results. A study of non-respondents was not conducted owing to the need for modifying the handbook in time for use at national workshops. Most respondents were familiar and

Table 2. Student's t-test for dependent variables comparing scores achieved by senior 4-Hers on judging activities at state events with scores achieved on corresponding activities at national events.

Activity	N	$\bar{X}$	s	df	t	P
Identifying common wildlife foods						
State event	25	78.3	19.41	24	0.069	0.945
National event	25	78.6	15.81			
Interpreting wildlife habitat from aerial photographs						
State event	25	84.1	13.91	25	3.61	0.0014
National event	25	69.8	10.98			
On-site habitat management recommendations						
State event	25	78.8	14.9	24	0.259	0.798
National event	25	79.6	11.76			
Wildlife management plan (Pooled variance)						
State event	6	73.3	34.59	27	0.737	0.234
National event	23	65.7	18.66			

knowledgeable with the program, and all ecological regions were represented. Opinions and ideas from newcomers and persons not involved with the program were not well represented and it is assumed they did not feel knowledgeable enough about the program to respond. Questionnaire results were useful in identifying several areas where the prototype needed improvement. A more thorough effort in questionnaire follow-up may have increased response rates.

Many variables influence learning about wildlife (Race 1990). Without control of these variables, conclusions about program effects are only speculative. Without a control group of non-participants, it is not possible to determine the unique function of participation in acquiring knowledge, skills and attitudes solely from the Wildlife Habitat Evaluation Program. However, mean scores from state competitions (Table 1) were relatively close to desired outcomes that were arbitrarily selected, and scores of youth at the national event (Table 2) were higher than the desired means.

The importance of experiential learning in wildlife education is well-documented, and some acquisition of knowledge and skills by participants in the program can be expected (Benson and Pomerantz 1990, Race 1990, Hair and Pomerantz 1987). Although the effect of this program on attitudes was not evaluated, Kellert and Westervelt (1983) suggested that there may be a correlation of knowledge with positive attitudes. If participation increases knowledge about wildlife and wildlife habitat, some positive attitudes also should develop.

Comparison of paired scores achieved by individuals on similar activities at the national and state contests demonstrated successful transfer of knowledge between different landscape regions of the U.S. Although wildlife and plant communities varied, concepts of ecology and wildlife habitat are applicable to all regions. In theory, these concepts are the nucleus of the program, and participants should be able to perform the activities equally in any region. Results indicate this may be true for identifying common wildlife foods and on-site habitat management recommendations activities (Table 2). There are many possible reasons for the large difference in scores on the interpreting wildlife habitat from aerial photographs. First, it may be more difficult to apply knowledge of interspersion, arrangement and size of habitat area concepts used in this activity to other regions. Second, how the activity was conducted at state and national events may have been dissimilar, so comparisons were inappropriate. Third, mean scores for this activity varied between 79.8 and 86.1 at state events except in North Dakota (41.7) where the national event was held. This may indicate that aerial photograph interpretation was more difficult for senior 4-Hers in areas with less vegetative and topographic contrast, such as the Great Plains Grassland Region.

The program is expanding nationwide. The final handbook was sent to all states for their printers in camera-ready black and white format. A color version was produced and is available for $12.00 per copy at the Colorado State University Bulletin Room. Six of eight states represented at leader workshops were just initiating the program. The 1991 national event was held outside of the eastern U.S. for the first time, and four additional states participated. The 1992 national event will be held in Missouri.

References

Baird, D. D. and R. R. Tolman. 1982. Attitudes of high school students and biology teachers toward animals. Unpubl. manuscript, Field Museum Natur. Hist., Div. of Mammals, Chicago, IL.

Bailey, R. G. 1980. Description of the ecoregions of the United States. U.S. Dept. of Agric., Misc. publ. No. 1391. 77 pp.

Benson, D. E. and G. Pomerantz. 1990. Status and trends of conservation education programs. Trans. N. Am. Wildl. and Nat. Resour. Conf. 55:85–93.

Croft, J., F. Kaehler, R. Brooks, and C. G. Staver. 1970. 4-H leaders guide. Colorado St. Univ. Coop. Ext. Serv. Publ. 10M 9–70. 46 pp.

Duby, E. 1987. Self-formative evaluation of instructional materials. Educ. Technol. 27:48–50.

Dyar, N. A. 1975. Assessing environmental attitudes and behaviors of a seventh grade school population. Ph.D. dissertation, Univ. California Berkeley. 150 pp.

Gay, L. R. 1980. Educational evaluation and measurement. Charles E. Merrill Publ. Co. 543 pp.

Hair, J. D. and G. A. Pomerantz. 1987. The educational value of wildlife. *In* Valuing wildlife: Economic and social perspectives. D. Decker and G. Goff, eds., Westview Press, Boulder, CO. 424 pp.

Kellert, S. R. and M. O. Westervelt. 1983. Children's attitudes, knowledge, and behaviors towards animals. U.S. Govt. Print. Off. Rept. No. 0–405–522/1101. 202 pp.

Lahart, D. E. 1978. The influence of knowledge on young people's perceptions about wildlife. Final rept. to the Natl. Wildl. Fed., College of Educ., Florida St. Univ., Tallahassee. 101 pp.

Neilson, E. L., Jr. and D. E. Benson. 1991. Wildlife habitat evaluation handbook. Natl. 4-H Council and Coop. Ext. and Agric. Communic., Colorado St. Univ., Ft. Collins. 130 pp.

Race, T. M. 1990. Project WILD's effect on student knowledge and attitude toward wildlife in Colorado. M.S. thesis, Colorado St. Univ., Fort Collins. 76 pp.

Stout, R. J. and R. B. Peyton. 1988. The need for wildlife education program evaluation: A case study. Trans. N. Am. Wildl. and Natur. Resour. Conf. Pages 552–559.

Special Session 4. *Wetland Conservation*

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Status of Wetlands Legislation in the 102nd Congress

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There is a growing belief and expectation that, in 1992, the United States Congress will enact wetlands legislation. If this occurs, it would be the first major enactment concerning wetlands regulation and protection in 15 years, when Congress last amended Section 404 of the Clean Water Act. Indeed, for some time there has been increasing recognition that, unless wetlands issues are addressed through legislation, consideration of other water quality subjects, including comprehensive reauthorization of the Clean Water Act, will not occur this year.

So far, in the 102nd Congress, more than 50 bills have been introduced concerning water quality issues. These bills deal with a wide range of topics—from water quality in the Nation's estuaries, to water conservation, to funding of municipal sewage treatment plant construction. However, concern over current implementation of wetlands regulatory programs has emerged as a key environmental issue in the 102nd Congress. The largest number of bills on water quality topics, almost one of every four, deals with wetlands protection and regulation. According to one view, regulatory efforts have gone too far and wet areas that provide few of the values associated with wetlands are being aggressively protected. But according to another view, a major impediment to maintaining and restoring wetland resources is the lack of a coordinated, consistent approach among federal, state and local governments that has led to significant gaps in wetlands protection.

Most groups involved in the debate over Clean Water Act reauthorization (environmental groups, state representatives, developers, agricultural interests and busi-

[1]Views expressed are the author's and not necessarily those of the Congressional Research Service or the Library of Congress.

nesses) have come to general agreement on at least two key points: that better protection is needed for wetlands (what some describe as the "real wetlands" problem) and that the existing Section 404 program has problems which need to be addressed. Despite this agreement, there are sharp differences over what the perceived problems are, what "better protection" would mean and in what has been proposed. Some groups advocate major changes to the Section 404 program to reduce federal jurisdiction, while others seek to strengthen and tighten the 404 program.

The comparison which follows examines major elements of five of the principal legislative proposals, particularly those concerned with regulatory issues. Bills dealing with related issues (such as whether wetlands regulation infringes on individual property rights and thus results in a "taking" of private property) also have been introduced, but are not discussed here. Major issues of interest are encompassed in these five legislative proposals:

- the Wetlands No Net Loss Act, introduced by Representative Charles Bennett (H.R. 251);
- the Wetlands Protection and Regulatory Reform Act, introduced by Representative John Paul Hammerschmidt (H.R. 404);
- the Comprehensive Wetlands Conservation and Management Act, introduced by Representative Jimmy Hayes (H.R. 1330) and Senator John Breaux (S. 1463);
- the Wetlands Stewardship Act, introduced by Representative Lindsay Thomas (H.R. 2400); and
- the Wetlands Reform Act, introduced by Representative Don Edwards (H.R. 4255).

Three Issues: Classification, Coverage and Institutional Arrangements

These five bills raise several issues. *First, should all wetlands be treated the same or not? If all wetlands have some functions and values, do some have more than others, and consequently, should those with lesser values be accorded less stringent regulatory protection?*

Jurisdictional wetlands, those areas identified as being subject to regulation, are subject to a permit process under current law. These wetlands themselves are not differentiated in any way, although the size and the characteristics of the impact of a proposed activity and the characteristics of the wetland resource can affect regulatory requirements that are placed on such an activity. To streamline the regulatory process, some propose that wetlands be classified to identify and protect those areas with the most significant values and functions. Others contend that classification systems are overly simplistic and scientifically invalid.

In the pending legislation, the Bennett bill (H.R. 251) would allow the regulatory process to make such distinctions as it now does. It would not propose or require classification.

So, too, the Thomas bill (H.R. 2400) would not mandate classification. However, it calls for the federal agencies (the Environmental protection Agency [EPA], U.S. Army Corps of Engineers [Corps] and others) to develop methods for classifying wetlands.

The Hammerschmidt bill (H.R. 404) would distinguish "high quality" wetlands from all others, based on habitat functions, aquifer recharge potential, flood protection, water quality benefits or sediment retention. This distinction, in essence a two-tier classification system, would be accomplished through revisions to EPA's Section 404(b)(1) guidelines.

The Hayes/Breaux bill (H.R. 1330/S. 1463) details a three-tier classification system in which all wetlands would be either Class A, Class B or Class C. Permits would generally be denied (unless there is overriding public interest) in Class A wetlands—those with highest quality; no permits would be required in Class C; and permits would be required in Class B. Differences between these classes would reflect the relative criticality and regional uniqueness of wetland functions in the respective classes. Criteria are spelled out in detail in the bill.

Finally, Representative Edwards' bill (H.R. 4255) calls for a one-year study by the National Academy of Sciences to determine scientifically and technically sound methods for wetlands identification and delineation. This concept—that the complex questions of wetlands classification should be addressed independently by scientists, rather than through the political process—is gaining support among many groups involved in the current debate.

Second, what activities or areas should be covered by the regulatory program? Should the law provide for additional or more precise exemptions from permit requirements, or should its coverage be broadened—for example should drainage be made subject to regulation?

Section 404 requires that a permit be obtained before a person may dredge or fill a wetland area. It does not require a permit for certain activities, such as draining a wetland, that nonetheless may reduce the wetland's functional values without filling it. The law also exempts certain major categories of activities (normal farming, ranching and silvicultural activities) that may be responsible for much of the current loss of wetlands nationwide.

The Bennett and Edwards bills would add drainage, excavation and channeling to covered activities that require a permit, and also would add driving of piles, placement of obstructions or other activities that lead to more than minimal change to the hydrologic regime, hydrophytic vegetation or disrupt streamflow. The Bennett bill would not expand the list of exempted activities now specified in Section 404(f) of the Clean Water Act, while the Edwards bill would clarify in the law how agricultural wetlands (including those converted to production of crops before December 1985) are to be treated for purposes of regulation.

The Thomas bill similarly would add drainage, excavation and channeling to covered activities. Unlike the Bennett and Edwards bills, though, it would both expand and modify activities that are exempt from permitting. It would add three types of activities: aquaculture activities; aggregate or clay mining activities carried out under a state or federal permit; and activities to restore the functions of altered or degraded nontidal wetlands on private lands, where that is done under an agreement between the landowner and the U.S. Fish and Wildlife Service (FWS) or Soil Conservation Service (SCS), under the Wetlands Loan Act or the wetlands reserve provisions of the Farm Bill. In addition, the Thomas bill would modify two current exemptions by, first, requiring the use of Best Management Practices for silviculture activities that are exempt, and second, by modifying the exemption for maintenance of drainage ditches.

The Hammerschmidt bill is the only one of these proposals that would not expand the list of covered activities to also include drainage, excavation or any others. However, it does address exemptions under Section 404(f). First, like Representative Thomas' bill, it modifies the exemption for maintenance of drainage ditches. It also would add an exemption for abandoned mine reclamation projects conducted under the Surface Mining Control and Reclamation Act.

Finally, the Hayes/Breaux bill—like Bennett's, Thomas' and Edwards'—adds drainage, channelization and excavation to the list of covered activities. It also addresses exemptions. First, of course, everything in Class C wetlands would be exempt from permitting. Like the Thomas bill, it adds an exemption for aquaculture and for aggregate or clay mining activities done under a permit. The Hayes/Breaux bill also adds five exemptions not included in the other bills. These would include: activities on farmed wetlands, so long as the use of land would not be changed; activities associated with marsh management under an approved program in Louisiana; activities in incidentally created wetlands; activities in lands in the coastal zone which are excluded from regulation under an approved Coastal Zone Management program; and expansion of ongoing farming operations for the obligate plant Vaccinium macrocarpin (i.e., cranberry production areas).

Third, should the institutional arrangements for implementing Section 404 be modified, for example, by giving all permit responsibility to a single agency, such as the Corps or even EPA, so as to eliminate delays that some people feel characterize the current program? Should existing provisions concerning state administration of the Section 404 program be modified to give states greater incentive to assume permitting responsibilities?

The Corps and EPA jointly administer Section 404—the Corps issues permits, utilizing environmental guidance from EPA, and only EPA has authority to veto a permit that the Corps proposes to issue. Other federal agencies also have advisory roles in the process. Some argue that these multiple participants and their interactive roles generate confusion and uncertainty for applicants. States may assume responsibility for aspects of the Section 404 program, but only Michigan has chosen to do so. Others have cited factors such as the potential for continued Federal interference and program costs as reasons for not seeking program delegation.

None of the pending bills proposes to give sole responsibility to EPA, but all of them address federal institutional issues, as well as the issues of state programs or state control.

The Bennett bill provides a detailed process for the Corps to consult with and obtain comments from the FWS and NMFS. It would make no change in EPA's existing veto authority, under Section 404(c). And it would enhance the role of EPA's Section 404(b)(1) guidelines by calling for criteria comparable to those under Section 403(c) of the Clean Water Act, concerning ocean discharges. The latter addition would incorporate into Section 404 a stringent standard of review and comparison of disposal alternatives, as is required by Section 403(c). On state programs, the Bennett bill would expand existing language in the Act by allowing a state to assume partial permit program responsibility, if it chooses to do so.

The Thomas bill appears to make no substantive change in the interagency review process, but does direct the Corps to respond in writing if it doesn't accept FWS recommendations on a permit. It also adds a requirement under EPA's veto authority for administrative appeal of a veto. On state programs, the Thomas bill also would allow a state to take partial administration of the program, for example, for one or more counties in the state, and would require biannual reports to EPA on state-administered programs. It also would allow states and the Corps jointly to do advance planning of wetlands areas. Finally, it would add a new section authorizing states to develop conservation plans and management strategies for reducing degradation, and preserve and enhance the quality and quantity of wetlands.

The Edwards bill contains some elements of H.R. 251 and H.R. 404, requiring the Corps to consult with the FWS and NMFS, and directing the Corps to respond in writing if it does not accept these agencies' recommendations on a permit. The major procedural change in H.R. 4255 would be creation of a Fast Track mechansism for expediting minor permits within 60 days of the notice of an application. Minor permits are defined as those involving no more than one acre of wetlands and which are proposed by an individual or small business and are not part of a larger proposal. It is unclear how permits in these small-acreage areas would relate to the activities now covered by the Corps' Nationwide Permit No. 26, a general permit for minor activities that take place in areas of less than 10 acres.

The Hammerschmidt bill would repeal EPA's veto authority. Except for generally requiring decisions on permits within 90 days, H.R. 404 would not modify other agencies' roles and responsibilities under the regulatory program. Further, it gives a combination of federal agencies (not just a single agency) responsibility for some new programs proposed in the legislation, such as national programs for wetlands restoration and creation, and giving the Corps and EPA shared responsibility to investigate and carry out mitigation baking demonstration projects. On state programs, the Hammerschmidt bill, like Bennett and Thomas, would allow states to assume partial responsibility for the program. Like Representative Thomas' bill, this one authorizes states to develop wetland conservation plans, but unlike H.R. 2400, this bill would link state administration of the permit program with development of such a conservation program.

Finally, the Hayes/Breaux bill—like Representative Hammerschmidt's—also repeals EPA's veto authority, but goes beyond this to give all regulatory responsibility to the Secretary of the Army. By totally rewriting Section 404, H.R. 1330/S. 1463 would eliminate EPA's responsibility to issue environmental guidelines under Section 404(b) and also would eliminate the interagency coordination that now is provided under Sections 404(m) and 404(q) of the Act. It should be noted, however, that, to the extent FWS and other agencies have responsibilities under statutes such as the Fish and Wildlife Coordination Act, some other agency involvement is likely to continue, but certainly less than is currently the case. On state programs, the Hayes/Breaux bill adds procedural details to the existing process, but, again, the Corps would be the agency to authorize state programs, not EPA. It would give the Corps one year to act on a state's permit program application, after which time the program would be deemed approved.

The Hayes/Breaux bill would not expressly allow for states to assume partial program responsibility under Section 404. Neither it nor Representative Edwards' bill would provide federal funding to assist state management, regulatory or wetland conservation programs. The Edwards bill, however, addresses funding in certain other ways. It would, for example, authorize federal funding to train wetland delineators, expedite mapping under the National Wetlands Inventory, and support education and outreach programs of the Corps and EPA.

Conclusion

Wetlands issues are highly visible in the Congress, fostered in large part by anecdotal reports about impacts of regulatory programs on farmers, small businessmen and individuals who own small parcels of land. However, whether the 102nd Congress will adopt any of these individual legislative proposals, draw concepts from one or more of them for an alternative proposal, or enact no legislation at all is unclear for at least two reasons.

First, currently there is no consensus on the issues raised in the wetlands debate, as indicated by the diverse approaches taken in the bills discussed here. Second, some observers hope that problems of wetlands delineation and regulatory process will be settled administratively by the federal agencies with responsibility for wetlands programs. Such a solution would leave complex scientific issues in the hands of those with greater technical expertise, while relieving Congress of the need to resolve difficult and divisive policy issues.

Private Property and Wetland Conservation

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Introduction

For the past 50 years, the main strategy for dealing with wetland losses and declining waterfowl populations has been the protection of wetlands through land acquisition, mainly by state and Federal agencies. During the 1960s the U.S. Fish and Wildlife Service (FWS) began an accelerated wetland acquisition program that was funded by the Wetlands Loan Act of 1961. In addition, 30 years of duck stamp receipts, monies from the Land and Water Conservation Fund and other receipts have resulted in hundreds of millions of dollars expended by the FWS for land acquisition since 1960. This includes the small wetlands acquisition program and other additions to the National Wildlife Refuge System. This is in addition to the monies spent on land acquisition by state wildlife agencies throughout the country.

Despite 30 years of wetlands acquisition, duck populations have declined and we have continued to lose wetlands. Wetlands in the U.S. have been reduced, largely as a result of man's activities, from an estimated 215 million acres during colonial times to 106 million acres in the mid-1970s (Jahn 1989) and to 103.3 million acres (97.8 million freshwater and 5.5 million coastal) by the 1980s (Dahl and Johnson 1991). The greatest rate of loss occurred in a 20-year period from the mid-1950s to the mid-1970s. During this period, 87 percent of these losses were to agricultural conversion, 8 percent from urban development and 5 percent from other activities (Jahn 1989). The most recent data confirm that these losses have continued from the mid-1970s to the mid-1980s, with agricultural land uses accounting for 54 percent of the conversions from wetland to upland (Dahl and Johnson 1991).

The common factor among all of these causes is that wetland losses are occurring primarily on private land. Seventy-four percent of the remaining wetlands in the continental United States (about 65 million acres) are privately owned (FWS 1990). Wildlife professionals have learned from these actions that we cannot maintain the desired wetland base and waterfowl populations as well as many other species of wildlife solely through land acquisition and management of public lands. It seems readily apparent that if adequate habitat is not provided on private lands, we will continue to see declines in wildlife populations and especially duck populations.

Due to a past emphasis of bringing land into production, agriculture has accounted for most wetland losses. For most of our nation's history, it was national policy to drain or fill wetlands and encourage agricultural development. However, the situation has changed. A gradual shift in public awareness and public policy helped to bring about change in the federal government, from providing programs that subsidized wetland drainage for agricultural development to the wetland benefits of the 1985 and 1990 Farm Bills. In 1989, President Bush announced the administration's goal of no net loss of wetlands. Also, the North American Waterfowl Management Plan is providing new and unprecedented opportunities for private wetland conservation. These new initiatives have opened the door between landowners and wildlife conservation interests. There is a greater awareness today of the potential for application of new and modified farming practices that can be beneficial to wildlife and associated habitats.

These new programs to protect wetlands on private property are extremely important. However, experience has shown that for private land conservation programs to be successful, policies need to be incentive oriented as well as regulatory.

In the fall of 1990, Ducks Unlimited (DU) began a major private lands program. This program is designed to deliver wetland projects that assist the landowner's operation as well as conserve the wildlife resource. The following paragraphs describe part of this program as an example of an incentive program to promote wetland conservation on private lands.

Private Lands Program of Ducks Unlimited

The Private Lands Program (PLP) is being delivered as an outreach and extension effort, as well as a direct habitat development program, through the regional offices of DU, which have multi-state responsibilities and are located in strategic waterfowl production and wintering areas. The PLP's major goal is the restoration, enhancement, creation and protection of wetlands and their associated upland habitats on private property. This is being accomplished by delivering programs in the following areas:

1. technical assistance;
2. demonstrations/applied research;
3. habitat development;
4. landowner workshops;
5. workshops for conservation and agriculture professionals; and
6. informational and educational materials development.

While DU is often the delivery organization with these techniques, our effort is really as a catalyst to encourage new partnerships that result in strategies, cultural changes in upland and wetland management by private landowners, operators of agencies, and others concerned with our continent's natural resources. The following descriptions and recommendations focus on the United States, but our program is operating throughout Canada and Mexico. The result of these international efforts is applied in all programs regardless of natural boundaries.

Northern Great Plains

DU's longest-term efforts on private lands have been in the prairie pothole states of the U.S. The following examples show the scope of this extensive private lands work and provide examples of programs that have shown considerable success. In nearly all cases, the landowner provides the land and an agreement period free of charge to DU in exchange for the installation of the practice.

Establishing water retention. DU is cooperating with Region 6 of the FWS in the funding and construction of retention dams for private landowners. Thirty-two conservation districts have pledged $5,000 each as a challenge grant to DU and the FWS for construction costs. The dams establish small, shallow wetlands in the Prairie Coteau and Missouri Coteau regions of South Dakota. These are extremely productive for waterfowl and are located near adequate brood waters. After the shallow wetland evaporates, the dugout provides livestock water. The landowner pays 25 percent of the construction costs, but this fee is waived if the landowner agrees to fence off the area and prevent grazing for a 10-year period. In cooperation with the FWS, the South Dakota Department of Game, Fish and Parks, the Soil Conservation Service (SCS) and conservation districts, DU hopes to assist in the construction of 500 retention dams this year.

Small wetland restorations. Numerous, small wetland restoration projects have been done on private land in cooperation with Regions 3 and 6 of the FWS. Restorations vary from approximately 0.5 to 10 acres in area. All are valuable pair habitat and some of the larger restorations can provide brood rearing habitat. Site selection is based on the value of the surrounding upland nesting habitat and care is taken to ensure that there is reliable brood rearing habitat in the vicinity. A typical landowner agreement is 10 years.

Conservation tillage. Various habitat management demonstrations are promoted on private lands in the Dakotas. One example involves the purchase of three undercutters by Ducks Unlimited, which are being used on fields in North Dakota as an alternative to summer fallowing. The technique encourages farmers to leave cover on the ground to provide habitat for nesting waterfowl and prevent soil erosion. These demonstrations are conducted in cooperation with the FWS, SCS and various conservation districts.

Grazing and haying demonstration. A grazing and haying demonstration is now underway in North Dakota that we hope will impact the future use of lands enrolled in the Conservation Reserve Program (CRP). CRP was initiated to reduce soil erosion, increase herbaceous cover, reduce sediment and other pollutants in waterways, provide wildlife habitat, and reduce surplus commodities. Wildlife, including waterfowl, has benefited from this program but there is great concern over the status of these lands once the CRP contracts end. Much of this land may again be put into crop production. This DU demonstration is aimed at encouraging producers to keep lands in grass to produce livestock. The fields that will be involved in this haying and grazing demonstration are highly erodible fields that averaged an annual soil loss of 26 tons per acre per year when they were cropped. Participating in this demonstration are the FWS, North Dakota Agricultural Experiment Station and Cooperative Extension Service, Soil and Water Conservation Districts, and the SCS. All PLP demonstrations include workshops, tours, published findings, and coverage by radio and television.

Rotational grazing systems. Fence materials and water developments are provided to landowners who agree to establish deferred grazing systems on their pastures. Such systems will keep portions of a pasture entirely free of grazing during the nesting season. This program involves both direct enhancement and demonstration, with the hope that many ranchers will see the benefits of rotational grazing and that it will become a typical practice within the ranching community. A typical agreement length is 10 years.

Seeding sweet clover on summer fallow. Sweet clover seed is provided to landowners who plant it into fields that are scheduled to be fallowed the next year and not disturbed until after the subsequent waterfowl nesting season is completed. The sweet clover provides excellent nesting cover on lands that would otherwise be disced several times during the nesting season for weed control and water conservation. The clover helps provide nitrogen to the soil, reduces wind and water erosion, and can add organic matter to the soil when it is turned under. If DU provides the seed for this practice, the landowner must agree not to cut the clover for hay until after the nesting season. A typical agreement is for one year.

Secure nesting habitat. Nesting islands, peninsula cut-offs and electric fence exclosures are the techniques used to provide secure nesting habitat. Typical agreement lengths are 10 years for nesting structures and electric fence exclosures, and 30 years for nesting islands and peninsula cut-offs.

Creation of upland nesting cover. Specific grass seed mixtures and/or seed-bed preparation costs are provided to landowners who agree to develop uplands for nesting birds. Often this activity occurs on the same property as DU's small wetland restorations. Minimum agreement length is 10 years. This program is designed to enhance wildlife cover on productive lands that do not qualify for CRP.

Wetland enhancement activities. Wetlands that are covered with dense, monotypic stands of cattail are improved with the selective use of herbicides, discing, burning, level ditching, etc. in order to open these areas to breeding waterfowl. Most agreement lengths are for one year, although the practices often last for many years.

Southern United States

Private land efforts in the southern United States have focused on working with individual landowners to provide winter habitat for migratory birds, especially waterfowl. The effort operates primarily in the Lower Mississippi Valley and Gulf Coast Joint Ventures.

DU provides technical assistance to landowners in the Mississippi Delta in cooperation with the Mississippi Partner's Project. This program is designed to provide wintering habitat for waterfowl through the installation of water control structures on private land. Partners include the Mississippi Department of Wildlife, Fisheries and Parks, the FWS (Region 4), the Delta Wildlife Foundation (beginning in 1992) and DU. In 1991, this joint effort resulted in more than 12,000 acres of seasonal water for migrating and wintering waterfowl in Mississippi. The success of this program has been largely a result of donations of large diameter steel pipe from gas and pipeline companies (over 15,000 feet to date). The pipe is used to make water control structures which are given to cooperating landowners, who then put in the structures at their cost. Landowners sign 10-year agreements that the fields will be flooded from November through March 1. This program is being extended to include Mississippi, Louisiana and Texas with a goal of an additional 23,000 acres of wintering habitat provided in the next year. The partners for this effort will be FWS, SCS, state wildlife agencies in each state, five private energy companies and DU.

In the rice prairies of coastal Texas, a technical assistance program is jointly funded by the FWS (Region 2), Texas Parks and Wildlife Department, the SCS and DU. Over $800,000 is provided by the FWS and the Texas Parks and Wildlife Department to support habitat development projects on private land in the rice prairies of Texas. In addition, DU is serving as the "banker" for funds donated by Phillips Petroleum Company for waterfowl habitat development in the Playa Lakes Joint Venture.

California's Central Valley

The Central Valley of California, where DU has focused PLP efforts, is an extremely important wintering area for waterfowl in the Pacific Flyway. One of our strongest private lands efforts is a large-scale demonstration on rice land to provide alternatives to burning rice stubble, a common practice in California. Air quality concerns have resulted in regulations that greatly restrict (down to less than 10 percent of current acreage) burning of stubble. By rolling the stems and then flooding the fields, which allows the stems to decompose, burning is not required. Current yields on demonstration fields are slightly higher than on the burned fields. The technique accomplishes the same end as does burning the stubble, but it has the benefit of restoring habitat created for wintering waterfowl.

DU formed a landowner cooperative in the San Joaquin-Sacramento Delta in order to assist in the management for wintering waterfowl. Through this cooperative, technical assistance is provided to farmers on the timing, duration and depth of flooding. These efforts directly influenced 9,000 acres, and impacted more than 24,000 acres of wintering waterfowl habitat in 1991–92. Water contracts were renegotiated with the California Department of Water Resources, California Department of Fish and Game, and the FWS for early fall flooding, principally for pintails, mallards and shorebirds. By mid-winter, the bird response to these sites was impressive. For example, the Staten Island Ranch, with approximately 5,000 acres flooded, was holding over 100,000 ducks, 20,000 tundra swans and more than 15,000 sandhill cranes.

One of the most important aspects of private wetland management in the West is private duck clubs. Technical assistance was provided to 250 club managers this past year from the Klamath Basin to the Imperial Valley.

Other Private Land Efforts of Ducks Unlimited

DU assisted with 17 professional improvement workshops for private and public wetland managers in the West this past year and jointly sponsored five regional workshops in Mississippi for private landowners. Recently, DU conducted a national workshop for county Extension agents from the rice-producing states in order to provide information on the integration of wintering waterfowl management with rice production and sponsored a workshop on playa lake management for biologists from the five states of the playa lakes region.

DU is providing financial support for the private land efforts of other agencies. For example, the private lands program in Indiana is a cooperative effort among the FWS, Indiana Department of Natural Resources and the National Fish and Wildlife Foundation. The GPRO is providing funding to the FWS for wetland restoration in the prairie pothole area and DU also has supported wetland efforts of the Reinvest In Minnesota (RIM) program.

Policy Options for Maintaining Wetlands

The private lands efforts of Ducks Unlimited, although new, are in high demand. The program is very popular with agricultural landowners due to the philosophy that everyone must benefit from the result. In almost every case, this program provides tangible benefits to the farm or ranch operation, as well as to wildlife. This is not to say that private wetlands can be fully protected only with incentive programs, but we do believe that numerous opportunities exist for incentive programs that benefit landowners, while protecting or enhancing the wildlife resource.

A comprehensive program to benefit wetlands will include a variety of policy options. It generally is agreed that it is not possible to acquire all remaining wetlands, or even to acquire enough of the wetland base to maintain waterfowl and other wetland wildlife populations. Because the majority of the wetlands base in the United States and Canada is on private lands, we must institute policies that influence this private lands base.

A coherent policy to protect wetlands on private lands will include regulations, incentives, acquisition of less than fee-simple rights, direct technical assistance, research and education. Such a program must be complimentary to a strong governmental and private acquisition program, and must continue to support high levels of funding to acquire important and threatened wetlands. Such acquisition will consist of outright purchase of all interests in the land and the purchase of sufficient rights to protect wetlands perpetually. While private stewardship of wetlands is extremely important, long-term, permanent protection of wetlands only is possible by acquisition.

It always is tempting to try new ideas and programs in any plan. However, there are tried and true methods of influencing private land stewardship and these tested approaches should not be overlooked. Traditionally, these methods have included extension education, demonstrations, and payments or subsidies. All of these methods are in use, and they do work. It is up to us to identify new ways to use these methods to increase the interest of private landowners in maintaining or enhancing wetlands habitats on lands they control.

The Need for Landscape Planning

Over the years, many governmental and other programs have been developed to encourage protection or improved management of wetlands. These programs have typically been site specific and isolated from other landscape protection measures. We believe that the most important policy need for wetlands is the incorporation of wetlands needs into larger scale planning efforts.

There are many calls for landscape-level planning for the protection of biological diversity, development of wildlife corridors, saving open space and so forth. It is our opinion that wetlands protection measures should be examined on the landscape scale. Many of the wildlife species that use wetlands depend on a network of wetland types to provide their life cycle needs, either at the local level or over wide distances during extensive migrations. Wildlife would obviously benefit from a broader examination of the wetland aspects of landscapes.

DU has developed in Canada a program called "Prairie Care" that is designed to examine large blocks of landscape to determine what factors are missing and feasible to develop in order to enhance waterfowl populations. This concept could be extended to important wetland and waterfowl areas of the United States. The planning effort in Canada is directly transferrable to the U.S. prairie states. A similar program could be developed for other areas with the intention of examining how wetlands on private and public lands fit into the entire landscape. This effort would fit well with the need to establish greater knowledge of the general landscape diversity and the conservation of a broad range of species.

The following paragraphs briefly discuss a few ways in which we might modify policies to positively influence wetlands on private lands. Each of these approaches could become a part of an extensive landscape effort to protect wetlands and associated uplands.

Conservation Reserve Program modification. The Conservation Reserve Program (CRP) has placed millions of acres of potential nesting habitat for waterfowl and other migratory birds on the ground. The full benefits of this program to migratory birds has not been realized due to the continuing drought in the prairie pothole states. It will be important for wildlife, and especially waterfowl, for agencies, agricultural organizations and conservationists to see that CRP stays in place beyond the tenure of existing contracts. The original purposes for CRP are still valid. We need to prevent the improper cultivation of these highly erodible acres. A range of innovative approaches to encourage the retention of permanent vegetative cover on CRP acres should be developed in the near future. Whenever possible, it would be desirable to place CRP acres under perpetual easement, to prevent them from returning to cultivation. The costs of CRP have been high, but the costs from allowing these areas to return to intensive cultivation will be even higher in the long run. It may be desirable to develop a similar bidding program to allow the U.S. Department of Agriculture to purchase perpetual easements on these areas. While this approach might seem expensive, it is cheapter in the long run than most other options. In fact, in many areas of the United States, the 10-year payout under current CRP contracts will exceed the total cost of an outright purchase of the land.

Wetlands Reserve Program. It is important that the pilot program be completed on schedule and that this program receive full funding in the next budget cycle. The easements purchased under this program should be perpetual rather than short-term. While some have advocated 30-year easements, this would not accomplish the need for permanent securement of wetlands on private lands.

Targeted conversion of croplands. Efforts in the northern great plains have shown that landowners who are given incentives and technical assistance in converting cropped areas into grazing systems will undertake these efforts voluntarily. It would be desirable to develop a governmental program to encourage such changes in areas of the Great Plains and other marginal farming areas where subsidies make current agricultural practices possible.

Point source pollution control. Created wetlands are being used in many areas for the treatment of effluent from existing sewage treatment facilities. This use should be expanded and made a part of the normal treatment systems throughout the U.S. This effort also can be expanded to include the treatment of runoff from agricultural feedlots and other identifiable pollution sources. This approach is proving successful in the treatment of acid mine drainage and it should be incorporated into the standard approaches for this problem nationwide.

Once additional techniques are developed for application to individual farm situations, this technique could find broad application in many areas. While subsidies would be desirable to encourage these practices, existing laws requiring treatment of effluent and cleanup of mine drainage problems would likely be sufficient to result in adoption of these practices once they are more fully developed.

Influencing non-point pollution control. We need to develop new techniques for the control of non-point source pollution runoff. Agricultural lands are a source of runoff that damage reservoirs and watercourses through the introduction of nutrients and contaminants. Retaining or slowing runoff is a proven technique for allowing waters to be cleansed through natural biological, chemical and physical processes. Wetlands provide the type of natural environment where these cleansing processes can be very effective. Wetlands are known for their ability to treat nutrients and to tie up contaminants. It would be positive to combine the restoration and creation of wetlands in agricultural areas with the need to control non-point source pollution. We would propose that the SCS be given a task to identify several test watersheds in various parts of the U.S. where the small watershed program would be used to develop a portion of the area into small wetlands which then would be strategically placed to intercept runoff, retain it in shallow basins and release it over an extended period. This program would vary from the current small watershed program in that the basins created would not be reservoirs, but many small retention areas where wetland vegetation would be fostered. Ideally, the test watersheds would be in areas where wetlands have been drained and are available for restoration. This effort should provide benefits to water quality while providing increased wildlife habitat.

Once the watershed tests are in place and operating, they should be used for demonstration through normal procedures, such as field tours. If the effort proves successful, subsidy programs should be developed to encourage widespread application to agricultural lands throughout those areas where the technique has application.

Water rights. In the western U.S., water is becoming an increasingly scarce resource. Obviously, the availability of water is critical to the proper management of wetlands. DU has taken several actions to purchase water rights that benefit both waterfowl and the landowner. While we do not have specific suggestions for the securement and protection of water rights for wetlands and wildlife that will be applicable nationwide, this *will* become the most important issue that wetland managers have to tackle. We must look for innovative partnerships with water right holders that improve our ability to manage wetlands and protect other natural resources, while preserving the water right holder's interests.

Inheritance tax program. One of the more significant problems with the long-term management of wetlands on private lands results with the change of attitude that a change in ownership often brings. Government policies currently make it difficult to transfer sizable properties, such as farms and ranches, to heirs upon the death of a current owner. Even when the heirs wish to keep a property intact, they may be required to sell all or a portion of the land and its assets to pay the variety of taxes that are imposed by the transfer. One long-term method to provide protection to existing landscapes, convert crop lands back into permanent cover and restore wetlands would be to provide relief from inheritance taxes for placing a perpetual easement on lands to maintain their natural or restored features. Over several generations, this method could influence broad landscapes, such as the Dakotas and eastern Montana. A similar concept could be applied in other areas where such a conversion is desirable.

Conclusion

Private lands long have been recognized as the key to maintaining wildlife. This is especially true for wetland wildlife. While it is important to continue adding wetlands to the public estate, it will be impossible to properly protect and manage wetlands without influencing private lands.

Improving wetlands protection and management on private lands can be accomplished through a combination of incentive and regulatory programs. We must look for innovative methods that benefit wildlife and other wetland values, while providing significant benefits to the landowner. Such programs do exist, but they must be expanded and encouraged throughout our nation.

References

Dahl, T. E. and C. E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970s to mid-1980s. U.S. Dept. Interior, Fish and Wild. Serv., Washington, D.C. 28 pp.

Jahn, L. R. 1989. Strengthening procedures for maintaining wetlands. Paper presented at the Annual Conference on Environmental Renaissance: From Backwater to Mainstream. The Georgia Conservancy 22nd Ann. Conf., Pine Mountain, GA. January 27–29, 1989. 10 pp.

United States Fish and Wildlife Service. 1990. Stewardship 2000, partners for fish and wildlife on private lands. U.S. Dept. Interior, Washington, D.C. 10 pp.

Wetland Protection Programs: Direction and Outlook of the U.S. Army Corps of Engineers

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Thanks for your invitation to this Conference. I salute the organizers for pulling together various interest groups and fostering an enormous amount of information sharing on a wide range of topics, many of them of keen interest to the U.S. Army Corps of Engineers, especially with the current Chief of Engineers, Lieutenant General Hank Hatch.

Speaking of General Hatch, he sends his greetings, his apologies for not being able to attend, and his assurance of the Corps of Engineers' strong commitment to environmental values and issues. He has quite a few things to attend to before he retires on June 4, 1992, after four years in the job.

The points I'll cover today include changes in Corps of Engineers' missions and direction, environmental initiatives as they pertain to wetlands, and the Section 404 Regulatory Program.

The Corps has been going through a change, just as other organizations and world events have been changing. Indeed, the topic of "change" seems present in everything we are involved with these days. it is mind-boggling, at least to me, the number of significant world political and military changes which have occurred in the past two–three years, such as removal of the Berlin Wall, Iraq's invasion of Kuwait and Operations Desert Shield and Desert Storm, the collapse of the U.S.S.R., and the downsizing of Soviet and U.S. military infrastructure, just to name a few. As these changes occur, our Nation is faced with the challenge of balancing the values and needs of its people.

As the needs of our Nation change, organizations change; and I would like to use the Corps as an example. Let me briefly run through some highlights of Corps' history and how it has changed to meet the changes in the Nation's needs and values. The corps was born in 1775, and immediately set about building fortifications at Bunker Hill. After independence, in 1802, Congress established the Nation's first engineering school—the U.S. Military Academy at West Point, New York. The Corps of Engineers ran West Point until after the Civil War.

In the 1800s, the Corps of Engineers was in the vanguard of westward expansion, mapping of trails, waterways and railroad routes. As the Nation grew, towns sprang up, largely along the waterways, which provided the best transportation possibilities at the time. Those waterways, however, posed navigation problems with clearing and snagging. In 1824, after extensive debate, Congress established a federal role in carrying out navigation improvements, and gave this mission to the Corps. In the 1890s, as part of its overall navigation mission, the Corps received authority to regulate work done by others in waterways in Section 10 of the Rivers and Harbors Act of 1899—the beginning of our Regulatory Program.

Jump ahead now to the 1920s, which saw devastating floods along the Ohio and

Mississippi Rivers, with local levees inadequate to contain them. Congress called on the Corps to design a comprehensive flood control system for the Lower Mississippi Valley. In the 1930s there were more flood, and Congress gave a nationwide flood control mission to Corps.

Then came 1941, and the mobilization effort for World War II. The overall military construction mission was transferred from Quartermaster Corps to the Corps of Engineers, who built scores of stateside and overseas bases, plus such engineering feats as the Pentagon, the Alaska Highway and the Manhattan Project.

In the late 1960s and early 1970s, environmental concerns received more public attention. NEPA was enacted, and the Corps became more deeply involved in the Regulatory Program through Section 404 of the Clean Water Act, which called on us to regulate disposal of dredged and fill material into all "waters of U.S.," including wetlands. The 1970s also were marked by a stoppage of authorization for new water resource development projects; some ongoing projects also were halted for environmental and other reasons.

The 1980s saw continued and growing national concern for the environment, with wetlands gaining more attention. It also was the era that saw passage of the 1986 Water Resources Development Act, with the first new authorization for water resources projects since the early '70s, and major reforms on cost-sharing policy.

In 1990, Congress passed another Water Resources Development Act, which emphasized the Corps' environmental protection and restoration mission by putting it on par with our traditional roles in flood control and navigation.

So where is Corps today?

We are an organization of about 41,000 civilians and 450 military officers, who carry out three basic programs: civil works (water resources), military construction and reimbursible work for 30 other federal agencies. Our total program for FY 92 comes to $9.5 billion: $4 billion for civil works; $5 billion for military construction; and $0.5 billion in work for others. We expect our total program for FY 93 will remain about the same.

Since I manage the civil works program and it is associated with many of the topics of your conference, I'd like to cover a few points of our program, especially as it relates to the environmental concerns and issues we're faced with.

In many ways, it's a balancing act, but many of us believe the environment will be the most significant engineering issue of the next decade. About two years ago, the Chief of Engineers set some new direction for the Corps, with increased emphasis on the environment. His philosophy embraced the sequencing concept: first avoid environmental damage where you can, then minimize the unavoidable damage, then mitigate remaining environmental losses when designing and constructing projects.

We also support the concept of Environmentally Sustainable Development. It's easy to say, but difficult to do, and we need your help in bringing about Environmentally Sustainable Development.

This brings me to the Corps' role in wetlands protection. It's significant, and has been ongoing for years, with increased emphasis in recent years.

On August 9, 1991, the President announced his Plan for Protection of Wetlands. It consists of three parts:

- strengthening wetlands acquisition programs;
- revising the Interagency Delineation Manual; and
- improving and streamlining the regulatory process.

The Corps is committed to support President's Plan, and let me briefly give some examples of what we're doing.

Wetlands research and development is a four-year, $22 million program, under the auspices of our Waterways Experiment Station in Vicksburg, Mississippi, and carried out at 45 sites. It builds on a previous Corps Wetlands Research Program (1982–89) which focused on regulatory affairs and delineation. The Wetland Evaluation Technique, a preliminary assessment of ecological function, was a product of that research.

Major thrusts of our current research include critical processes in wetlands, stewardship and management of wetlands, delineation and evaluation, and restoration and establishment of wetlands.

A key facet of this research is the emphasis on partnerships with others. The Environmental Protection Agency (EPA), Departments of the Interior (DOI), Agriculture and Transportation, and the National Oceanic and Atmospheric Administration (NOAA) are involved, as are Ducks Unlimited, the Nature Conservancy, and numerous state agencies. Technology transfer among these and other parties will be a major area of emphasis.

The Corps also recently embarked on a Coastal Wetlands Restoration Program under the auspices of P.L. 101–646, commonly known as the "Breaux Bill" after its sponsor, Senator John Breaux of Louisiana, passed in 1991. It is funded by $35 million per year from a sport fish restoration account, derived from a small engine gas tax. This fiscal year, the program will emplace 14 projects, primarily in Louisiana, at a cost of $33 million. The Corps chairs a task force of federal and state agencies looking at short-range projects and long-range plans.

Stewardship of Corps projects and lands is covered by Section 1135 of the Water Resources Development Act of 1986. This section authorizes the Corps to modify structures and operation of its existing projects to undo environmental problems. There is a $15 million annual cap for this work, and a requirement for 25 percent non-federal cost sharing. We currently have 26 projects and reports ongoing under this authority.

The Corps also participates in the Coastal America Partnership. Congress did not specifically fund it, but the goals and objectives are being achieved through participating agencies' (DOI, EPA, NOAA, Corps) existing programs. The Partnership is carrying out seven projects in FY 92, dealing with the problems of non-point source pollution, contaminated sediments, and restoration of coastal fish and wildlife habitat. The Corps has the lead for the Northeast and Southwest regional Coastal America demonstration projects: the Galilee Bird Sanctuary Salt Marsh Restoration Project, Narragansett, Rhode Island; and the Sonoma Baylands Tidal Wetlands Restoration Project, in San Francisco Bay.

The Corps plays a role in the North American Waterfowl Management Plan, under a cooperative agreement with the U.S. Fish and Wildlife Service (FWS) signed in January 1989. The Corps has stewardship of 12 million acres at its project sites, of which almost a million acres have been identified as having significant use or potential as waterfowl habitat. We are promoting joint projects with the FWS, SCS, Ducks Unlimited, Nature Conservancy and others to develop these sites as habitat.

One example of a wetlands demonstration project is *Riverlands 2000*, at Alton, Illinois, on the Mississippi River near St. Louis, a 1,200-acre site that adjoins the new Melvin Price Lock and Dam, and includes wetlands, wildlife habitat and prairie grass.

Our major role in wetlands protection, however, is the regulatory program—one of the most complex, controversial and sometimes frustrating things we do in the Corps.

The program has a long history, dating back to 1899 and Section 10 of the Rivers and Harbors Act, which gave us authority to block obstructions to navigation. The program maintained its navigational focus until the 1970s, when Section 404 of the Clean Water Act, recognizing the regulatory apparatus we already had in place, broadened our authority to regulate dredging and filling in all waters of the U.S.—including wetlands.

Carrying out the regulatory program, we employ a workforce of 1,000 people—70 percent of whom are biologists, ecologists and other natural scientists. We are currently in the middle of an effort to increase this staff by 25 percent, which will enable us to speed up processes, monitoring and enforcement.

The current workload of the regulatory program includes 17,000 individual permit applications per year, 60,000 activities under general (regional) permits, and 60,000 activities covered under general (national) permits—36 of them.

The Corps and the agencies with whom we cooperate on the Regulatory Program are working to implement the President's mandate to streamline the permitting process. The Corps has been designated as the sole federal agency to coordinate permit applications, consult with other agencies and encourage their involvement in pre-application meetings. There also is a rule under consideration that would deem permit applications to be approved after six months have gone by, unless an agency (including ourselves) can show us good cause to extend that deadline.

We also are working to revise and refine the interagency delineation manual, in concert with EPA, FWS and SCS. I can't get into specifics; since the work is still in progress, but I will note that we received over 90,000 comments on a draft that appeared last year. We hope for completion late this year.

As I've tried to briefly lay out for you, the Corps of Engineers, like other agencies and organizations, has been going through a variety of changes in which we are trying to balance the values and needs of our society to meet the requirements of today, as well as the future. To be a useful service organization to our nation, we solicit your ideas and assistance. This Conference is certainly one way of exchanging ideas, so thanks for inviting me today.

U.S. Wetland Protection Programs: Direction and Outlook of Stewardship Agencies

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The remarks given are those of the speaker and not necessarily those of the State of California or the Department of Fish and Game (DFG). They reflect the ideas developed as a fish and wildlife administrator, and my views as a wetlands enthusiast and duck hunter.

There is no doubt that in many parts of the country, including California, with which I am most familiar, that the past loss of wetlands (including over 85 percent of all coastal and 90–95 percent of all interior wetland) has made the possibility of any further loss of wetlands a nonnegotiable item.

I recognize that in other parts of the country, where wetlands are more prevalent, political realties may dictate an approach that has greater flexibility. It appears, however, from my personal perspective, that the issue of delineating a wetland from a scientific perspective can be and, in fact, legally has been separated from the issue of who makes the final regulatory decision of what is done with a wetland. For example, as I understand the 404 process, the Corps of Engineers, after alternative analysis review which are intended to fully weigh the consequences of potential impacts on wetlands, makes the final decision on whether to authorize fill or other activities, and whether or not mitigation will be required. At least in California, wetland decisions made outside of the Corps process are likewise finalized by local jurisdictions following an environmental review process, in which the impacts are required to be fully disclosed and from which mitigation may be required as a term of permits for development.

From the perspective of a wildlife agency, our role is clear. We recommend, at all times, a no net loss of acreage or value. Our determination and recommendation of wetland acreage is based on the Cowardin approach to identifying wetlands. We continue to believe that such an approach is scientifically valid, understandable and defensible. Our recommendation to the final decision makers is based on that approach. This single approach helps to ensure consistency on the part of our agency personnel and to provide regulated comments with consistency, as well.

In 1985, the DFG developed this policy. Following public hearings, the Fish and Game Commission (FGC), in 1987, concurred in this approach relative to all DFG comments on projects impacting wetlands. Thus, the regulated community knows, going in, the approach and direction that the DFG will take. The adoption of this policy by both the DFG and the FGC was challenged as creating an underground or *de facto* regulation. After review of the subject by the Office of Administrative Law, a decision was rendered that indicates this approach by the DFG and the FGC was appropriate, since it guided our internal recommendations and that other agencies at both the federal and local levels made the final call on what was ultimately to be done with wetlands. Only our department is bound by this policy, when it comes to our property.

It is unfortunate, from my perspective as a former wildlife administrator, that this distinction is rarely realized. In my opinion, if there is concern relative to the adequacy of this wetland identification approach, which was borrowed from the U.S. Fish and Wildlife Service, then I believe it would be appropriate to ask the National Academy of Sciences to review this wetland definition approach and, if necessary, recommend changes. Thus, a higher degree of consistency using a solid scientific method of identification can be utilized. Differences of applicability will still be left to the regulatory agency, such as the Corps, after weighing all relevant factors, both biological and economic, on a case-by-case basis.

From our agency's perspective, and to provide assurance and a consistency approach to the regulated community, we implement our no net loss of acreage or values policy with a recommendation that any mitigation needed be in-kind and onsite first (with the caveat that such wetlands should have long-term sustainability and benefits to wildlife). When mitigation is authorized to be accomplished offsite, it must be in-kind, with full consideration for long-term sustainable benefits to wildlife and in reasonable proximity to the area of impact. We believe that, once—on a case-by-case basis—a decision has been made to mitigate, it would be possible to have the mitigation occur preapproved, predeveloped and fully operating, and maintain sites that would assure working mitigation for the long term. In other words, we will consider mitigation banks. Such preapproved sites must be in reasonable proximity to the area of impact and would usually be done at the compensation rate of greater than 1:1.

Actual on-ground practice has shown that there is usually little difference in the final determination of wetland acreage between what our agency or the U.S. Fish and Wildlife Services (USFWS) has concluded is appropriate and in what the Corps has determined was appropriate, following their review and determination of wetland acreage requiring mitigation or avoidance. In practice, the Corps usually considers other waters of the United States. These are applied to areas such as mudflats, which are wetlands under our approach but may not be under the current Corps parameters of definition. In addition, if the Corps does an adequate review from historic wetlands and applies that to their permitting process, further conflicts are usually avoided. Prolonged drought conditions tend to be an occasional complicating factor. The primary problem has come in when the applicant has attempted to locate alternative mitigation locations that meet the standards for in-kind, fully sustainable wetlands in reasonable proximity to the project.

Regulatory review provides only part of the wetlands answer, at least from my outlook as the former administrator of a stewardship agency. Tough application of regulatory review, whether it be through the 404 process or rigorous enforcement of the swamp buster provisions of the Farm Bill, can only prevent further loss. It does not begin to address the balance of the wetland equation particularly in places like California, where we already have sustained losses that we know must be offset in order to address endangered species issues or to accomplish North American Waterfowl Management Plan goals, for example. Our State Legislature has recognized this and charged the DFG with developing a program to attempt to increase the wetland acreage within the State by 50 percent by the year 2000. Therefore, it seems appropriate that I take a couple of minutes to address the balance of the equation as I look at wetlands from the standpoint of a stewardship agency.

Obviously, land acquisition and restoration of wetlands by stewardship agencies at the state or federal level is the most assured means of meeting our long-term goals. Virtually every federal agency and most state agencies have recognized this concept and are putting in place programs to ensure continued protection of existing wetlands and enhancement or restoration to increase our wetland acreage. The USFWS and many state wildlife agencies have become very aggressive in land acquisition programs to ensure protection of wetlands. The habitat joint ventures under the North American Waterfowl Management Plan place a premium on nongovernmental partners in helping to accomplish our task.

In our efforts to acquire, enhance and restore wetlands, numerous nongovernmental partners, such as The Nature Conservancy (TNC) and Ducks Unlimited, are helping to achieve our wetlands goals. Both within and in areas outside of habitat joint ventures, I believe there is a real need for state and federal agencies to regularly coordinate our program for land acquisition to ensure that we are not caught in bidding wars amongst ourselves when attempting to acquire the most significantly remaining wetlands.

In California, we also are meeting with nongovernmental organizations (NGOS) to try to coordinate our activities and to stretch scarce land acquisition dollars. Strong support from NGOS was a critical factor in gaining passage in 1984 of legislatively passed and gubernatorial endorsed bonds for continued land acquisition. Our current Governor has again endorsed a bond measure that will hopefully appear on the 1992 ballot to provide continuing funding for wetland acquisition. In California, NGOS, such as the California Waterfowl Association, Planning and Conservation League, TNC and others, supported an initiative measure to ensure ongoing bond funds for wetlands acquisition. We recognize, however, that solely acquiring property without the means to provide for ongoing operations and maintenance (O&M) does not fully accomplish our purposes. Therefore, we are delighted when NGOS were able to help secure O&M funding for wetlands projects, including easements and annualized payment programs through the passage of the Tobacco Tax Initiative. This initiative dedicated a fixed percentage of revenue from that source not only to fish and wildlife needs, but also to wetlands.

Recognizing the resistance in some quarters to a program solely for land acquisition, we are working to implement an easement program which supplements and expands the existing federal programs in the area of easements and waterbanking. We also are working to develop programs that will provide annual payments both to private wetlands managers, such as duck clubs, who enter into programs that assure long-term maintenance of wetlands. Likewise, we are working with groups, such as TNC, Ducks Unlimited and California Waterfowl Association, within the context of the Central Valley Habitat Joint Venture to put in place incentive programs for agriculture to provide winter flood-up for the benefit of not only waterfowl but many nongame and endangered species that are dependent on wetlands. The Resources Agency has recently received a grant from the U.S. Environmental Protection Agency to establish a comprehensive policy recognizing these approaches and, hopefully, searching for others.

It is my personal belief that only such a fully integrated approach which balances regulatory protection with acquisition, incentives and sustainable management programs will be effective in protecting and increasing wetlands in our current political climate.

Special Session 5. *Biological Diversity in Wildlife Management*

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Focusing Conservation of a Diverse Wildlife Resource

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> *F. C. Knopf is a dreamer about wildlife. . . . When he grows up, he decides to build a park for wildlife only, mostly for extinct species* (F. Clifton Knopf [age 11] February 1992).

Like professional careers (Kennedy 1984), professions themselves evolve from relatively simple, naive premises to incorporate broader, more complex perspectives. The professions of forestry, range management, and wildlife management have moved from early emphases on production of commodities to management of sustainable resources. This professional transition began with the late-career writings of Aldo Leopold and rapidly gained public support after the publication of Rachel Carson's *Silent Spring* (1962), the catching on fire of the Cuyahoga River in Cleveland (1969) and Earth Day (1970). In the last 30 years, the wildlife management profession broadened its perspectives from the nearly exclusive management of game species to incorporate nongame considerations in the 1960s, contaminants impacts and management of endangered species in the 1970s, and conservation of biological diversity in the late 1980s. The conservation of biological diversity has generated major, new challenges for professionals in wildlife management.

Historic and contemporary roles of the wildlife management profession in conserving biological diversity were recently summarized by The Wildlife Society's Ad Hoc Committee on Biological Diversity (Scott et al. 1992). Today's session was developed at the request of The Wildlife Society Council and Wildlife Management Institute, with the charge of providing perspectives on how the wildlife conservation profession needs to focus actions to protect biological diversity during the 1990s, the decade when most of the great environmental struggles will be either won or lost (Lovejoy 1988).

What is biological diversity? The definitions are as diverse as the biological resource. As definitions become broader and less specific, conservation action becomes increasingly more burdensome. How does an agency, a regional director, or a local resource specialist manage for the "variety of life?" What can be done? What cannot be done? Wildlife managers/conservation biologists must assure that actions to conserve biological diversity will not, in practice, become counterproductive (Murphy 1989). I detect an overwhelming sense of anxiety within the profession relative to resolving the complexities of diversity conservation.

Ecology, as a science, is a diverse subdiscipline. What ecology brings to the larger science of biology is environmental perspectives for viewing genetics, organisms, populations, and ecosystems. Inquiries into biological diversity must be viewed as ecologically dynamic, including spatial scales that range from habitats to landscapes and continents, and temporal scales that include instantaneous, seasonal, life span, or evolutionary perspectives. It is the complexities of scales that have fostered operational disillusion with attempts to define and manage biological diversity. This session, as structured, is about the biological and ecological scales of viewing and conserving the diversity of wildlife in North America.

References

Carson, R. 1962. Silent spring. Houghton Mifflin Co., Boston, MA.

Kennedy, J. J. 1984. Understanding professional career evolution—an example of Aldo Leopold. Wildl. Soc. Bull. 12:215–226.

Lovejoy, T. E. 1988. Will unexpectedly the top blow off? BioScience 38:722–726.

Murphy, D. D. 1989. Conservation and confusion: Wrong species, wrong scale, wrong conclusions. Cons. Biol. 3:82–84.

Scott, J. M., E. D. Ables, T. C. Edwards, R. L. Eng, T. A. Gavin, L. D. Harris, J. B. Haufler, W. M. Healy, F. L. Knopf, O. Torgerson, and H. P. Weeks, Jr. 1992. Conservation of biological diversity: Some perspectives and a look to the future for the wildlife profession. Wildl. Soc. Bull. (In press).

Genetics and Biodiversity in Wildlife Management

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Introduction

Biodiversity is often considered synonymous with species diversity. In this approach to biodiversity, communities are sampled, number of individuals of represented species are recorded and various indices of species diversity are calculated. This view of biodiversity is focused on a single level of biological organization and on one measure of diversity taken within each community. Emphasis also should be placed upon diversity at other levels of organization (e.g., populations), alternate measures of diversity (e.g., genetic variability), and diversity within and among biological systems across the landscape. Measures of diversity can be derived from a number of different characteristics measured for biological systems ranging from the community to the individual level (Figure 1).

Reasons for interest in biodiversity center around the conservation of biological systems and maintenance of their ability to adapt to changing environments. Part of this adaptation will take place by species replacement within communities, but it will also involve the evolution of populations by changes in their genetic characteristics. Because of the latter, it is advisable to also consider biodiversity in terms of genetic measures of diversity. This approach has been difficult, if not impossible, until fairly recently when a variety of techniques have become available to rapidly assess the genetic characteristics of a number of organisms from bacteria (McArthur et al. 1988) to higher plants and animals (Nevo et al. 1984). Total communities have not yet been assessed, but assemblages of species within communities have been examined and measures of diversity calculated (Johnson 1973).

Measures of genetic diversity within biological systems commonly include multilocus genetic variability or heterozygosity, proportion of polymorphic loci and alleles per locus. Genetic diversity measures among biological systems include various indices of genetic distance or identity. These genetic measures have been used frequently for comparing populations or species, but not for communities or species assemblages. Using genetic data for comparison of species and populations may be of more value in wildlife management than measures of species diversity. Genetic data also can be used to calculate more familiar indices, such as the Shannon Wiener Index, by considering each new allele in a manner similar to that of an individual of a new species (Lewontin 1974). Considering biodiversity from a genetic perspective still puts emphasis on the basic variability of the system, and it can be measured in a way that is applicable to various levels of biological organization and allows quantification of differences among systems. Diversity expressed in genetic terms is also a measure of the information content of a biological system.

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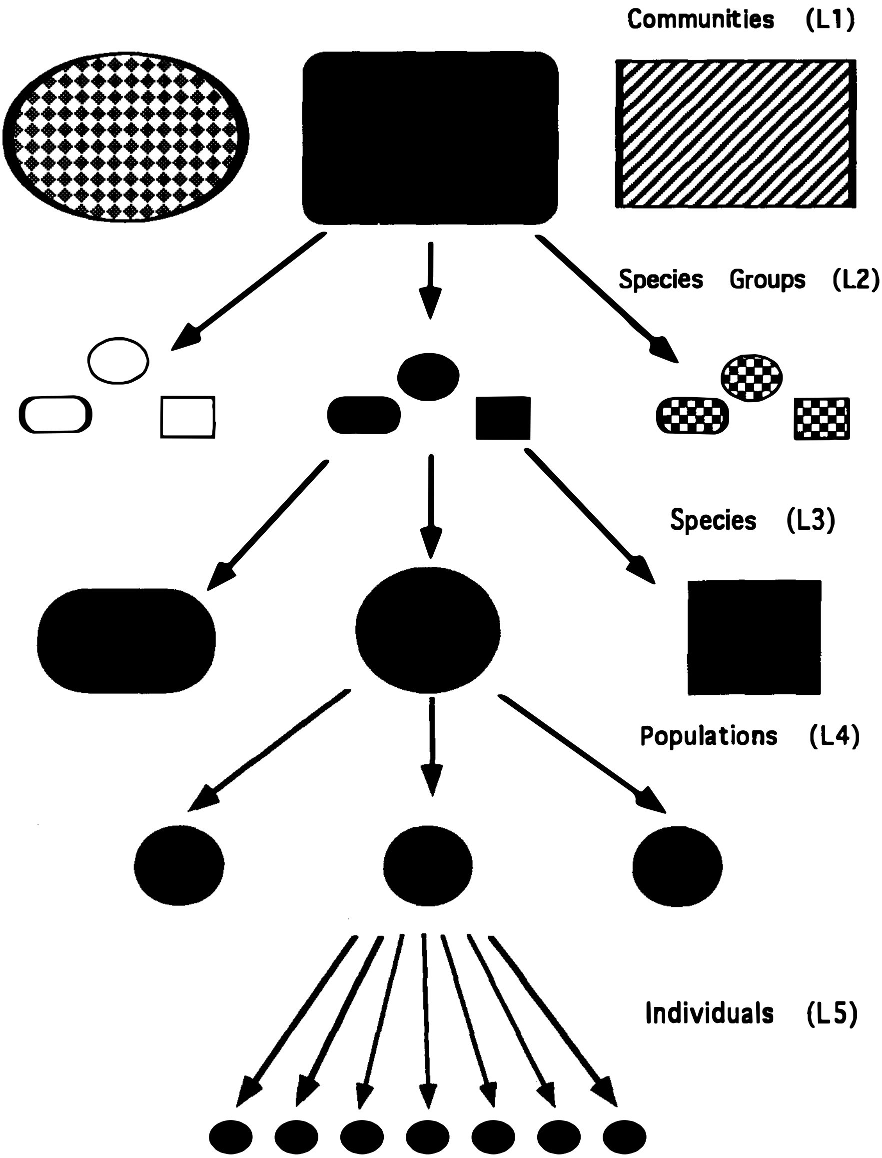


Figure 1. Hierarchical levels (L1–L5) of biological organization from communities down to individuals are presented. Each step down the hierarchy represents one unit at the level directly above it (e.g., species groups from a community [L1 to L2] or individual species from a single species group [L2 to L3]). Units (L2) with similar shading represent species of related assemblages. Each species group can be broken up into its component species (L3). Each species is usually composed of multiple populations (L4), which are composed of multiple individuals (L5). Other levels of organization could be included in the figure.

Levels of Biological Organization

Biological systems can be considered to be organized into a number of hierarchical levels (Figure 1). There is variation within each organizational level (e.g., community) considered, as well as among different units at the particular level (e.g., upland versus bottom land hardwood communities) being considered. Accordingly, for the genetic measures of diversity, there is an average value for multilocus heterozygosity, proportion of polymorphic loci and alleles per locus for each community, species group, species, population or individual. There also would be a genetic difference among the organizational units at each hierarchical level (e.g., different species groups within a community). Diversity among units may be more important at times than the diversity within the units. The best management strategy for conserving among-unit diversity may be to manage the units as separate entities, whereas the within-units diversity might require a management strategy of exchange among units.

Communities and Species Groups

Species assemblages are the highest hierarchical level yet studied for genetic diversity. Johnson (1973) studied genetic diversity in Hawaiian *Drosophila*. As the number of species in an assemblage increase, the allelic diversity also increases. A similar relationship has been found for assemblages of southeastern freshwater fish dominated primarily by sunfish (Centrachidae). Although Johnson (1973) did not study the relationship between genetic and species evenness in Drosophila, there is evidence for a relationship between these components of diversity in a set of 11 species assemblages of southeastern freshwater fish (Figure 2). Genetic diversity

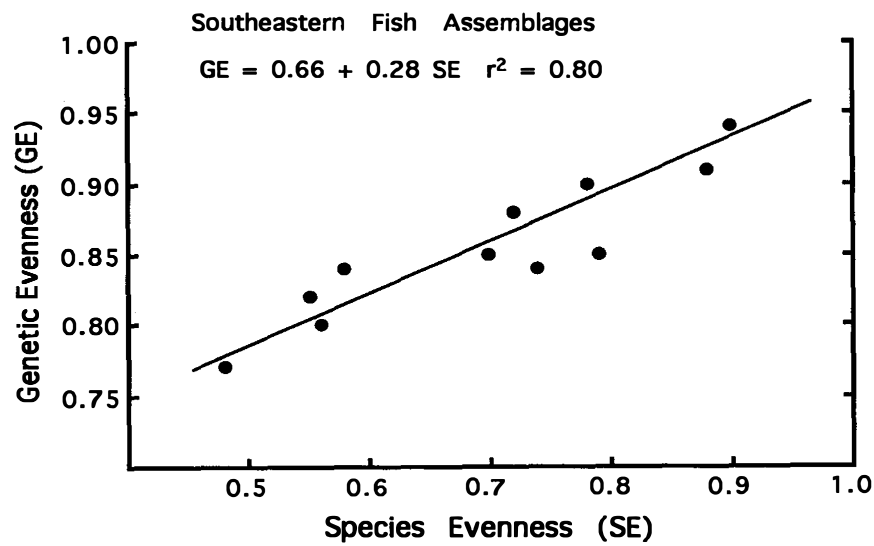


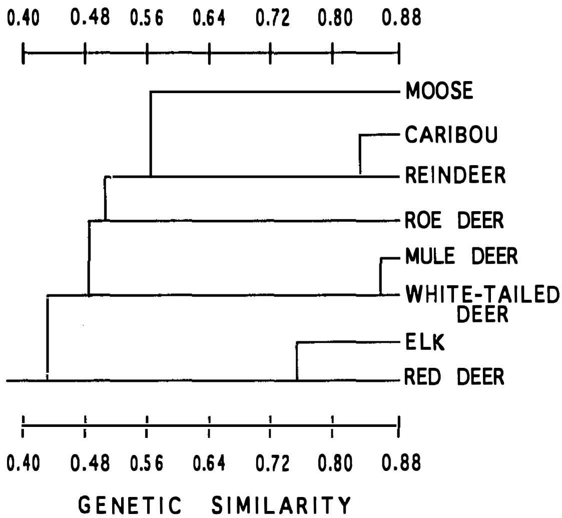
Figure 2. Genetic and species evenness are plotted for 11 fish assemblages from South Carolina and Florida. The linear relationship between the variables and coefficient of determination (r^2) are given.

(Shannon Wiener index) was also related to species diversity for these assemblages. This suggests that diversity at different hierarchical levels may be correlated, possibly because genetic information contained at one level is heavily dependent upon the information content at lower hierarchical levels. Interrelationships among diversity at different levels need further study, and hypotheses need to be generated as to what the relationships should be.

Species

There are three genetic considerations that need to be taken into account in a management program designed to conserve species. These include genetic dissimilarity, genetic variability and degree of genetic adaptation to environmental differences. Decisions should be made by considering all three together.

Large amounts of data have been collected on genetic diversity within species and genetic distances among species (Nevo et al. 1984, Avise and Aquadro 1982). The best example for wildlife species may be for members of the Cervidae. The genetic relationships among, and genetic variability within several Cervid species are summarized in Figure 3. These species do not really comprise a species assemblage within a community, but illustrate how the results of such an analysis might appear. Cervid species separated from others in the dendrogram by greater branch lengths are the most genetically dissimilar forms. For example, North American elk and Eurasian red deer (both *Cervus elaphus*) are genetically most similar to one another,



	H	P	A
MOOSE	0.4	2.4	1.27
CARIBOU	0.0	0.0	1.00
REINDEER	2.2	17.7	1.24
ROE DEER	2.4	10.5	1.11
MULE DEER	3.6	17.1	1.2
WHITE-TAILED DEER	10.4	32.3	1.94
ELK	2.1	17.9	----
RED DEER	2.1	22.8	1.26

Figure 3. A dendrogram representing genetic relationships among 8 forms of Cervidae was constructed using an unweighted pair group cluster analysis with genetic identity values (Nei 1972) taken from Baccus et al. (1983). Measures of genetic variability within each species are given as percent multilocus heterozygosity (H), percent polymorphic loci (0.01 criterion, P) and average number of alleles per locus (A). Values of H, P and A were taken from Smith et al. (1990) and Baccus et al. (1983). Scientific names of species that are not provided in the text are: caribou, *Rangifer tarandus*; moose, *Alces alces*; mule deer, *Odocoileus hemionus*; reindeer, *Rangifer tarandus*; and roe deer, *Capreolus capreolus*.

but represent the most genetically dissimilar species among those analyzed. The most genetically dissimilar species should be given some preference in management programs, especially when financial resources are limited and choices must be made as to which species are conserved (Vane-Wright et al. 1991).

The second general feature of concern in a management program should be the level of genetic variability. By any measure, the white-tailed deer (*Odocoileus virginianus*) is the most genetically variable cervid species among those analyzed and is among the most genetically variable mammal yet studied (Breshears et al. 1988). Other things being equal, the most genetically variable species should be given preference over less variable ones if limited resources force choices in a management program designed to conserve genetic diversity.

Genetic adaptation is another factor which needs to be taken into account. It would make no sense to maintain genetic diversity by featuring a biological unit that is not adapted to the available habitat. For example, a low altitude community or population that is genetically unique and quite diverse would be inappropriate if the available habitat were high mountains. Genetic adaptation to such gross environmental differences (i.e., high versus low altitude) is not difficult to demonstrate (Ayala 1982), but it is much more difficult to determine the degree of adaptation in some quantitative way when the environmental differences are less subtle. It would take considerably more effort to determine the level of adaptation in many situations than it would the genetic distances among or variability of the forms involved. Even if quantitative estimates of the degree of genetic adaptation, distance or variability were available, a way to combine these characteristics into a decision matrix to decide which species should be given priority in a management program has not been developed.

Populations and Individuals

Measures of genetic diversity within and among populations of animals are perhaps the most relevant to many current wildlife management programs. This is because wildlife biologists often focus on individual populations or metapopulation complexes for research and management purposes. In addition to within population measures of genetic diversity, such as heterozygosity, percent polymorphic loci and numbers of alleles per locus, biologists often use genetic distance or identity values as well as information about genetic variance partitioning (F-Statistics, Wright 1978, Nei 1977) to compare genetic diversity among populations of animals. Factors such as gene flow, mating system, genetic drift and selection all interact to create changes in genetic diversity within and among populations (Crow and Kimura 1970).

Populations may exhibit wide ranges of genetic diversity. Differences in gene frequencies among populations exist on a local scale within any one community or among populations in different communities across the landscape. Spatial heterogeneity among local populations is a general phenomenon observed in many animal species and has been especially well studied in vertebrates (Avise and Aquadro 1982, Gyllensten 1985, Smith et al. 1991, Rhodes 1991, Stangel 1991). For example, white-tailed deer in South Carolina exhibit significant shifts in gene frequencies over distances as short as 5 km (Ramsey et al. 1979).

Local differentiation can also occur in the amount of genetic diversity within populations. For example, multilocus heterozygosity changes with latitude in populations of the old-field mouse (*Peromyscus polionotus*) distributed along the east coast of the United States (Selander et al. 1971, Figure 4). These changes in population

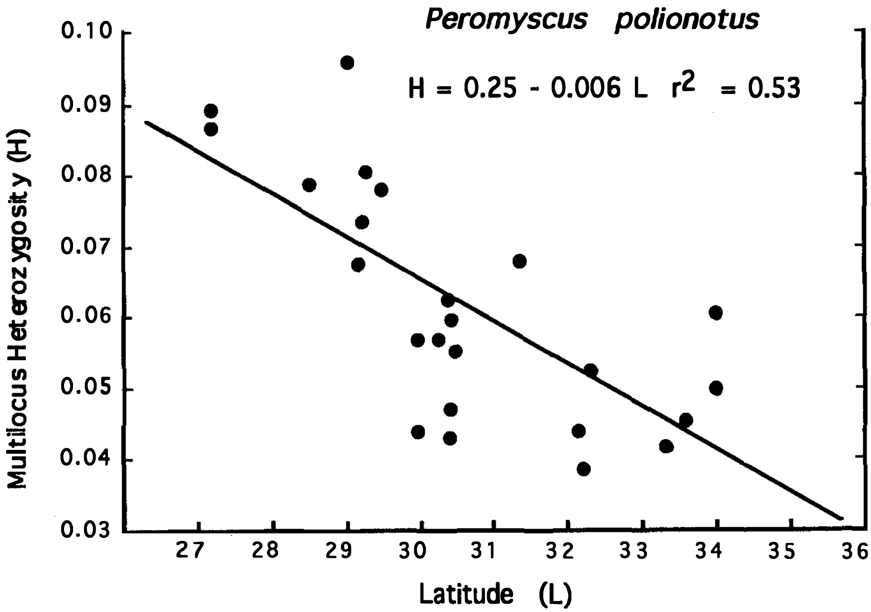


Figure 4. Expected multilocus heterozygosities of 24 southeastern populations of the old-field mouse (calculated from allele frequencies of Selander et al. 1971) plotted against latitude of collection for each population. The linear relationship between the variables and coefficient of determination (r^2) are given.

heterozygosity may be a function of selective pressures associated with a latitudinal environmental gradient (Bryant 1974), the probability and direction of gene flow, and genetic drift. Because some old-field mouse populations have more than three times the amount of genetic diversity than others (Figure 4), they have different potentials for management and evolution. For example, high diversity populations could be used as a stocking source into populations which have lost their genetic diversity. Local differentiation in the amount of genetic diversity within populations occurs in many wildlife species, including the white-tailed deer (Smith et al. 1984) and the wild turkey (*Meleagris gallapavo*) (Leberg 1991). The levels of genetic diversity in the old-field mouse also are positively correlated with reproductive rate and density, characteristics of prime importance in any wildlife management program, which may suggest a functional significance for the varying levels of genetic diversity (Smith et al. 1975). Populations that have diverged in their genetic characteristics serve as potential sources of genetic information and their uniqueness needs to be considered in management programs.

Genetic diversity of species is preserved both within and among populations. However, when the numbers of population units or individuals within those units decrease, loss of genetic diversity at the population and individual levels can be accelerated. When population sizes decrease, inbreeding and genetic drift can reduce the genetic diversity within individuals and populations (Crow and Kimura 1970, Leberg 1991). The accumulated effects of inbreeding depression may eventually lead to extinction of numerous populations and thus, to a loss of the overall genetic diversity represented within the remaining populations (Morton et al. 1955, Chesser 1991). Therefore, populations should be managed to maintain a size adequate to avoid inbreeding and loss of genetic variation (Gilpin and Soule 1986).

Management strategies which affect land use patterns or population size, and which create habitat fragmentation due to landscape disturbances, may substantially alter genetic diversity at all levels of biological organization (Harris et al. 1984). Whenever population structure is impacted in such a way as to increase inbreeding, genetic diversity within individuals will be reduced. If loss of the genetic diversity represented within individuals results in population or species extinction, then overall genetic diversity within and among species groups and communities will be reduced.

Loss of genetic diversity within individuals is important to wildlife biologists not only because of its accumulated effects for the biological systems at higher levels of organization, but because of its potential impact on population function. Numerous investigators have hypothesized the potential benefits of increased heterozygosity to individual fitness (Mitton and Grant 1984, Allendorf and Leary 1986), and heterozygosity within individuals may be positively associated with metabolic efficiency in a number of species (Hawkins et al. 1986, Teska et al. 1990). Specific examples where heterozygosity has been positively correlated to functional characteristics of wildlife species are available for white-tailed deer (Rhodes and Smith in press), waterfowl (Rhodes 1991) and numerous other species of animals (Allendorf and Leary 1986) and plants (Ledig 1986). Thus, genetic diversity should be an important characteristic for consideration in management programs.

Conclusions

Measures of diversity that utilize genetic information contained within and among units at each level of biological organization may be more useful than conventional measures that focus on species composition alone. Wildlife managers can use genetic diversity measures to assess biodiversity in individuals or across landscapes and to determine the particular contribution of each biological unit to overall diversity. Important points to consider in the management of biodiversity are: (1) diversity should be measured in different ways, and, in many cases, genetic measures are more relevant to conservation and management than those of species composition; (2) diversity can and should be characterized both within and among units at each hierarchical level of biological organization (Figure 1); (3) larger species assemblages contain greater genetic diversity, and species number provides information to managers about this type of diversity (Figure 2); (4) management decisions must consider the genetic uniqueness (low similarity) of the units (Figure 3); (5) the amount of within-unit genetic diversity can vary substantially across the landscape and this variation can be used for management purposes (Figure 4); and (6) genetic diversity should be conserved because of its correlation with functional characteristics and its importance to adaptability at any organizational level. Genetic diversity measures can provide wildlife biologists with comprehensive information about biological systems with which to make management decisions.

Acknowledgments

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References

Allendorf, F. W. and R. F. Leary. 1986. Heterozygosity and fitness in natural populations of animals. Pages 57–76 *in* M. E. Soule, ed., Conservation biology: The science of scarcity and diversity, Sinauer Assoc., Sunderland, MA.

Avise, J. C. and C. F. Aquadro. 1982. A comparative summary of genetic distances in the vertebrates: Patterns and correlations. Evol. Biol. 15:151–185.

Ayala, F. J. 1982. Population and evolutionary genetics. Benjamin/Cummings Publ. Co., Inc., Menlo Park, CA. 268 pp.

Baccus R., N. Ryman, M. H. smith, C. Reuterwall, and D. Cameron. 1983. Genetic variability and differentiation of large grazing mammals. J. Mamm. 64:109–120.

Breshears, D. D., M. H. Smith, E. G. Cothran, and P. E. Johns. 1988. Genetic variability in white-tailed deer. Heredity 60:139–146.

Bryant, E. H. 1974. On the adaptive significance of enzyme polymorphisims in relation to environmental variability. Am. Nat. 108:1–19.

Chesser, R. K. 1991. Influence of gene flow and breeding tactics on gene diversity within populations. Genetics 129:573–583.

Crow, J. F. and M. Kimura. 1970. An introduction to population genetics theory. Burgess Publ. Co., Minneapolis, MN. 591 pp.

Gilpin, M. E. and M. E. Soule. 1986. Minimum viable populations: Processes of species extinction. Pages 19–34 *in* M. E. Soule, ed., Conservation biology: The science of scarcity and diversity, Sinauer Assoc., Sunderland, MA.

Gyllensten, U. 1985. The genetic structure of fish: Differences in the intraspecific distributions of biochemical genetic variation between marine, anadromous, and freshwater species. J. Fish. Biol. 26:691–699.

Harris, L. D., M. E. McGlothlen, and M. N. Manlove. 1984. Genetic resources and biotic diversity. Pages 93–107, *in* L. D. Harris, ed., The fragmented forest: Island biogeography theory and preservation of biotic diversity. Univ. Chicago Press, Chicago, IL.

Hawkins, A. J. S., B. L. Bayne, and A. J. Day. 1986. Protein turnover, physiological energetics, and heterozygosity in the blue mussel, *Mylitus edulis*: The basis of variable age-specific growth. Proc. Roy. Soc. Lond. B 229:161–176.

Johnson, G. B. 1973. Relationship of enzyme polymorphism to species diversity. Nature 242:193–194.

Leberg, P. L. 1991. Influence of fragmentation and bottlenecks on genetic divergence of wild turkey populations. Conserv. Biol. 5:522–530.

Ledig, F. T. 1986. Heterozygosity, heterosis, and fitness in outbreeding plants. Pages 77–104 *in* M. E. Soule, ed., Conservation biology: The science of scarcity and diversity, Sinauer Assoc., Sunderland, MA.

Lewontin, R. C. 1974. The genetic basis of evolutionary change. Columbia Univ. Press, New York, NY. 346 pp.

McArthur, J. V., D. A. Kovacic, and M. H. Smith. 1988. Genetic diversity in natural populations of a soil bacterium across landscape gradient. Proc. Natl. Acad. Sci. 85:9621–9624.

Mitton, J. B. and M. C. Grant. 1984. Associations among protein heterozygosity, growth rate and developmental homeostasis. Ann. Rev. Ecol. and Syst. 15:479–499.

Morton, N. E., J. E. Crow, and H. J. Muller. 1955. An estimate of the mutational damage in man from data on consanguineous marriages. Proc. Natl. Acad. Sci. 42:855–863.

Nei, M. 1972. Genetic distance between populations. Am. Nat. 106:283–292.

———. 1977. F-statistics and analysis of gene diversity in subdivided populations. Ann. Hum. Genet. 41:225–233.

Nevo, E., A. Biles and R. Ben-Shlomo. 1984. The evolutionary significance of genetic diversity: Ecological, demographic, and life history correlates. Pages 13–213 *in* G. S. Mani, ed., Evolutionary dynamics of genetic diversity, Springer-Verlag, New York, NY.

Ramsey, P. R., J. C. Avise, M. H. Smith, and D. F. Urbston. 1979. Biochemical variation and genetic heterogeneity in South Carolina deer populations. J. Wildl. Manage. 43:136–142.

Rhodes, O. E., Jr. 1991. Genetic structure, heterozygosity, and energetic patterns in wintering mallard and American wigeon populations on the Southern High Plains of Texas. Ph.D. diss., Texas Tech. Univ., Lubbock, TX. 235 pp.

Rhodes, O. E., Jr. and M. H. Smith. In Press. Genetic perspectives in wildlife management: The case of large herbivores. *In* D. McCullough and R. Barrett, eds., Wildlife 2001: Populations, Elsevier Science Publishers, Essex, England.

Selander, R. K., M. H. Smith, S. Y. Yang, W. E. Johnson, and J. B. Gentry. 1971. Biochemical polymorphism and systematics in the genus Peromyscus. I. Variation in the old field mouse (*Peromyscus polionotus*). Univ. Texas Publ. 7103:49–90.

Smith, M. H., C. T. Garten, Jr., and P. R. Ramsey. 1975. Genetic heterozygosity and population dynamics in small mammals. Pages 85–102 *in* C. L. Market, ed., Isozymes, IV-Genetics and Evolution, Academic Press, New York, NY.

Smith, M. H., H. O. Hillestad, R. Baccus, and M. N. Manlove. 1984. Population genetics. Pages 119–128, *in* L. K. Halls, ed., White-tailed deer: Ecology and management. Stackpole Books, Harrisburg, PA.

Smith, M. H., K. T. Scribner, L. H. Carpenter, and R. A. Garrot. 1990. Genetic characteristics of Colorado mule deer (*Odocoileus hemionus*) and comparisons with other cervids. Southwest Nat. 35:1–8.

Smith, M. H., K. B. Willis, and P. E. Johns. 1991. Spatial-genetic variation in a white-tailed deer herd. Pages 80–84 *in* S. Myrberget, ed., Trans. XIX Inter. Union of Game Biol., Trondheim, Norway.

Strangel, P. W. 1991. Genic differentiation among avian populations. Pages 2,442–2,453 *in* A. J. Van Noordwijk and P. W. Stangel, eds., Symposium 46, Acta XX Congressus Internationalis Orithologici. New Zealand Ornithological Trust Board, Wellington, New Zealand.

Teska, W. R., M. H. Smith, and J. M. Novak. 1990. Food quality, heterozygosity, and fitness correlates in *Peromyscus polionotus*. Evolution 44:1318–1325.

Vane-Wright, R. I., C. J. Humphries, and P. H. Williams. 1991. What to protect?—Systematics and the agony of choice. Biol. Conserv. 55:235–254.

Wright, S. 1978. Evolution and the genetics of populations. Vol. 4. Variability Within and Among Natural Populations. Univ. Chicago Press, Chicago, IL. 580 pp.

Population Processes and Biological Diversity

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Introduction

A major goal of conservation biologists is to preserve biological diversity. The accelerating destruction of habitats by human beings has resulted in fragmented landscapes, which has led to a reduction in biological diversity (Wilson 1988). As fragmentation increases, it leads to a decrease in average habitat patch size and an increase in average distance between patches (Wilcox 1980). Both habitat loss and insularity may reduce population sizes to such low levels that species may go extinct.

The formidable task facing conservation biologists is to develop land management programs to protect species. Successful programs must be based on a thorough understanding of ecological and evolutionary processes of the populations under consideration. The need for information about population processes for the protection of threatened and endangered species is underscored by the continuing debate whether a single large reserve or several small reserves will protect more species (Wilcox and Murphy 1985, Wiens 1989). Reserve design is still a contentious issue after 15 years because not all species respond in the same way to habitat fragmentation (Wilcove et al. 1986).

An interesting question related to the preservation of biological diversity is: What fundamental unit should be preserved? Should the focus be on a local population, a set of interacting local populations (metapopulations), community or ecosystem. As the level of biological complexity increases from populations to ecosystems, the number of interactions increases, making higher levels of biological organization more difficult to study. These higher levels of biological organization have emergent properties resulting from interspecific interactions, thus communities and ecosystems are not simply the sum of their parts. Ideally, we would like to preserve ecosystems but they are not amenable to experimentation. The advantage of a population approach allows for experimental manipulation.

Management decisions about the conservation of biological diversity need to be made quickly because there is neither enough time nor funds to study the population dynamics of all species in a community. Under these difficult circumstances the manager is required to decide which population should be studied. The choice is often based on political forces, rather than on sound biological reasons. An understanding of the population biology of certain keystone species (Paine 1966) might be particularly useful in the development of management programs to conserve a large fraction of the entire community (Gilbert 1980, Terborgh 1986, Simberloff 1988).

Population changes in keystone species that provide habitat structure for other species may have profound effects on biological diversity. For example, lichens in some Austrian alpine grasslands required spaces created by the sedge *Carex curvula*

(Grabherr 1989). When the sedge disappeared, the lichen's productivity decreased, which could lead to a population decline for lichen-dependent species. Keystone species often function as predators that control the numbers of prey species. Their predatory effects can increase the biological diversity of subordinate prey species by reducing densities of a preferred dominant prey species. For instance, in central Chile a rocky intertidal community had a higher diversity index when the major gastropod predator was present than when the predator was absent (Duran 1989). In the absence of predation, the dominant competitor could itself be the keystone species if its presence determines the distribution and abundance of subordinate species. For example, the cotton rat (*Sigmodon hispidus*) was the largest and competitively dominant species that affected the smaller and subordinate species in the small mammal community discussed in the case study below.

We believe that continuous progress will most likely come from conservation efforts focused at the population level (Shaffer 1981). With well-understood organisms, such as small mammals, we can test some of the theories that bear on questions of population persistence for poorly-understood organisms, and supply generalizations for those theories. As we mentioned, there are some problems associated with a reductionist approach, but there are few alternatives given the time and resources available.

In this review, we will examine the role of population processes in determining biological diversity. We first briefly discuss how the basic concepts of minimum viable population and metapopulation relate to biological diversity. We then present data from our ongoing study of the effects of habitat fragmentation on population dynamics of small mammals and how this fragmented landscape affects biological diversity. We conclude with recommendations for future research on the effects of habitat fragmentation on population processes.

Minimum Viable Population Concept

Gilpin and Soulé (1986) considered two kinds of population extinctions, deterministic and stochastic. Deterministic extinctions are due to forces that inexorably result in the disappearance of a population. For example, deforestation in the tropics would be a deterministic force for different species of trees. The outcome is predictable if deforestation continues at its present rate. Stochastic extinctions are those due to random events. Shaffer (1981, 1987) distinguished four sources of variation that could result in the random extinction of a population: (1) demographic stochasticity due to random events in individual survival and reproduction; (2) environmental stochasticity due to unpredictable changes in abiotic factors such as weather, or biotic factors such as predators, competitors and parasites; (3) natural catastrophes such as fires and floods, which occur at random intervals; and (4) genetic stochasticity due to genetic drift and inbreeding, which may affect individual survival and reproduction.

Several points are worth noting about the distinction between deterministic forces of extinction and stochastic forces. First, the relative effect of stochastic forces increases as populations become smaller. Second, many extinctions are caused by a deterministic event reducing population size to such an extent that stochastic forces will eventually lead to extinction. Third, different stochastic forces operating at low population densities may interact to cause extinctions. For example, an environmental perturbation could reduce population size to a level where a loss of variation in the population would occur as a result of genetic drift. The increase in genetic homozygosity could then reduce individual survival and reproduction.

Population biologists have known for some time that the smaller the population, the more susceptible it is to extinction (Shaffer 1981). However, what is required by managers is a precise way to relate population size to the probability of extinction. Attempts to understand and predict the relationship of population size to extinction have spawned a burgeoning literature on the minimum viable population concept. The basic premise of the minimum viable population concept is that a threshold population density must be maintained for a population to persist. Shaffer (1981:132) defined minimum viable population for any given species in any given habitat as "the smallest isolated population having a 99 percent chance of remaining extant for 1,000 years despite the foreseeable effects of demographic, environmental and genetic stochasticity, and natural catastrophes."

Three approaches have been used to estimate minimum viable population sizes and related area requirements: observational, experimental and theoretical. The observational approach examines biogeographic patterns of abundance and distribution across a species' range. If populations occur in habitat patches of different sizes, one can estimate the smallest patch inhabited by a species and the percent of the patches of a certain size supporting that species. Additional information that is needed to estimate minimum viable population size, but is most difficult to obtain, is species-specific colonization and extinction rates for different-sized habitat patches. There are three critical assumptions in this biogeographic approach: (1) communities are at equilibrium in different patches; (2) population characteristics of a species are solely a function of patch size and do not vary in different parts of its range; and (3) there are no systematic differences in other patch attributes as a function of patch size.

In the experimental approach, minimum viable population size and area requirements are assessed by creating patches of different sizes and monitoring population parameters within them. For instance, Lovejoy et al. (1984, 1985, 1986) have studied the rate of disappearance of populations in 2.4-acre (1 ha) and 24-acre (10 ha) reserves in a Brazilian rain forest. Fragment size determined the persistence rates of different tropical species. Other researchers also have found that fragmentation affects persistence rates in a variety of species (Quinn et al. 1989, Paine 1989, Bergen 1990) and distributions of various-sized animals (Bennett 1991). We are conducting an experiment on habitat fragmentation on a small mammal community in eastern Kansas, which we discuss below. The major drawback of the experimental approach is that it requires long-term monitoring of populations. Unfortunately, the results of these experimental studies often will be too late to be of use due to the high rate of habitat destruction. Furthermore, such studies are impractical for many species and ecosystems.

Theoretical models have been developed to predict the probability that a population of a given size will go extinct and the time to extinction. Goodman (1987) used a classical birth-and-death process model incorporating environmental fluctuations to predict persistence times of different-sized populations. Persistence time strongly depended on the magnitude of the variance in population growth rate. Belovsky (1987) used Goodman's model to calculate the population size needed for mammalian species, that ranged in body mass from 2 ounces to 99 tons (10^1 to 10^6 g), to persist

100 or 1,000 years with a 95-percent probability. Population sizes ranged from hundreds to millions of individuals, with corresponding minimum area requirements of tens to millions of mi^2. As body size increased, the minimum viable populations decreased. The disturbing result was that those small populations of larger bodied species still required larger areas than their smaller bodied counterparts.

The minimum viable population is a useful concept only in that it provides non-biologists who may be in positions of influence, such as politicians, with a single number of individuals needed for a population to persist. As is the case for most oversimplifications, there is danger in the misuse of minimum viable population because there is no universal population number for a species. Also, a single number diverts attention from the mechanistic processes accounting for population persistence or extinction, and places the focus on the final outcome or product. It may be more productive to analyze the population processes that result in the minimum viable population rather than estimate this single number. This mechanistic approach has been taken by Gilpin and Soulé (1986), which they refer to as population vulnerability analysis.

Metapopulation Dynamics and Population Persistence

In our discussion of minimum viable population, we ignored the effects of spatial structuring on population persistence. Metapopulation dynamics provides a framework for analyzing the persistence of species inhabiting patchy environments and should prove useful in elucidating the conservation implications of fragmentation. Following Levins (1980), Hanski and Gilpin (1991) defined a metapopulation as "a set of local populations which interact via individuals moving among populations." Most models of metapopulations incorporate local extinctions followed by recolonization of individuals dispersing from extant populations (Holt 1985, Pulliam 1988).

Several generalities about metapopulation extinction emerge from simple diffusion models (Harrison and Quinn 1989, Hanski 1989). Metapopulations may go extinct when: (1) habitat patches are small, leading to low population density; (2) the number of habitat patches is decreased, thereby increasing population isolation and decreasing dispersal; (3) the population dynamics in different patches are correlated, leading to a correlation of extinction probabilities.

Spatial heterogeneity in the environment may cause differences in habitat quality among populations within a metapopulation. Populations in higher quality habitats may contain a surplus of animals that might disperse to neighboring populations. Thus, populations may persist in low quality habitats due to the colonization of individuals from higher quality habitats. Holt (1985) and Pulliam (1988) described populations that produce a surplus of dispersing animals as "sources," and populations in suboptimal habitat maintained by dispersal as "sinks."

Fragmented landscapes containing an array of different patch sizes may lead to sources/sink population dynamics. For most species, there should be a minimum patch size below which a population cannot persist without immigration. In the following case study, we report on our experiments investigating source/sink population structure in a small mammal community and how this structure affects small mammal biological diversity.

Case Study

In our continuing research in northeastern Kansas, we investigate the effects of habitat fragmentation on the rodent species within a 29.6-acre (12-ha) successional old-field (Foster and Gaines 1991). Since 1984, the vegetation has been maintained by mowing to produce archipelagos (Figure 1). Each archipelago consists of one large patch (5,980.0 yd^2 = 50 × 100 m), or 6 medium patches (each 344.5 yd^2 = 12 × 24 m), or 15 small patches (each 38.27 yd^2 = 4 × 8 m). We view the large patches as controls with no fragmentation. The archipelagos of medium and small patches represent increasing levels of fragmentation. The areas between archipelagos are mowed every two weeks during the growing season and are assumed to be unsuitable habitat. Total area of suitable habitat is 4.7 acres (approximately one-sixth of the original field). The rodent community consists of species that range in body size from large cotton rats (*Sigmodon hispidus*), with adults weighing at least 4.13 ounces (118 g), to intermediate prairie voles (*Microtus ochrogaster*), weighing at least 0.87 ounce (25 g). Adults of the two smallest species, deer mice (*Peromyscus maniculatus*) and western harvest mice (*Reithrodontomys megalotis*), weigh at least 0.64 ounce (18 g) and 0.25 ounce (7 g), respectively.

Biological diversity on the small patches is lower than on the large patches because cotton rats are not resident there (Foster and Gaines 1991, Gaines et al. 1992). All species are distributed among habitat types relative to their body sizes, such that cotton rats have highest densities on the large patches, prairie voles have highest densities on the medium patches, and deer mice and western harvest mice have

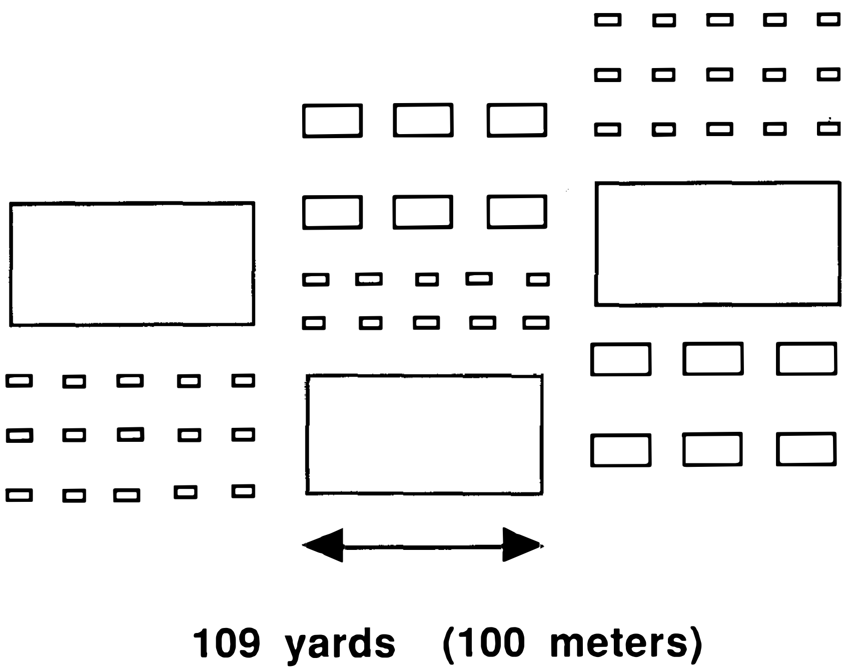

Figure 1. Study site showing archipelagos.

highest densities on the small patches. Western harvest mice became rare after 1987 for reasons still unclear. One cause may be due to changes in the plant community. Western harvest mice may prefer early successional grasses over later successional forbs (Birkenholz 1967, Fitch et al. 1984, Johnson and Gaines 1988). The annual and perennial grasses have been gradually replaced by perennial forbs since 1984 (Foster and Gaines 1991). Due to low numbers, western harvest mice are not considered here.

Significant differences in persistence rates between patch sizes indicate that population processes are affected by habitat fragmentation, but these effects vary among species (Foster and Gaines 1991, Gaines et al. 1992). Although sample sizes of cotton rats on medium and small patches are small, persistence rates of cotton rats are highest on large patches and essentially zero on small patches. Persistence rates of prairie voles are lowest on small patches, presumably because small patches have less suitable habitat. That persistence rates of prairie voles are highest on large patches and intermediate on medium patches leads us to suggest that vole densities should be greatest on large patches, but this is not the case (Foster and Gaines 1991). The lower density of voles inhabiting large patches rather than medium patches could be due to negative competitive interactions with cotton rats (Gaines et al. 1992), although the few voles establishing themselves on large patches are maintaining their territories.

Persistence rates of deer mice are either highest on smaller patches (Foster and Gaines 1991) or equal across all habitat types (Gaines et al. 1992), depending on the season. This contrast between deer mice and the two larger species may be explained by the manner in which deer mice utilize the mowed "interstitial areas" between habitat patches. Based on trapping data, deer mice appear to exploit the interstitial areas between habitat patches, whereas the other species do not (Foster and Gaines 1991). This ability to exploit resources in the most unsuitable habitats may explain why deer mice can persist and maintain high densities on small patches. Individuals residing in interstitial areas may move freely onto small patches. Moreover, the small patches and interstitial areas may serve as refuges from larger and more aggressive prairie voles and cotton rats. Competition and competitive refuge effects come from negative correlations in abundances between the deer mice and the two larger species (Gaines et al. 1992). From 1984 to 1987, deer mouse densities increased in the interstitial areas and declined on large and medium patches as prairie vole densities increased (Foster and Gaines 1991). Deer mouse densities remained lowest on large and medium patches from 1987 to 1991, while cotton rat densities increased on large patches and prairie vole densities increased on medium patches (Gaines et al. 1992).

Our system consists of three metapopulations, one for each species, made up of different subpopulations based on patch size. Source habitat patches where individuals persist the longest should contain a high number of dominant individuals who establish territories and are reproductively active. Subordinate individuals born in these source populations should disperse to less suitable sink habitats when carrying capacities in the source habitats are exceeded. A source/sink structure appears to occur in cotton rats, prairie voles and deer mice (Gaines et al. 1992). In our earlier studies (Foster and Gaines 1991, Gaines et al. 1992), we made no attempt to determine the age structure and reproductive activity of source and sink populations. However, this information is useful for population viability analyses (Mace and Lande 1991).

Habitats in which individuals of a species persist the longest should have the greatest percentage of adults because those older and more experienced individuals aggressively exclude younger, inexperienced ones. For instance, most of the cotton rats occurring on the large patches are predicted to be adults, whereas individuals on medium patches will be younger animals. Voles persist longest on large patches, so we predict that large patches will have the highest percentage of adults. Deer mice will have the highest percentage of adults on small patches because they persist longest there.

Due to high variability in the data, we used the Friedman's method for randomized blocks to test for patch effects. Data are separated by patch size and blocked by year for each season. Percentages of adult cotton rats did not differ significantly between medium and large patches. The lack of statistical significance may be due to the small numbers of cotton rats on medium patches. More than 90 percent of all males, and more than 88 percent of all females occur on the large patches which represent only 3.7 out of 29.6 acres (⅛ of the original field). Thus, if cotton rats were unable to sustain themselves on large patches then they would probably become extinct from the entire study site.

Percentages of adult male and female prairie voles differed significantly among patches during winter seasons (males: $X^2_{[2]} = 7.14$, $p<0.05$; females: $X^2_{[2]} = 12.3$, $p \leq 0.05$); and spring seasons (males: $X^2_{[2]} = 10.29$, $p<0.01$; females: $X^2_{[2]} = 6.0$, $p \leq 0.05$). The pooled data for winter and spring are presented in Figure 2. There tended to be higher percentages of adults on large patches for all seasons. As expected, the deer mouse response was opposite to that of the prairie vole. Percentages of adult male deer mice were higher on small patches, but not significantly. Except in the summer, percentages of adult female deer mice were also higher on small patches, but not significantly.

Finally, cotton rats, prairie voles and deer mice should have greater percentages of reproductive adults in source habitats where individuals persist the longest. We classified adults as reproductively active based on testes position (scrotal), and nipple size (medium or large). Reproductive activity did not differ significantly among patches for any species. However, percentages of reproductively active male and female cotton rats were always higher on large patches. There were no apparent trends for voles and deer mice.

Habitat fragmentation had different effects on the age structure and reproductive activity of small mammals within habitat patches of different sizes. Fragmentation affected biological diversity: there are fewer rodent species on small patches because of the absence of cotton rats. However, the higher densities of small-bodied species on smaller patches may be due to competitive release from the cotton rat. There were no obvious effects of fragmentation on the age structure and reproductive activity of prairie voles and deer mice. However, cotton rats, prairie voles and deer mice were utilizing the landscape differently. We suggest that the demographic consequences of body size are necessary population statistics when considering what area of habitat fragment is needed to sustain populations (Belovsky 1987).

There are several lessons from this study that are germane to understanding the relationship of population processes and biological diversity:

(1) It is difficult to generalize about the effects of habitat fragmentation on population processes of different species;

(2) Competition may be a factor superimposed on source/sink dynamics. The effect

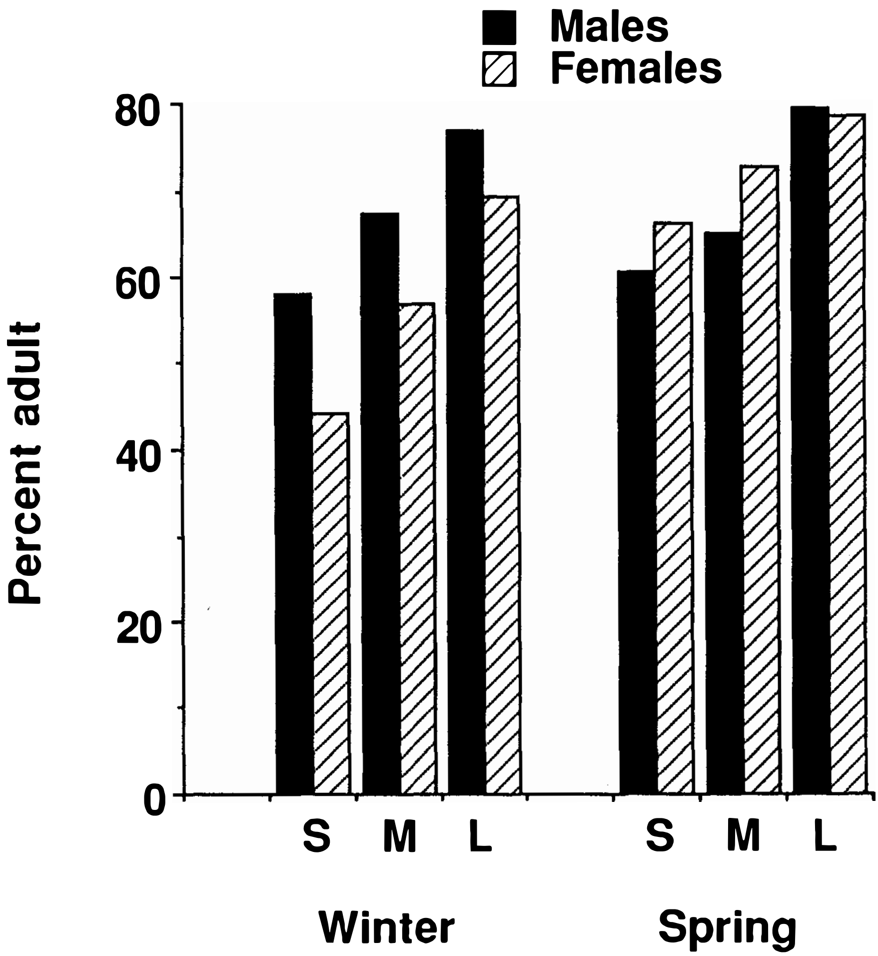

Figure 2. Percentage of male and female adult voles within total vole population on small (S), medium (M), and large (L) patches for winter and spring seasons. Data were pooled for all seven years.

of fragmentation apparent in one species (e.g., a competitive dominant) may indirectly reflect the impact of fragmentation on another species (e.g., a competitive subordinate); and

(3) Sink populations may contribute to the total number of individuals in an area and retard species' extinctions from fragmented habitats, but the species' chances of going extinct through stochastic processes are high due to poor-quality habitat. Because fragmentation is likely to produce source/sink structures, the total size of a population may be a poor index of how vulnerable a species is to further habitat degradation.

Conclusions

Much work needs to be done before a unified approach to conservation biology emerges. Several issues remain unresolved, including scale. An anthropocentric bias towards small spatial scale was illustrated by a survey (Karieva and Anderson 1988) in which 80 percent of experimental community studies were done in areas $\leq 9\ ft^2$ ($1\ m^2$). Some ecologists claim that the processes affected by habitat fragmentation on small spatial scales are similarly affected at large spatial scales. Ims (1990) and Stenseth (1990) suggested that small mammals in small-scale fragmented landscapes can serve as "empirical model systems" for larger mammals living in areas fragmented by human activity. Similarly, J. A. Wiens (personal communication: 1991) believes that it might be possible to use information obtained at a micro-landscape level (e.g., beetles on a lawn) to make predictions about larger scales (e.g., elephants on the Serengeti). To extrapolate processes that occur at a microscale to a macroscale phenomena is appealing because the smaller the scale, the more amenable the system is to experimental manipulation. However, making generalizations about population dynamics from small to large landscapes may be possible only if ecological processes scale monotonically with area. The complexity of biotic and abiotic interactions increases with area so that a straightforward relationship between small and large scale ecological processes is unlikely.

Another major area of contention is the relative role of genetic and demographic factors in causing population extinctions. The "50/500" rule, which has been disputed (Simberloff 1988), focuses on the relationship between genetic stochasticity and population extinction. An effective population size of 50 results in inbreeding depression (a short-term effect), whereas 500 results in genetic drift and a loss of genetic variation (a long-term effect). In both cases there would be a high probability of population extinction, particularly in a changing environment. However, Lande (1988:1,455) concludes from theoretical and empirical examples "that demography is usually of more immediate importance than population genetics in determining the minimum viable sizes of wild populations." Nevertheless, Lande (1988) suggests that future conservation plans include integration of ecology and population genetics. An understanding of the ecological genetics of threatened and endangered species in fragmented habitats may be the only hope for species' survival.

A fertile area for future research is population persistence in the context of source/sink dynamics. Species live in a heterogenous landscape with subpopulations occurring on patches of varying quality. Habitat fragmentation due to human disturbance has greatly contributed to this heterogeneity. Detailed information on movements between semi-isolated refuges and the manner in which corridors facilitate this movement is needed. Information about the mating success of individuals after they immigrate to a new patch can be obtained with recent advances in radiotelemetry and DNA fingerprinting.

As wildlife conservation increases in scope and sophistication, ecological theory will be needed in conservation planning and management policy. The development of relevant theory has been rapid, despite the complexity of the questions addressed. The concepts of minimum viable population and population vulnerability analysis (Gilpin and Soulé 1986) have provided a valuable heuristic tool: small populations are vulnerable, and very small ones may quickly succumb to stochastic processes. However, a more fundamental issue is how to keep populations and whole species from falling below a critical size. Since nearly all species exist as several populations, and most threatened species are limited to a few disconnected subpopulations, theories of metapopulation dynamics seem promising. Metapopulation models can be further refined within a source/sink structure by determining how individuals are exchanged between subpopulations. Our experimental work with small mammals in fragmented populations lends support to these new theoretical approaches, and that source/sink components incorporated in metapopulation dynamics should be particularly fruitful. As the need for informed conservation management decisions increases, our understanding of the ecology of threatened populations continues to grow.

Acknowledgments

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References

Belovsky, G. E. 1987. Extinction models and mammalian persistence. Pages 35–58 *in* M. E. Soulé, ed., Viable Populations for Conservation. Cambridge Univ. Press. Cambridge, MA. 189 pp.

Bennett, A. F. 1991. Habitat corridors and the conservation of small mammals in a fragmented forest environment. Landscape Ecology 4:109–122.

Berger, J. 1990. Persistence of different-sized populations: An empirical assessment of rapid extinctions in bighorn sheep. Conservation Biology 4:91–98.

Birkenholz, D. E. 1967. The harvest mouse *(Reithrodontomys megalotis)* in central Illinois. Trans. Illinois St. Acad. Sciences 60:49–53.

Duran, L. R. 1989. Variation and persistence of the middle rocky intertidal community of central Chile, with and without human harvesting. Marine Biology 103:555–562.

Fitch, H. S., V. R. Fitch, and W. D. Kettle. 1984. Reproduction, population changes and interactions of small mammals on a natural area in northeastern Kansas. Occa. Papers of the Mus. Nat. Hist. Univ. Kansas. No. 109.

Foster, J. and M. S. Gaines. 1991. The effects of a successional habitat mosaic on a small mammal community. Ecology 72:1358–1373.

Gaines, M. S., G. R. Robinson, J. E. Diffendorfer, R. D. Holt, and M. L. Johnson. 1992. The effects of habitat fragmentation on small mammal populations. *In* D. R. McCullough and R. H. Barret, eds., Wildlife 2001: Populations. In press.

Gilbert, L. E. 1980. Food web organization and the conservation of neotropical diversity. Pages 11–33 *in* Soulé, M. E. and Wilcox, B. A., eds., Conservation Biology: An Evolutionary-Ecological perspective. Sinauer. Sunderland, MA.

Gilpin, M. E. and M. E. Soulé. 1986. Minimum viable populations: Processes of species extinction. Pages 19–34 *in* M. E. Soulé, ed., Conservation Biology, Sinauer, Sunderland, MA. 584 pp.

Goodman, D. 1987. The demography of chance extinction. Pages 11–34 *in* M. E. Soulé, ed., Viable Populations for Conservation, Cambridge Univ. Press, Cambridge, MA. 189 pp.

Grabherr, G. 1989. On community structure in high alpine grasslands. Vegetatio 83:223–227.

Hanski, I. 1989. Metapopulation dynamics: Does it help to have more of the same? Trends in Ecology and Evolution 4:113–114.

Hanski, I. and M. Gilpin. 1991. Metapopulation dynamics: Brief history and conceptual domain. Biological J. Linnean Soc. 42:73–88.

Harrison, S. and Quinn, J. F. 1989. Correlated environments and the persistence of metapopulations. Oikos 56:293–298.

Holt, R. D. 1985. Population dynamics in two-patch environments: Some anomalous consequences of an optimal habitat distribution. Theoretical Population Biology 28:181–208.

Ims, R. A. 1990. The effect of habitat fragmentation on social systems: Small rodents as an empirical model system. Abstract, V International Congress of Ecology meetings.

Johnson, M. L. and M. S. Gaines. 1988. Demography of the western harvest mouse, *Reithrodontomys megalotis*, in eastern Kansas. Oecologia 75:405–411.
Kareiva, P. and M. Anderson. 1988. Spatial aspects of species interactions: The wedding of models and experiments. *In* A. Hasting, ed., Community Ecology. Springer-Verlag. New York, NY.
Lande, R. 1988. Genetics and demography in biological conservation. Science 241:1,455–1,460.
Levins, R. A. 1980. Extinction. Am. Mathematical Soc. 2:77–107.
Lovejoy, T. E. 1985. Forest fragmentation in the Amazon: A case study. Pages 243–252 *in* H. Messel, ed., The Study of Populations. Pergamon Press, Sydney, Australia.
Lovejoy, T. E., J. M. Rankin, R. O. Bierregaard, K. S. Brown, L. H. Emmons, and M. E. Van der Voort. 1984. Ecosystem decay of Amazon Forest fragments. Pages 295–325 *in* M. H. Nitecki, ed., Extinctions. Univ. Chicago Press. Chicago, IL.
Lovejoy, T. E., R. O. Bierregaard, Jr., A. B. Rylands, J. R. Malcolm, C. E. Quintela, L. H. Harper, K. S. Brown, Jr., A. H. Powell, G. V. N. Powell, H. O. R. Schubart, and M. B. Hays. 1986. Edge and other effects of isolation on Amazon Forest fragments. Pages 257–285 *in* M. E. Soulé, ed., Conservation Biology. Sinauer, Sunderland, MA. 584 pp.
Mace, G. M. and R. Lande. 1991. Assessing extinction threats: Toward a reevaluation of IUCN threatened species categories. Conservation Biology 5:148–157.
Paine, R. T. 1966. Food web complexity and species diversity. Am. Nat. 100:65–75.
———. 1989. Habitat suitability and local population persistence: Field experiments on the sea palm *Postelsia palmaeformis*. Ecology 69:1787–1794.
Pulliam, H. R. 1988. Sources, sinks and population regulation. Am. Nat. 110:107–119.
Quinn, J. F., Wolin, C. L. and Judge, M. L. 1989. An experimental analysis of patch size, habitat subdivision, and extinction in a marine intertidal snail. Conservation Biology 3:242–251.
Shaffer, M. L. 1981. Minimum population sizes for species conservation. Bioscience 31:131–134.
———. 1987. Minimum viable populations: Coping with uncertainty. Pages 69–86 *in* M. E. Soulé, ed., Viable Populations for Conservation. Cambridge Univ. Press, Cambridge, MA. 189 pp.
Simberloff, D. 1988. The contribution of population and community biology to conservation science. Ann. Rev. Ecology and Systematics 19:473–511.
Soulé, M. E. 1987. Where do we go from here? Pages 175–184 *in* M. E. Soulé, ed., Viable Populations for Conservation. Cambridge Univ. Press, Cambridge, MA. 189 pp.
Stenseth, N. C. 1990. Habitat fragmentation: Reflections on landscape ecological studies on model organisms. Abstract, V International Congress of Ecology meetings.
Terborgh, J. 1986. Keystone plant resources in the tropical forest. Pages 330–334 *in* M. E. Soulé and B. A. Wilcox, eds., Conservation Biology. Sinauer, Sunderland, MA. 584 pp.
Weins, J. 1989. The ecology of bird communities. Vol. 2. Processes and Variations. Cambridge Univ. Press. Cambridge, MA.
Wilcove, D. S., C. H. Mclellan, and A. P. Dobson. 1986. Habitat fragmentation in the temperature zone. Pages 237–256 *in* M. E. Soulé, ed., Conservation Biology. Sinauer, Sunderland, MA. 584 pp.
Wilcox, B. A. 1980. Insular ecology and conservation. Pages 95–117 *in* M. E. Soulé and B. A. Wilcox, eds., Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer, Sunderland, MA.
Wilcox, B. A. and D. D. Murphy. 1985. Conservation strategy: The effects of fragmentation on extinction. Am. Nat. 125:879–887.
Wilson, E. O. 1988. The current state of biological diversity. Pages 3–18 *in* E. O. Wilson and F. M. Peter, eds., Biodiversity. Nat. Acad. Press, Washington, D.C. 521 pp.

Managing Genetic Diversity in Captive Breeding and Reintroduction Programs

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Introduction

Captive breeding and reintroduction are the most intensive (and hence most expensive) forms of wildlife management (Conway 1986, Kleiman 1989). The need for such intensive management is usually a sign that society has failed to adequately restrict some human impact on a taxon, such as habitat loss and degradation, direct or indirect mortality, or the introduction of an exotic species. Thus, a captive breeding and reintroduction program for a taxon of conservation concern should be part of a comprehensive conservation strategy that also addresses the problems affecting the taxon in the wild (Ballou in press, Foose 1989, Povilitis 1990). Under these circumstances, such programs can make substantial contributions to the preservation of endangered taxa. For example, captive breeding and reintroduction has enabled the peregrine falcon (*Falco peregrinus*) to repopulate much of North America (Cade 1990) and Arabian oryx (*Oryx leucoryx*) have been successfully reintroduced in several areas of their original range (Stanley-Price 1989).

Once the need for a captive breeding program is identified, it is advisable to initiate the program as soon as possible. Starting the program before the wild population has been reduced to a mere handful of individuals increases its chances of success. This strategy provides time to solve husbandry problems, increases the likelihood that enough wild individuals can be removed to give the new captive population a secure genetic and demographic foundation, and minimizes adverse effects of removing individuals on the wild population.

Over the last decade, it has generally become recognized that captive populations of threatened and endangered species should be managed to maintain the genetic diversity present in the wild individuals from which the captive population is descended (Hedrick and Miller 1992, Hedrick et al. 1986, Ralls and Ballou 1986, Soulé et al. 1986, Templeton 1990). The first formal cooperative breeding programs designed to maintain genetic diversity in captive populations were the Species Survival Plans of the American Association of Zoological Parks and Aquariums (AAZPA) (Foose and Seal 1986); similar programs now have been developed in several other countries (Hutchins and Wiese 1991) and efforts at international coordination are underway (Jones 1990).

Managing captive populations to maintain maximum genetic diversity counters unwanted genetic changes in captivity due to selection (Frankham et al. 1986) and avoids possible deleterious effects of inbreeding (Ralls et al. 1988). It also preserves future options for both the taxon and its managers (Templeton 1990): without genetic variation, the captive individuals or their reintroduced progeny would be unable to adapt to future environmental changes (Frankel and Soulé 1981) and various management strategies, such as within-family selection against recessive lethals or serious pathologies (Foose et al. 1986), would not be possible options.

Here, we summarize current management techniques for maintaining genetic diversity in captive populations and the genetic and demographic aspects of selecting captive individuals for reintroduction to the wild. We illustrate the use of these techniques with data from captive breeding and reintroduction programs for two avian species, the Guam rail (*Rallus owstoni*) and California condor (*Gymnogyps californianus*), and two mammalian species, the black-footed ferret (*Mustela nigripes*) and golden lion tamarin (*Leontopithecus rosalia*).

A few of the last rails were captured for a captive breeding program before the remaining rails, and most of the birds on Guam, were exterminated by the introduced brown tree snake (*Boiga irregularis*) (Witteman et al. 1990). The condor population was extremely small and rapidly declining when the last wild individuals were brought into captivity (Dennis et al. 1991, Wallace in press). A distemper epidemic reduced the only known wild ferret population to a few individuals that were used to begin the captive breeding program (Thorne and Belitsky 1989). The tamarin population was in danger of extinction due to the destruction of most of its Atlantic forest habitat in Brazil and illegal capture for pet trade (Kleiman et al. 1986).

The rail project is a joint program of the U.S. Fish and Wildlife Service (USFWS) and the AAZPA's SSP; the condor program is directed by the USFWS with the advice of the Condor Recovery Team (Wallace in press); the ferret program is overseen by the Wyoming Game and Fish Department, the USFWS and the AAZPA's SSP; and the tamarin program is coordinated by the Golden Lion Tamarin International Cooperative Research and Management Committee (Kleiman et al. 1986).

What Do We Mean by Genetic Diversity?

The genetic variation present in individuals, populations or species can be measured and compared in several ways (Hedrick et al. 1986, Lande and Barrowclough 1987). One common measure is the amount of heterozygosity. Most vertebrate individuals are diploid, that is, each has two alleles at every genetic locus. An individual inherits one of these alleles from its mother, via an egg, and the other from its father, via a sperm. Thus, a typical vertebrate individual is either homozygous (the two alleles are the same) or heterozygous (the two alleles are not the same) at each of its approximately 100,000 genetic loci (Gilpin and Wills 1991). The concept of heterozygosity is illustrated in Table 1 with hypothetical data on the genotypes of 10 individuals at three genetic loci. At locus A, all 10 individuals are homozygous for the dominant allele A. At locus B, individuals 1, 3, 6, 7 and 9 are homozygous for the dominant allele B, individual 10 is homozygous for the recessive allele b, and individuals 2, 4, 5 and 8 are heterozygous with one B allele and one b allele. At locus C, only individual 2 is homozygous. The heterozygosity of an individual can be estimated as the average heterozygosity across the number of loci for which we have data (Hedrick et al. 1986). From our example, individual 4 has the highest heterozygosity (2 of 3 loci are heterozygous = 0.67). The heterozygosity of a population (H bar) is the individual heterozygosities averaged over all the individuals within the population (Table 1: H bar = 0.43; Hedrick et al. 1986). Typically in mammals, population heterozygosity is about 4 percent (Nevo 1978).

Table 1. Hypothetical data on the genotypes of 10 individuals at three genetic loci: A, B and C. Dominant alleles are represented by capital letters and recessive alleles by lowercase letters. Locus C has a dominant allele, C, and four recessive alleles, c_1, c_2, c_3 and c_4.

Individual number	Locus A	Genotype at Locus B	Locus C
1	AA	BB	Cc_1
2	AA	Bb	c_1c_1
3	AA	BB	Cc_2
4	AA	Bb	Cc_3
5	AA	Bb	c_1c_2
6	AA	BB	c_1c_3
7	AA	BB	Cc_4
8	AA	Bb	c_1c_4
9	AA	BB	c_1c_3
10	AA	bb	c_1c_2

Another aspect of genetic variation is allelic diversity or the number of different types of alleles at a locus. Empirical studies have shown that there is little or no variation at many loci, that is, most or all individuals in the population are homozygous for a single allele (as at locus A in our example) (Fuerst and Maruyama 1986). If other alleles occur at the locus, they are very rare. Other loci are highly polymorphic, that is, several alleles at the locus are reasonably common within the population. The concept of allelic diversity also is shown in Table 1. There is no allelic diversity at locus A, as only one allele, A, is present. There is some allelic diversity at locus B, with two alleles, B and b present. There is a great deal of allelic diversity at locus C, where there are five alleles present: the dominant allele C and four recessive alleles represented as c_1, c_2, c_3 and c_4.

Although the data shown in Table 1 are hypothetical, actual data of this type, at least for some small fraction of the many genetic loci present in any species, can be obtained for most wild populations by collecting blood or tissue samples and using various descriptive genetic techniques, such as protein electrophoresis (Lewontin 1974).

Pedigrees Versus Laboratory Data

The goal of current strategies for maintaining genetic diversity in a captive population is to preserve as much as possible of the genetic variation, in the form of heterozygosity and allelic diversity, that was present in the wild individuals used to found the population. Laboratory data on the extent of genetic variation present in the population are not required; we can manage to preserve genetic variation with no knowledge of how much genetic variation there is to preserve!

Current techniques rely on models of the expected loss of heterozygosity predicted by population genetic theory in the absence of mutations and selection (Frankel and Soulé 1981, Lacy et al. in preparation, Soulé et al. 1986) and various analyses of the captive population's pedigree, including computer simulations of the loss of hypothetical alleles (Ballou in press, Hedrick and Miller 1992, Lacy 1990, MacCluer et al. 1986). Thus, although laboratory measures of genetic variation are not required, accurate pedigree data are essential. The captive individuals must be housed in such a way that the parentage of all offspring is known with certainty and detailed records on all individuals born in captivity, including their sire, dam, birth date and death date, must be maintained (Glatston 1986). A number of computer software systems have been developed for this purpose (ISIS 1991, Odum 1990).

Even when descriptive genetic data of the type shown in Table 1 do exist for a specific captive population, as for example, the rail (Haig et al. 1990), management to maintain genetic variation is still based on the population's pedigree rather than the actual alleles known to be present at a few loci in each individual. The reason is that heterozygosity measured by electrophoresis is a poor estimator of the overall level of genetic diversity of the individual (Hedrick et al. 1986). Managing to preserve diversity in a small part of an individual's genome based on descriptive genetic data (such as the results of electrophoretic surveys) results in greater over-all loss of diversity than managing on the basis of pedigree analyses (Haig et al. 1990, Hedrick et al. 1986, Lande and Barrowclough 1987). Thus, management to preserve genetic diversity revealed by electrophoresis is generally not advisable.

A specific form of management based on descriptive genetic data rather than pedigree analysis was advocated by Hughes (1991). He recommended management to maintain allelic diversity (as indicated by the use of DNA probes and antibody reagents) at the major histocompatibility complex (MHC), because the MHC is known to play an important role in pathogen recognition (Klein 1986, Miller and Hedrick 1991). However, this approach has not been adopted by those responsible for the management of captive populations. The arguments against it, including the fact that it would result in greater over-all loss of genetic variation than management based on pedigrees, have been presented by Gilpin and Wills (1991), Miller and Hedrick (1991), and Vrijenhoek and Leberg (1991).

Phases of a Captive Breeding Program

Ideally, the first step in the development of a captive breeding program is consensus among all concerned parties (agency personnel, outside scientific advisors, non-governmental conservation groups) that such a program likely would benefit a specific taxon. This step may be difficult to achieve as value systems differ and there are no precise scientific guidelines for the optimal point at which to begin capturing animals for a captive breeding program. However, the IUCN Policy Statement on Captive Breeding recommends starting a captive population well before the wild population reaches a critical state: "Management to best reduce the risk of extinction requires the establishment of captive populations much earlier, preferably when the wild population is still in the thousands. Vertebrate taxa with a current census below one thousand individuals in the wild population require close and swift cooperation between field conservationists and captive breeding specialists to make their efforts complementary and minimize the likelihood of extinction. . . ." (IUCN 1987). This recommendation does not imply that a full-fledged captive breeding and reintroduction program is needed for all wild taxa with populations in the thousands but rather than it often is prudent to develop and maintain the capacity to implement such a program (captive animals, proven husbandry and reintroduction techniques) as a safety measure. Although probably not appropriate for all taxa, the "below one thousand individuals in the wild" criterion from this IUCN statement is being tried as a "general benchmark," indicating that a captive breeding program may be advisable (Foose 1991, Seal 1991).

Once a captive breeding program is initiated, its subsequent development can be pictured as three phases: the founding phase, during which the population is initiated; the growth phase, during which the population rapidly increases to the final size desired by its managers (the "target" population size); and the carrying capacity phase, during which the population is maintained at its target size (Figure 1) (Ballou in press). Management concerns change as the population progresses through these phases. The major concerns during each phase are discussed in turn below.

Management Concerns During the Founding Phase

Initially, management concerns center upon removing individuals with minimal impact on the wild population, getting the species to breed reliably in captivity, setting general goals and plans for the captive population, and obtaining enough wild individuals to ensure a sound genetic and demographic base for the captive population.

Removing animals from the wild. Ways of reducing the impact of removing the captured animals from the wild population include removing eggs from nests (many birds, e.g., condors, will lay another egg to replace the one removed); capturing dispersing young, which often have a high mortality in the wild, e.g., ferrets; and

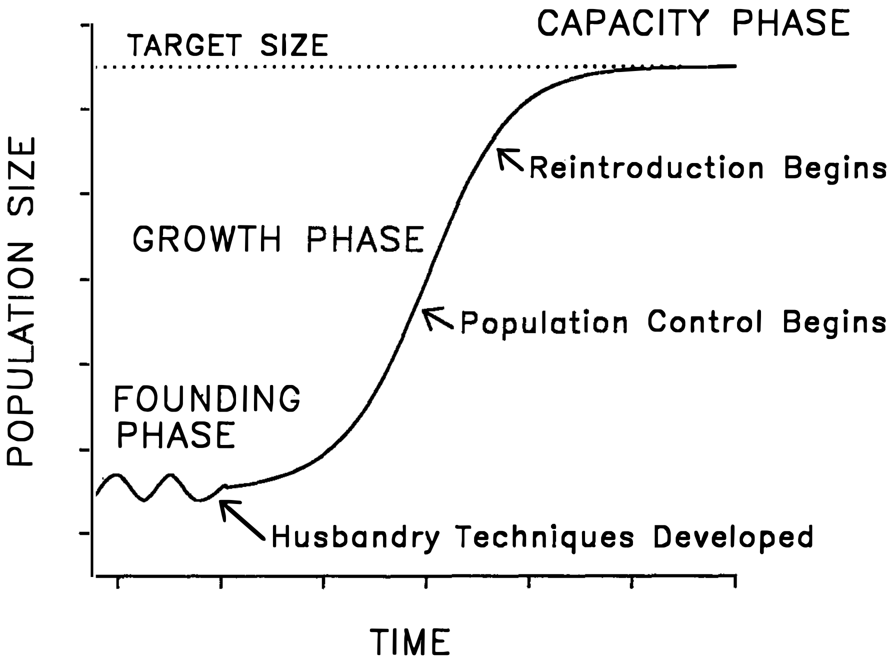

Figure 1. The development of a generalized captive breeding and reintroduction program from the founding to the capacity phase. The captive population usually is subdivided at some point in the growth phase.

using young animals which have become separated from their mothers, e.g., California sea otter (*Enhydra lutris*) pups sometimes wash ashore.

If the program is begun before the wild population has reached the "crisis" stage, it is wise to begin with the capture of a few wild individuals (or the capture of some wild individuals belonging to a closely related "model" taxon) to enable the development of suitable husbandry techniques. There are many taxa, for example, kangaroo rats (*Dipodomys*), that zoos do not know how to breed reliably in captivity. In such cases, research on genetics, behavior, nutrition, disease or reproduction may be necessary to find the reasons for the lack of breeding success, and research takes time. In the case of the tamarin, the husbandry problems concerned both behavior and nutrition (Kleiman et al. 1986). Once they were solved, in the mid-1970s, the captive population grew rapidly (Figure 2). Initial problems in maintaining and breeding the ferret population involved disease and reproductive synchronization of the males and females during the short breeding season; they were overcome by 1989 (Thorne and Oakleaf 1991). Siberian polecats (*Mustela putorius*) and domestic ferrets (*Mustela putorius furo*) were used as surrogates for ferrets during the breeding season and for research on reproductive biology (Wildt et al. 1989). Both rails and condors bred fairly well in captivity from the start, because zoos had experience with these or closely related species (Derrickson 1987, Wallace in press).

General goals and overall planning. Genetic goals for captive populations are specified in terms of the proportion of genetic variation (expressed as heterozygosity) to be maintained and the length of time for which it is to be maintained. The proportion of genetic variation retained within a closed population depends upon the population's effective size and the number of generations for which it remains closed. The effective size of a population can be defined as the size of an ideal population (a hypothetical population with specific properties central to population genetics theory—*see* Falconer 1981, Hedrick 1985) that would have the same rate of loss of heterozygosity as the actual population under consideration. The effective population size generally is only a fraction of the actual population size (Lande and Barrowclough 1987). Generation length is critical because some genetic variation is lost when the parent generation passes its genetic variation on to the next generation (an offspring contains only half the genetic material present in each of its parents). Thus, the longer the generation time of a species, the smaller the proportion of genetic variation that will be lost during a given time period (Soulé et al. 1986).

A general goal for captive populations is the maintenance of 90 percent of the genetic variation present in the source (wild) population for 200 years (Soulé et al. 1986). The panel of experts that made this recommendation concluded that "the 90 percent threshold represents, intuitively, the zone between a potentially damaging and a tolerable loss of heterozygosity" and that two hundred years was an arbitrary but "reasonably conservative" planning time-frame (Soulé et al. 1986).

Goals for the tamarin, rail, ferret and condor programs are compared in Table 2. The tamarin program has adopted the "90 percent for 200 years" goal. We also have shown this goal for the condor program, although the USFWS has not yet adopted an official goal. The ferret and rail programs are using the goal of "90 percent for 50 years." Planning for a shorter time period was deemed appropriate in these cases due to the short generation times for these species (*see* Table 2) and plans for the rapid re-establishment of several wild populations (Ballou and Oakleaf

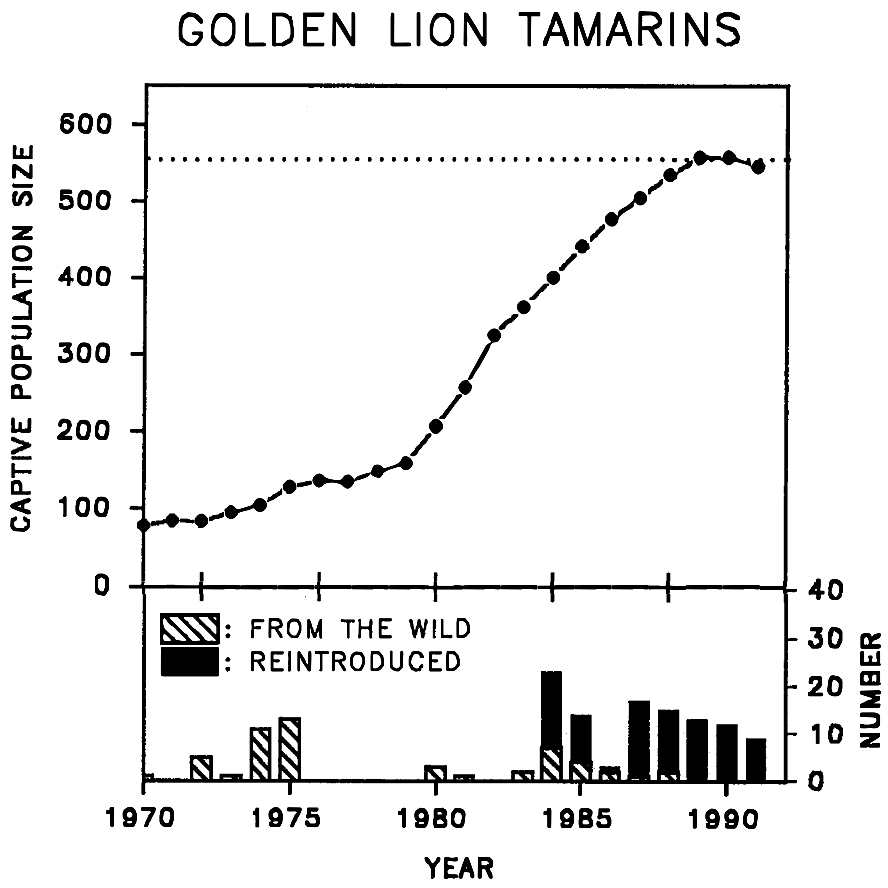

Figure 2. The historical development of four captive breeding and reintroduction programs: A) golden lion tamarins; B) Guam rails; C) black-footed ferrets; D) California condors. The dotted line indicates the target size for each captive population.

1989, Derrickson 1991). Some programs may adopt the "90 percent for 200 years" goal initially and change to a less demanding one, e.g., "90 percent for 100 years" if the size and viability of the wild population(s) improve to the point where the captive population is less critical for preserving the genetic variation of the species. This approach has been considered by the tamarin management committee.

Setting a specific goal enables estimates, based on population genetics theory, of the number of wild animals that must be captured and induced to breed in captivity (the number of "founders" needed for the captive population) and the target population size (the number of individuals that must be maintained in captivity during the planning period) needed to meet the goal (Soulé et al. 1986). Planning to retain a higher percentage of genetic variation increases the necessary target size. For example, maintaining 92 percent, instead of 90 percent, of the ferret genetic variation for 50 years would require a target population of 2,700 rather than 500 individuals.

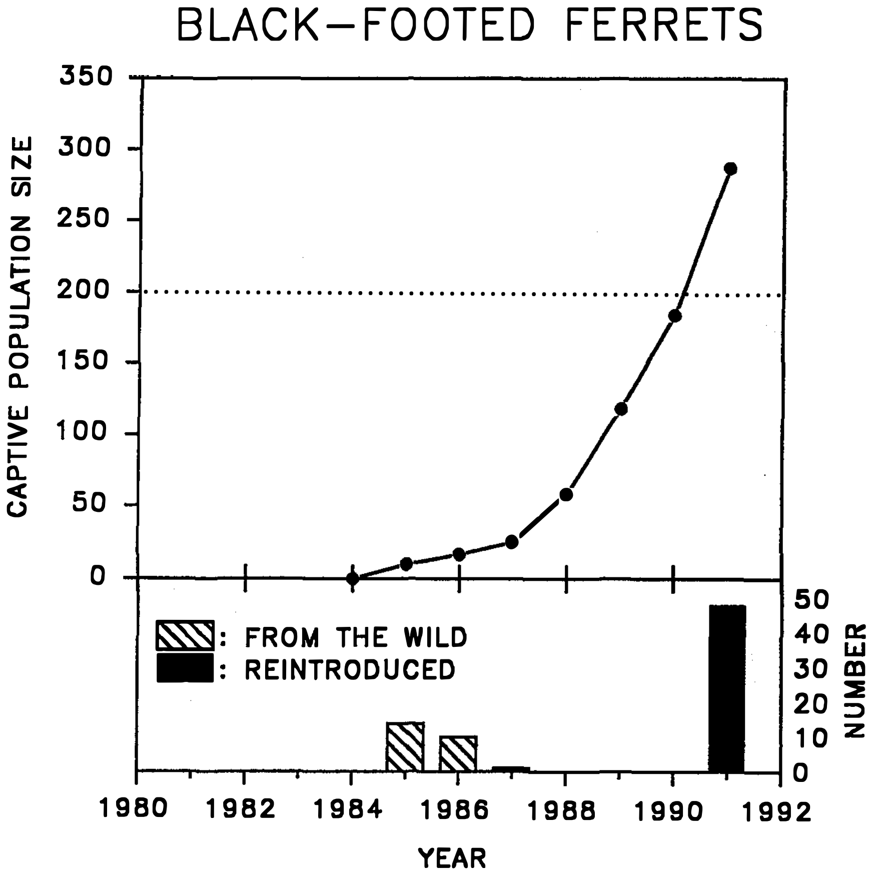

Figure 2B. continued

Increasing the planning period has a similar effect. For example, maintaining 90 percent of the ferret genetic variation for 100 years instead of 50 years would require a target population of 1,300 rather than 500 individuals (Ballou and Oakleaf 1989).

For any given goal, increasing the number of founders reduces the required size of the target population. As a "rule of thumb," 20 to 30 unrelated founders representing the genetic diversity present in the wild population generally are sufficient (Soulé et al. 1986). In the ferrets, condors and rails (Table 2), captive breeding was not initiated until after it was impossible to obtain this many founders. In such cases, the number of founders cannot be changed. If it had been possible to obtain 25 founders for the ferret program, the target size would be 200 rather than 500 individuals. Although a small number of founders reduces the probability that a captive breeding program will be successful, it does not reduce it to zero. For example, all Speke's gazelles (*Gazella spekei*) currently in captivity are descended from four individuals and this population appears to be thriving due to careful management (Templeton and Read 1984). (However, it will require several more gazelle gener-

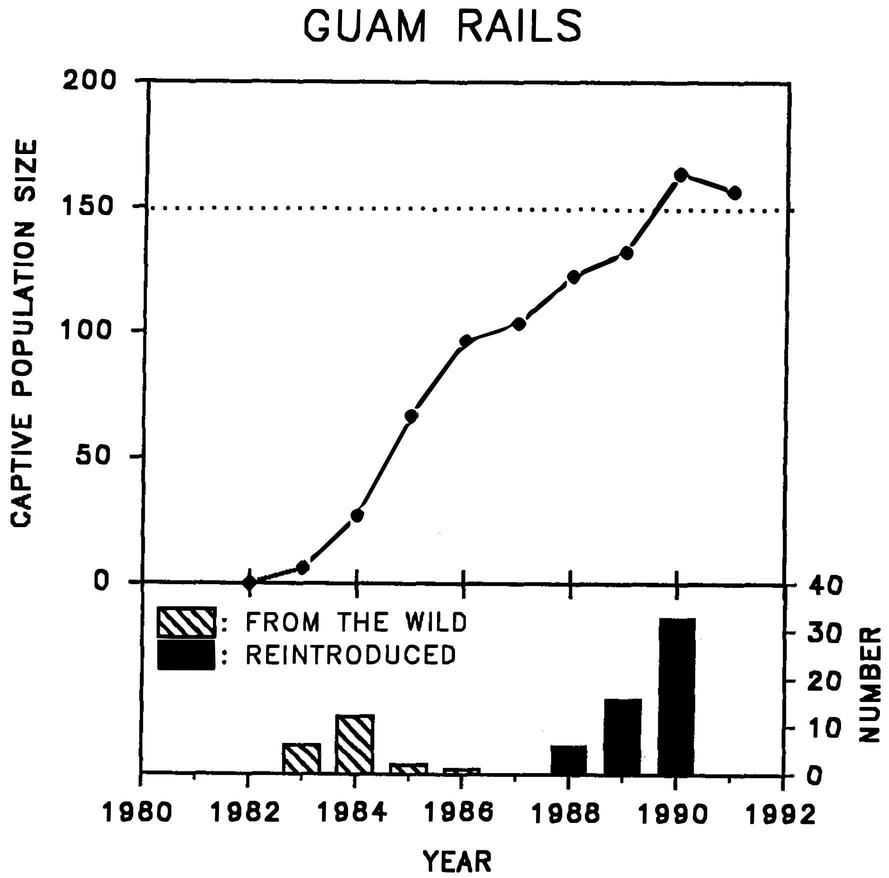

Figure 2C. continued

ations to truly evaluate the success of this program.) Thus, the lack of an ideal number of founders is not justification for abandoning or failing to initiate a captive breeding program.

The target size also depends upon the generation length of the taxon under consideration and how rapidly the population can grow from the founding phase to the target size: given the same goal, fewer individuals will be required if the taxon has a relatively long generation time or could grow more rapidly each generation (Ballou 1987, Soulé et al. 1986). In the golden lion tamarin, if generation time could be artificially extended from 6 to 10 years (e.g., by delaying age of first reproduction) the target size would be 290 rather than 550.

In addition to genetic and demographic factors, the target population size also must consider the number of spaces available in zoos. Populations of species that are difficult to exhibit, e.g., the Guam rail, may be limited by the number of zoos that can participate in the captive breeding program. The target size therefore may

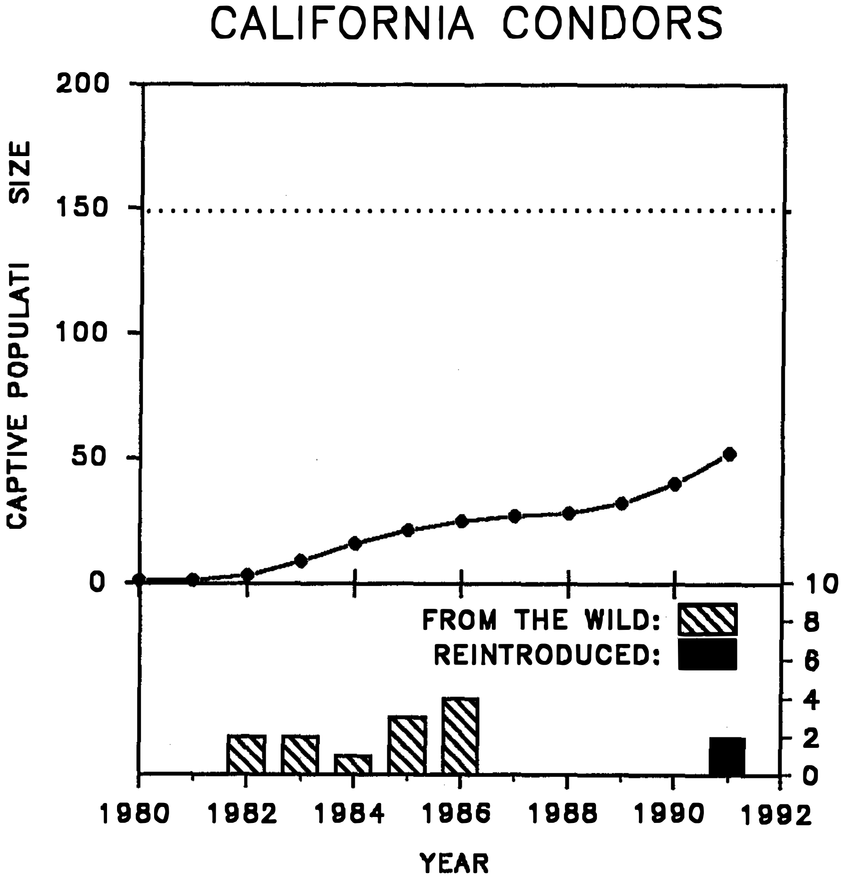

Figure 2D. continued

be a compromise between the number of animals required according to genetic and demographic considerations and the limited resources available (Ballou and Foose in press).

The target population size determines the number of breeding animals in the captive population and, thus, the potential number of offspring available for reintroduction each year. Thus, it could conceivably be desirable to specify a target size above the number of individuals required for genetic reasons if very large numbers of young were wanted for reintroduction.

Acquiring the remaining founders. Once the taxon is breeding well in captivity, it is desirable to capture the required number of founders as soon as possible. The speed with which this can be accomplished depends upon many variables, such as the available captive facilities and the impact of removing individuals from the wild population. The founders for the ferret, rail and condor populations were obtained within a three to five year period (Figure 2, B–D). The original founder animals (or

Table 2. The goals and founder status of four captive breeding programs with reintroduction components. Species listed in order of increasing number of generations encompassed in the program length.

	Species			
	California condor[a]	Black-footed ferret	Guam rail	Golden lion tamarin
Heterozygosity goal	90 percent	90 percent	90 percent	90 percent
Length of program (years)	200	50	50	200
Number of generations	10	20	22	33
Target population size	150	500	150	550
Number wild-caught	14	18	21	69[d]
Number of contributing founders[b]	13	10	13	45
Founder genome equivalents[c]	8	5	5	12

[a]Heterozygosity goal, program length and target population size have not been officially adopted by program managers; other data from Kieler (1991).
[b]Founders with currently living descendants.
[c]The number of theoretically ideal founders taking into consideration loss of genetic diversity in the current captive population (Lacy 1989).
[d]Includes the number of wild-caught tamarins acquired after the captive program was initiated in 1981 in addition to the number of founders and wild-caught individuals alive at the initiation of the program.

their descendants) were already in captivity when the tamarin program was initiated in 1981 (Figure 2, A). However, wild animals continue to be available; the 24 wild tamarins that have been added to the captive population since its initiation were animals turned over to the captive breeding program by authorities that had confiscated tamarins illegally captured from wild populations. In addition, interactive management of the captive and wild tamarin population should expand the founder base for the captive population in the future.

Capturing all the individuals at one location may not obtain an adequate sample of the taxon's genetic diversity (Templeton 1990). Genetic surveys of the wild population(s) using electrophoretic or molecular techniques may be helpful in determining the geographic distribution of genetic variation in the wild and devising the best sampling plan.

Unfortunately, the number of wild animals captured usually does not translate directly into the number of founders. Wild-caught animals may be related, fail to breed or, if they do breed, their descendants may fail to reproduce. For example, although 25 wild ferrets were captured from Meeteetsee, Wyoming, the first 6 died of distemper (Thorne and Belitsky 1989). Several others were known to be parents and offspring, thus reducing the number of potential founders to only 10 presumably unrelated individuals (Ballou and Oakleaf 1989). Furthermore, some potential ferret founders failed to reproduce, while those that did have reproduced unequally, severely skewing their genetic contribution to the population's gene pool. Such processes further erode the genetic contribution of the founders (Lacy 1989). As a result, the current ferret population is founded by the theoretical equivalent (founder genome equivalents [Lacy 1989]) of only five ferrets (Table 2). Similar events occurred in the tamarin, condor and rail populations, thereby reducing the number of theoretical founder equivalents to well below the 20 to 30 recommended by Soulé et al. (1986) (Table 2).

Management Concerns During the Growth Phase

The emphasis during this phase is upon rapid population growth until the target population size is attained. This is because rapid growth minimizes both the loss of genetic diversity in the captive population and the likelihood that the population will become extinct due to the stochastic factors associated with small size (Soulé et al. 1986). Attempts are made to breed all individuals. While inbreeding is minimized and efforts are made to retain the founders' allelic diversity, rapid population growth is a primary consideration, particularly during the very early period when the population is extremely small. The risk of population extinction during this vulnerable period outweighs the risk associated with a few suboptimal genetic pairings. Therefore, mate selection during this phase may be influenced by behavioral (which female prefers which male) or demographic considerations (use of proven breeders of one sex with unproven breeders of the opposite sex) in addition to genetic ones. Figure 2 shows this period of rapid growth for the tamarin, ferret, rail and condor populations; only the condor population is still in the growth phase. At some point during the growth phase, a captive population should be geographically subdivided to reduce the risk of extinction from catastrophe (disease, fire, etc.) at a single breeding facility.

Management Concerns During the Capacity Phase

As the population approaches its target size, it enters the capacity phase. The selection of breeding individuals is increasing based on genetic measures, as all individuals are no longer allowed to breed. Two genetic measures, obtained by pedigree analysis, are used to evaluate the importance of each living individual for maintaining genetic diversity. These measures are mean kinship, which is related to heterozygosity, and genome uniqueness, which is related to allelic diversity.

An individual's mean kinship is the average of the kinship coefficients between that individual and all living individuals in the population. The kinship coefficient, the probability that an allele chosen randomly from one individual is the same as an allele chosen randomly from a second individual (Falconer 1981), is a measure of how closely two individuals are related. Individuals with many relatives in the population have high mean kinships and those with few relatives have low mean kinships. It can be shown mathematically that minimizing mean kinship values in the individuals used for breeding maximizes the expected heterozygosity levels of the offspring (Ballou in press).

Genome uniqueness is a measure of the proportion of an individual's genes that is potentially unique, that is, not shared by any other living individual in the population (Lacy 1990). It is simulated by a "gene drop" analysis of the population's pedigree (MacCluer et al. 1986). The transmission of hypothetical alleles at a single locus through the pedigree is simulated by assigning each of the founders two unique alleles. That is, founder one is assigned alleles 1 and 2, founder two is assigned alleles 3 and 4, and so on. Each time the pedigree indicates that a pair of individuals has produced an offspring, the computer randomly chooses one of the two alleles of each parent (with a 50-50 chance for each) to assign to the offspring. The computer can perform this process of "dropping genes" (alleles) a large number of times (e.g., 1,000); genome uniqueness then is estimated by comparing the simulated genomes of all living individuals.

Individuals with high mean kinship tend to have low genome uniqueness, especially in extended, multi-generational pedigrees. However, it is wise to consider both measures, especially in the early generations of a program, because some individuals with low mean kinship may have low genome uniqueness and some individuals with moderate mean kinship may have high genome uniqueness (Ballou in press).

Mean kinship and genome uniqueness are used to identify priority individuals for breeding. In many cases, individuals with similar low levels of mean kinship may be closely related. Therefore, proposed pairings based on these measures should also be evaluated with respect to the level of inbreeding in the progeny that pair would produce. The priority individuals for breeding identified by this process then are combined with demographic recommendations for the population, i.e., the number of young desired each year, to produce a detailed breeding plan (Foose and Seal 1986). This plan specifies whether or not each individual should be bred, and, if so, to whom, where and how often.

Once the population has reached the capacity phase, often comparatively few offspring are needed each year to maintain it at this size. The number of offspring required for zero population growth can be calculated by life-table analysis (Goodman 1980). Additional offspring can be produced for reintroduction or, if the reproductive potential of the captive population exceeds the number of animals that the reintroduction program can use, some adults may be prevented from breeding. Some common methods of curtailing reproduction are housing adults in same-sex groups or using contraceptive techniques. For example, the captive tamarin population currently is at its target size of about 550 individuals. These 550 individuals potentially can produce over 400 offspring per year. As only about 80 offspring are needed to maintain the population at its target size and the number of individuals that can be reintroduced to Brazil each year is limited by habitat availability and funding, a contraceptive effort was initiated in 1985 to control reproduction. In 1991, reproduction of some 90 female tamarins was inhibited by being housed solely with another female or a non-reproductive male, or by the use of contraceptive hormonal implants (Ballou 1991).

Supplementary Techniques

Descriptive genetic information can be obtained through laboratory techniques, such as electrophoresis, karyotyping, analyses of mtDNA and DNA fingerprinting. Such data can help to define appropriate genetic management units (distinct populations, "evolutionarily significant units," subspecies or species), improve or confirm uncertain pedigrees, and evaluate introgression of genetic material from other taxa (Avis 1989, Ballou and Cooper in press, Ryder 1986, Ryder et al. in preparation, Wayne and Jenks in press). DNA fingerprinting and mtDNA data are currently being used to estimate probable relationships between the founders of the California condor and Guam rail populations (Haig in press, O. Ryder personal communication: 1991).

Laboratory techniques, such as cryopreservation of gametes or embryos, artificial insemination, *in vitro* fertilization and embryo transfer, are the subjects of intensive research in several zoos but are not yet in general use in captive breeding programs

(Wildt 1989). Cryopreservation of gametes or embryos can potentially save genetic material from founders or other genetically important individuals, particularly those that fail to breed naturally. Artificial insemination and *in vitro* fertilization can enable genetically desirable matings that would otherwise be impossible due to geographical separation of potential mates or behavioral problems. Embryo transfer to females of a closely related species could be used to increase reproductive rates (Ballou and Cooper in press).

Reproductive rates of captive avian populations often can be increased by the removal and artificial incubation of eggs, as many birds will produce another clutch if their first is removed. This technique has contributed to the rapid growth of both the rail and condor populations. The effect in condors is dramatic: wild condors typically lay one egg every two years but several captive females have produced as many as three eggs per year (Wallace in press).

Coordinating Reintroduction and Captive Breeding Programs

The feasibility and schedule of a reintroduction program can be limited by a variety of factors including habitat availability, funding, the availability of captive-bred individuals for reintroduction and development of species-specific reintroduction techniques. As in the early stages of captive breeding, considerable research, both in captivity and in the field, often is necessary during the early stages of the reintroduction process to develop successful techniques (Stanley Price 1991, Kleiman 1989).

The reintroduction of captive-bred individuals can pose a considerable technical challenge that must be addressed before the reintroduction begins. Trial reintroductions of a closely-related surrogate species may be helpful, e.g., the techniques being used to reintroduce California condors and black-footed ferrets were developed using Andean condors and Siberian polecats (Wallace in press, T. Thorne personal communication: 1991). Behavioral deficiencies are often a problem. Captive-bred ferrets tend to be inefficient at recognizing and avoiding coyotes and other predators; Siberian polecats were used as research surrogates for ferrets for predatory avoidance studies prior to the first ferret reintroduction (Miller et al. 1990). The first tamarins released exhibited poor locomotor and foraging skills. A combination of pre- and post-release training and experience is helping to improve survival rates of reintroduced tamarins (Kleiman et al. 1986).

Reintroductions may be delayed because of insufficient numbers of captive animals if the captive population has not yet completed its growth phase. It generally is advisable to wait until the captive population is near its target size before removing individuals for reintroduction. The advantages of this strategy are that it maximizes both the preservation of genetic diversity in the captive population and the probability that the captive population will not become extinct due to unforeseen chance events.

The first tamarins, rails and ferrets were not reintroduced until the captive populations were at or near the target sizes (Figure 2, A–C). However, some condors are being reintroduced during the growth phase (Table 2, Figure 2, D) due to other pressing concerns, particularly the need to preserve habitat. Reintroducing individuals during the growth phase reduces the growth of the captive population and, thus, increases the number of years required for the population to reach its target size. Although this approach maximizes the number of individuals that are reintroduced in the short-term, the trade-off is that it minimizes the total number that can be reintroduced over the longer term.

Table 3 illustrates these trade-offs based on a simple deterministic model of the condor population under conditions that reflect average reproduction to date (each captive adult female produces about 1.5 chicks/year). The predicted results of two different management plans, A and B are shown. Plan A calls for allowing the captive population to grow to the target size as fast as possible before any chicks are released. Plan B specifies that the captive population be bred at the maximum rate but only be allowed to grow at the minimum rate that will enable it to reach the target size within 10 years (about 11 percent a year). Chicks produced in excess of the number required to achieve this growth rate are used for reintroduction. While this rough model may not be an accurate estimate of the projected growth of the population, it does illustrate that earlier reintroduction (Plan B) results in a smaller number of animals being reintroduced over the 10-year period. Thus, a complex series of trade-offs between the size (and, thus, demographic and genetic security) of the captive population, the advantages of early reintroductions and the advantages of reintroducing more individuals in a given time period must be evaluated when the decision is made to reintroduce individuals during the growth phase.

When the captive population is at its target size, there are two general strategies for producing animals for a reintroduction program. One approach is to pair and breed individuals for the specific purpose of producing excess young for the reintroduction. This is most appropriate when the number of animals to be released and the schedule of reintroduction are predictable relative to the reproductive time-frame

Table 3. Relationships between the growth rate of the captive condor population, the projected length of time until the population reaches its target size (150), and the number of individuals available for reintroduction. Management plan A allows the captive population to grow to 150 as fast as possible before chicks are released, while B reflects a slower rate of population growth due to individuals being removed for reintroduction while the population is in its growth phase; details in text.

Year	Size of captive population under management plan		Individuals available for reintroduction under management plan	
	A	B	A	B
1991	52	52	0	0[b]
1992	69	58	0	9
1993	85	64	0	8
1994	102	72	0	6
1995	120	80	0	6
1996	148	89	0	11
1997	150[a]	101	24	15
1998	150[a]	111	35	20
1999	150[a]	124	42	21
2000	150[a]	135	48	26
2001	150[a]	150[a]	54	28
Total			203	149

[a]Captive population at hypothetical target size.
[b]Two individuals were reintroduced in 1991.

(e.g., inter-birth interval) for that species. This strategy has been followed for the Guam rail. An alternative strategy is to select reintroduction candidates from the existing population and later establish breedings to replace reintroduced individuals. This strategy is useful for programs with relatively unpredictable reintroduction schedules but with high reliability for breeding specific individuals in captivity. For example, the tamarin reintroduction program is primarily limited by funding and habitat availability, not the numbers of animals that can be produced for reintroduction. This results in a less predictable reintroduction schedule. The strategy used in this program has not been to purposefully breed animals for the reintroduction program, but to use animals existing in the population as they are needed and then breed to replace these individuals (using close relatives) in the immediate future. A similar strategy was used in the 1991 ferret and condor reintroductions.

An additional demographic consideration is the effect of removing animals on the age structure of the captive population. Removing young animals for reintroduction is likely to be a common strategy. However, this may have a de-stabilizing effect on the age structure, causing future fluctuations in reproductive rates and population size, particularly if large numbers of young are used (Goodman 1980). Likewise, some types of removal strategies (particularly sex-specific removals) may affect the genetically effective size of the captive population (Ryman et al. 1981). Demographic analyses should be conducted to evaluate the effect of various removal (harvest) strategies on both the demographic and genetic stability of the population.

Although demographic factors, such as the number of offspring that can be produced by a population at its target size, may determine the number of individuals that are potentially available for release each year, genetic methods are important for determining which individuals will be chosen. In the early stages of a reintroduction program, when reintroduction techniques are still being refined and survival of the reintroduced individuals may be poor, the most genetically expendable individuals should be chosen for release. These individuals will have high mean kinship scores and low genome uniqueness scores. An important goal of a reintroduction program, however, is to establish one or more wild populations that contain all the genetic variation present in the captive population. Thus, emphasis will gradually shift to choosing individuals that are not closely related to the individuals already present in a given wild population (Ballou in press). This strategy is currently being followed by the condor, ferret, rail and tamarin reintroduction programs. The tamarin program is slightly more complicated because survival is improved if animals are reintroduced as social groups (families) rather than individuals. Thus, groups of tamarins (a breeding pair and their offspring of various ages), rather than individuals, must be chosen for release.

Summary and Conclusions

(1) A captive breeding program for a taxon of conservation concern should be part of a comprehensive conservation strategy that also addresses the problems affecting the taxon in the wild.

(2) Captive populations for such taxa should be founded well before the wild population has been severely reduced in size. This minimizes the impact of removing individuals from the wild population, assures a solid genetic and demographic base for the captive population, and provides ample time for the captive pop-

ulation to become established prior to the possible need for a reintroduction program.

(3) Captive breeding programs can make their most effective contribution to the conservation of endangered taxa if captive populations are demographically and genetically managed.

(4) Genetic management focuses on maintaining genetic diversity in order to minimize undesirable genetic changes due to selection in the captive environment, avoid the possible effects of inbreeding depression and maintain future options for genetic management.

(5) The number of animals available for reintroduction from a captive breeding program depends on the size and status of the captive population. Numbers can be limited by both genetic and demographic concerns.

(6) Captive breeding and reintroduction programs involve both research and management actions. Although genetic and demographic management techniques for captive populations are fairly well developed and can be applied to most taxa, husbandry and reintroduction techniques tend to be taxon-specific, and existing information often is insufficient to guide the development of a new program. Thus, considerable research and funding are often necessary to develop a successful captive breeding and reintroduction program for a particular taxon.

References

Avis, J. C. 1989. A role for molecular genetics in the recognition and conservation of endangered species. Trends in Ecology and Evolution 4:279–281.

Ballou, J. D. 1987. Small populations, genetic diversity and captive carrying capacities. Proc. 1987 AAZPA Ann. Conf.: 33–47.

———. 1991. 1990 International Golden Lion Tamarin Studbook. Nat. Zool. Park, Washington, D.C.

———. In press. Genetic and demographic considerations in endangered species captive breeding and reintroduction programs. *In* D. McCullough and R. Barrett, eds., Wildlife 2001: Populations. Elsevier, Barking, U. K.

Ballou, J. D. and K. A. Cooper. In press. Application of biotechnology to captive breeding of endangered species. Mace, G. and U. McDonnell, eds., Zool. Soc. London. England.

Ballou, J. D. and T. J. Foose. In press. Demographic and genetic management of captive populations. *In* S. Lumpkin and D. G. Kleiman, eds., Wild Mammals in Captivity. Univ. Chicago Press.

Ballou, J. D. and R. Oakleaf. 1989. Demographic and genetic captive-breeding recommendations for black-footed ferrets. Pages 247–267 *in* U. S. Seal, E. T. Thorne, M. A. Bogan, and S. H. Anderson, eds., Conservation biology and the black-footed ferret. Yale Univ. Press, New Haven, CT. 302 pp.

Cade, T. 1990. Peregrin falcon recovery. Endangered Species Update 8:40–45.

Conway, W. 1986. The practical difficulties and financial implications of endangered species breeding programs. International Zoo Yearbook 24/25:210–219.

Dennis, B., P. L. Munholland, and J. M. Scott. 1991. Estimation of growth and extinction parameters for endangered species. Ecological Monographs 61:115–143.

Derrickson, S. R. 1987. Current status and captive propagation of the endangered guam rail. Pages 187–195 *in* A. C. Risser, ed., Proc. Jean Delacour/IFCB Symposium on Breeding Birds in Captivity. IFCB. North Hollywood, CA.

———. 1991. Guam rail (*Rallus owstoni*). Pages 152–154 *in* M. Hutchins, R. J. Wiese, K. Willis, and S. Becker, eds., AAZPA Ann. Rept. on Conservation and Science 1990–91. Am. Assoc. Zool. Parks and Aquariums, Washington, D.C. 263 pp.

Falconer, D. S. 1981. An introduction to Quantitative Genetics. 2nd. ed. Longman, London and New York. 340 pp.

Foose, T. J. 1989. Species survival plans: The role of captive propagation in conservation strategies. Pages 210–222 *in* U. S. Seal, E. T. Thorne, M. A. Bogan, and S. H. Anderson, eds., Conservation biology and the black-footed ferret. Yale Univ. Press. New Haven, CT. 302 pp.
———. 1991. Viable population strategies for re-introduction programmes. Pages 165–172 *in* J. H. W. Gipps, ed., Beyond captive breeding: Re-introducing endangered mammals to the wild. Zool. Soc. London Symposia 62, Clarendon Press, Oxford, U. K. 284 pp.
Foose, T. J. and U. S. Seal. 1986. Species survival plans for large cats in North American zoos. Pages 173–198 *in* S. D. Miller and D. D. Everett, eds., Cats of the World. National Wildl. Fed., Washington, D.C.
Foose, T. J., R. Lande, N. R. Flesness, G. Rabb, and B. Read. 1986. Propagation plans. Zoo Biology 5:139–146.
Frankel, O. H. and M. E. Soulé. 1981. Conservation and evolution. Cambridge Univ. Press, Cambridge, England. 327 pp.
Frankham, R., H. Hemmer, O. A. Ryder, E. G. Cothran, M. E. Soulé, N. D. Murray, and M. Synder. 1986. Selection in captive populations. Zoo Biology 5:127–138.
Fuerst, P. A. and T. Maruyama. 1986. Considerations on the conservation of alleles and of genic heterozygosity in small managed populations. Zoo Biology 5:171–180.
Gilpin, M. and C. Wills. 1991. MHC and captive breeding: A rebuttal. Conserv. Biol. 5:554–555.
Glatston, A. R. 1986. Studbooks: the basis of breeding programs. International Zoo Yearbook 25:162–167.
Goodman, D. 1980. Demographic intervention for closely managed populations. Pages 171–195 *in* M. E. Soulé and B. A. Wilcox, eds., Conservation biology: An evolutionary-ecological perspective. Sinauer Associates. Sunderland, MA. 395 pp.
Haig, S. In press. Genetic management of the Guam rail. Acta XX Congresses Internationalis Ornithologica.
Haig, S. M., J. D. Ballou, and S. R. Derrickson. 1990. Management options for preserving genetic diversity: Reintroduction of Guam rails to the wild. Conserv. Biol. 4:290–300.
Hedrick, P. W. 1985. Genetics of populations. Science Books International, Boston, MA. 629 pp.
Hedrick, P. W., P. R. Brussard, F. W. Allendorf, J. A. Beardmore, and S. Orzack. 1986. Protein variation, fitness, and captive propagation. Zoo Biology 5:91–100.
Hedrick, P. W. and P. Miller. 1992. Conservation genetics: Techniques and fundamentals. Ecological Applications 2:30–46.
Hughes, A. L. 1991. MHC polymorphism and the design of captive breeding programs. Conserv. Biol. 5:249–251.
Hutchins, M. and R. J. Wiese. 1991. Beyond genetic and demographic management: The future of the Species Survival Plan and related AAZPA conservation efforts. Zoo Biology 10:285–292.
International Species Information System. 1991. SPARKS (Single Species Animal Record Keeping System). Apple Valley, MN.
International Union for the Conservation of Nature and Natural Resources. 1987. The IUCN Policy Statement on Captive Breeding. Gland, Switzerland. 3 pp.
Jones, S. R. ed. 1990. Captive propagation and reintroduction: A strategy for preserving endangered species? Endangered Species Update 8:1–88.
Kieler, C. 1991. California condor studbook. San Diego Zoo, San Diego, CA.
Kleiman, D. K. 1989. Reintroduction of captive animals for conservation. BioScience 39:152–161.
Kleiman, D. G., B. B. Beck, J. M. Dietz, L. A. Dietz, J. D. Ballou and A. F. Coimbra-Filho. 1986. Conservation program for the golden lion tamarin: Captive research and management, ecological studies, education strategies, and reintroduction. Pages 959–979 *in* K. Benirschke, ed., Primates: The road to self-sustaining populations. Springer-Verlag. New York, NY. 1,044 pp.
Klein, J. 1986. The natural history of the major histocompatibility complex. Wiley, NY.
Lacy, R. C. 1989. Analysis of founder representation in pedigrees: Founder equivalents and founder genome equivalents. Zoo Biology 8:111–123.
———. 1990. GENES: Pedigree analysis software. Chicago Zoological Park, Brookfield, IL.
Lacy, R., J. Ballou, A. Starfield, E. Thompson and A. Thomas. In preparation. Pedigree analyses. *In* J. D. Ballou, M. Gilpin, and T. Foose, eds., Population Management for Survival and Recovery.
Lande, R. and G. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87–124 *in* M. E. Soulé, ed., Viable populations for conservation. Cambridge Univ. Press, Cambridge. 189 pp.

Lewontin, R. C. 1974. The genetic basis of evolutionary change. Columbia Univ. Press, New York, NY. 346 pp.
MacCluer, J. W., J. L. Vandeberg, B. Read, and O. A. Ryder. 1986. Pedigree analysis by computer simulation. Zoo Biology 5:147–160.
Miller, B., D. Biggins, C. Wemmer, R. Powell, L. Calvo, L. Hanebury, and T. Wharton. 1990. Development of survival skills in captive-raised Siberian polecats (*Mustela eversamnni*) II. Predator avoidance. J. Ethology 8:95–104.
Miller, P. S. and P. W. Hedrick. 1991. MHC polymorphism and the design of captive breeding programs: Simple solutions are not the answer. Conserv. Biol. 5:556–558.
Nevo, E. 1978. Genetic variation in natural populations: Patterns and theory. Theoretical Population Biology 13:121–177.
Odum, A. 1990. Species management system computer software. Houston Zoological Society, Houston, TX.
Povilitis, T. 1990. Is captive breeding an appropriate strategy for endangered species conservation? Endangered Species Update 8:20–23.
Ralls, K., J. Ballou, and A. R. Templeton. 1988. Estimates of lethal equivalents and the cost of inbreeding in mammals. Conserv. Biol. 2:185–193.
Ralls, K. and J. Ballou. 1986. Preface to the proceedings of the Workshop on genetic management of captive populations. Zoo Biology 5:81–86.
Ryder, O. A. 1986. Species conservation and systematics: The dilemma of subspecies. Trends in Ecology and Evolution 1:9–10.
Ryder, O., J. Avise, S. Haig, M. Lynch, and G. Geyer. In preparation. Applications of molecular genetic techniques in population management and conservation biology. *In* J. D. Ballou, M. Gilpin, and T. Foose, eds., Population Management for Survival and Recovery.
Ryman, N., R. Baccus, C. Reuterwall, and M. H. Smith. 1981. Effective population size, generation interval, and potential loss of genetic variability in game species under different hunting regimes. Oikos 36:257–266.
Seal, U. S. 1991. Life after extinction. Pages 39–56 *in* J. H. W. Gipps, ed., Beyond captive breeding: Re-introducing endangered mammals to the wild. Zool. Soc. London Symposia 62, Clarendon Press, Oxford, U.D. 284 pp.
Soulé, M. E., M. Gilpin, W. Conway, and T. Foose. 1986. The Millenium Ark: How long a voyage, how many staterooms, how many passengers? Zoo Biology 5:101–114.
Stanley-Price, M. R. 1989. Animal reintroductions: The Arabian oryx in Oman. Cambridge Univ. Press, Cambridge, England. 291 pp.
———. 1991. A review of mammal re-introductions, and the role of the Re-introduction Specialist Group of IUCN/SSC. Pages 9–25 *in* J. H. W. Gipps, ed., Beyond captive breeding: Re-introducing endangered mammals to the wild. Zool. Soc. London Symposia 62. Clarendon Press, Oxford, U. K. 284 pp.
Templeton, A. R. 1990. The role of genetics in captive breeding and reintroduction programs for species conservation. Endangered Species Update 8:15–17.
Templeton, A. R. and B. Read. 1984. Factors eliminating inbreeding depression in a captive herd of Speke's gazelle. Zoo Biology 3:177–200.
Thorne, E. T. and D. W. Belitsky. 1989. Captive propagation and the current status of free-ranging black-footed ferrets in Wyoming. Pages 223–234 *in* U. S. Seal, E. T. Thorne, M. A. Bogan, and S. H. Anderson, eds., Conservation biology and the black-footed ferret. Yale Univ. Press. New Haven, CT. 302 pp.
Thorne, E. T. and R. Oakleaf. 1991. Species rescue for captive breeding: Black-footed ferret as an example. Pages 241–261 *in* J. H. W. Gipps, ed., Beyond captive breeding: Re-introducing endangered mammals to the wild. Zool. Soc. London Symposia 62. Clarendon Press, Oxford, U. K. 284 pp.
Vrijenhoek, R. C. and P. L. Leberg. 1991. Let's not throw the baby out with the bathwater: A comment on management for MHC diversity in captive populations. Conserv. Biol. 5:252–254.
Wallace, M. P. In press. Captive management for the long-term survival for the California Condor. In D. McCullough and R. Barrett, eds., Wildlife 2001: Populations. Elsevier, Barking, U. K.
Wayne, R. and S. Jenks. In press. The use of morphologic and molecular techniques to estimate genetic variability and relationships of small endangered populations. *In* D. McCullough and R. Barrett, eds., Wildlife 2001: Populations. Elsevier, Barking, U. K.

Wildt, D. 1989. Reproductive research in conservation biology: Priorities and avenues for support. J. Zoo and Wildl. Med. 20:391–395.

Wildt, D. E., M. Bush, C. Morton, and J. G. Howard. 1989. Semen characteristics and testosterone profiles in ferrets kept in a long-day photoperiod, and the influence of hCG timing and sperm dilution medium on pregnancy rate after laparoscopic insemination. J. Reproduction and Fertility 86:349–358.

Witteman, G. J., R. E. Beck, S. L. Pimm, and S. R. Derrickson. 1990. The decline and restoration of the Guam rail, *Rallus owstoni*. Endangered Species Update 8:36–39.

Landscape Considerations for Viable Populations and Biological Diversity

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Introduction

Wildlife management typically focuses on individual species. Attention to single species comes historically from management of game species based on maximum sustainable yield concepts (Holt and Talbot 1978). Species need to be examined individually and in different regions of their geographic range to understand habitat requirements (Noon et al. 1980, James et al. 1984, Knopf et al. 1990), but they also need to be considered in the context of other species with which they may coexist. Management for one species may affect other potentially-coexisting species, plus effects of management on other coexisting species that are competitors, predators or parasites may affect demography of target species. In addition, land use practices surrounding a given habitat also may affect the numbers and types of coexisting species as well as population viability, and has generated increased interest in ''landscapes.'' Thus, effects of management practices on biological diversity and population viability need to be considered at several spatial scales.

Landscape refers to interspersion of heterogeneous land forms, vegetation types and land uses (Urban et al. 1987). Increased landscape diversity (greater interspersion and numbers of landscape elements) can increase the numbers of species coexisting in the landscape (Johnston 1947, Johnston and Odum 1956, Crawford et al. 1981). In addition, interspersion of vegetation or ''cover'' types is also associated with increased population sizes of some species. For example, population sizes of Bobwhite Quail (*Colinus virginanus*) are correlated with indices of cover interspersion (Baxter and Wolfe 1972). Nevertheless, while increased landscape diversity may result in increased plant and animal diversity locally, it may have detrimental effects on habitat suitability for individual species (defined by fitness within the habitats—Fretwell 1972, van Horne 1983) and affect regional diversity. These and other conflicts must be carefully considered when addressing biological diversity in management recommendations. Moreover, many relationships and patterns considered in landscape and fragmentation issues are based on assumptions that are not well-studied. Unproven assumptions must be recognized so that caution can be exercised when generalizing predicted relationships and patterns. Here, I briefly discuss some of these conflicts and assumptions. I do not directly discuss corridor effects because they represent edge habitats and, thus, simply fit in the larger issue of edge effects. I draw largely on avian examples because of my greater familiarity with that literature and because the ideas are general enough to apply to a wider range of taxa.

Landscape Diversity and Edges

Wildlife managers have long been interested in edges and cover interspersion. Leopold (1933) emphasized the importance of edges for wildlife and concluded that abundance of game, as well as diversity of species, increased with the amount of edge per unit area (*see also* Johnston 1947, Johnston and Odum 1956). This ''edge effect'' was thought to occur because an edge has greater vegetation structural complexity and reflects the juxtaposition of different habitat types, each of which may supply different needs of species. Consequently, some argued that the most effective means of managing wildlife was to create edges and to diversify and maximize interspersion of cover types (Leopold 1933, King 1938, Bump et al. 1947, Kelker 1964). Such viewpoints and evidence were firmly incorporated into wildlife management fundamentals and many wildlife management textbooks still encourage development of edges and cover interspersion (e.g., Giles 1978, Bailey 1984, Robinson and Bolen 1984). However, while increased landscape diversity can lead to increased numbers of species locally, the types and population viabilities of species in those landscapes need careful consideration.

Types of Species

Species that depend upon forest interior habitat have received much attention because anthropogenic disturbances tend to minimize such habitat conditions. The definition of forest interior habitat is nebulous and yet species can be clearly identified as interior-dwelling (e.g., Whitcomb et al. 1981, Blake and Karr 1984, Newmark 1991). Increased landscape diversity caused by increased diversity and interspersion of cover types effectively fragments habitats, leading to loss of many forest interior species while favoring edge-dwelling species (Galli et al. 1976, Whitcomb et al. 1981, Blake and Karr 1984, Robbins et al. 1989a, Newmark 1991). Typically, edge species are widespread in distribution, tend to have high reproductive potential (Whitcomb et al. 1981), and are less likely to develop severe population problems than interior species (Martin 1993). Thus, high landscape diversity promotes high local species richness, but at the expense of the types of species (i.e., forest interior) that are in greatest need of conservation actions (Blake and Karr 1984) and, thereby, negatively impacting the diversity of species at larger (e.g., regional) spatial scales.

Forest-edge species can increase in areas of high landscape diversity because shrub and vegetation density increases along edges in fragmented landscapes and supplies the habitat that these species commonly use even away from edges. In fact, some forest edge species will occupy forest interior when suitable habitat (e.g., shrubby vegetation caused by light gaps in the canopy) exists (Kendeigh 1944, Noss 1991). These species are simply exhibiting habitat preferences favored by their evolutionary histories without regard to current landscape conditions. For example, a species such as the northern cardinal (*Cardinalis cardinalis*) prefers shrubby habitat conditions and will choose such conditions in a pure shrub habitat with no overstory (Conner et al. 1986), shrubby conditions along forest edges (Blake and Karr 1987), or shrubby openings in forest interior (Kendeigh 1944). A problem arises for some species, however, when the habitat conditions that they prefer, based on their evolutionary histories, occur more commonly in unnatural landscapes (e.g., forests surrounded by agricultural fields) due to anthropogenic disturbance. Such landscape conditions can be detrimental to population viability.

The key to understanding the distribution and abundance of any species or group of species lies in determining the evolutionary bases of their habitat requirements and their reproductive (life history) potential. For example, we know forest interior species are lost with fragmentation, but we still do not understand why. Much attention has focused on increased nest predation or brown-headed cowbird (*Molothrus ater*) parasitism in fragments and edges, but direct evidence is weak and potentially over-emphasized. The absence of species from small fragments may occur because the probability of occurrence of specific habitat conditions required by interior species simply decreases with forest area. These species may occur in smaller forests if the required habitat conditions were present. For example, the worm-eating warbler (*Helmitheros vermivorus*) generally nests on steep hillside conditions within forests (Graber et al. 1983, unpublished data). Such conditions are less likely to exist in small than large forests. Similarly, such conditions are less likely to occur in some geographic locations (e.g., worm-eating warblers were not present on even the largest sites of Blake and Karr [1987] in relatively flat terrain in Illinois, even though the species exists in more hilly geographic regions both north and south of those sites [*see* Graber et al. 1983]). Such patterns indicate that the birds are distributed with respect to availability of their specific habitat requirements and argue for a need to study species across their geographic range to determine habitat requirements (*see* Noon et al. 1980, James et al. 1984, Knopf et al. 1990). Indeed, the specific habitat requirements of most forest interior species are poorly known. We need to ascertain the specific habitat requirements of species that depend on interior habitat over the next decade if we are to maintain biological diversity. Moreover, we need to understand the evolutionary bases of habitat requirements, because the habitat features that affect fitness components (e.g., reproduction, survival) can have the greatest direct effect on demography of the population (Martin 1992). Such information can only be obtained by directly examining fitness components in relation to habitat conditions at local sites and across the geographic range of species.

Viability of Populations

One problem that many species currently face is that habitat preferences shaped by their evolutionary histories may not be appropriate under current landscape conditions; species may be present in habitat conditions that represent population "sinks," where reproduction is insufficient to maintain the population and immigration is necessary instead (Pulliam 1988). Edge and habitat fragments are often thought to represent "ecological traps" (Gates and Gyusel 1978), where species are attracted to the greater structural diversity of habitat at edges, but suffer lower reproductive success at these edges. Consequently, species may be present in disturbed conditions, but the demographic viability of their populations may be low. For example, vesper sparrows (*Pooecetes gramineus*) nest in agricultural fields and only obtain 13 percent nest success, which is insufficient to maintain the population (Rodenhouse and Best 1983). Other examples of low reproductive success in disturbed landscapes also exist (*see* Gates and Gysel 1978, Robinson 1988).

On the other hand, while potential negative effects of edges have been widely extolled (Gates and Gysel 1978, Yahner 1988), the extent to which edges are actually detrimental is still undetermined. Some studies show that predation is greater along edges (Gates and Gysel 1978, Chasko and Gates 1982, Johnson and Temple 1990), but others show predation is no greater along edges than in interior habitat (Yahner and Wright 1985, Angelstam 1986, Ratti and Reese 1988, Small and Hunter 1988, Noss 1991). Detrimental effects of edges may depend upon surrounding landscape characteristics. Thus, caution must be exercised in generalizing patterns too widely and then concluding, for example, that edges are always detrimental.

Edges and Their Landscape Context

A commonly held assumption is that creation of edges automatically leads to an increase in predation or brown-headed cowbird parasitism (Brittingham and Temple 1983, Yahner 1988). Yet, early work was conducted in landscapes with an extensive agricultural component; even the largest forests studied were near agricultural landscapes. As a result, parasitism by brown-headed Cowbirds near openings in large forests in locations such as Wisconsin (Brittingham and Temple 1983) may be the result of cowbird recruitment from nearby agricultural areas. The influence of forest openings in a non-agricultural landscape (e.g., in a forested landscape where openings are created by timber cutting) on probability of predation and parasitism are less clear. Artificial nests in a forested landscape in Maine actually suffered lower predation rates near edges than those in the forest interior (Small and Hunter 1988). Similarly, work on edges in other forest landscapes failed to find increased predation near the edge (Yahner and Wright 1985, Ratti and Reese 1988, Noss 1991). The rates of brown-headed cowbird parasitism near edges and openings in a generally-forested landscape have not been reported. Thus, while creation of edges through fragmentation or forest openings may be highly detrimental in landscapes with a strong agricultural component, the detrimental nature in forested landscapes is less clear.

Creation of forest openings of appropriate sizes can mimic a natural process (e.g., formation of tree-fall gaps) that increases habitat heterogeneity and animal diversity (Pickett and White 1985, Martin and Karr 1986, Blake and Hoppes 1986, Noss 1991). Moreover, Noss (1991) found that increased natural habitat heterogeneity caused by light gaps in old-growth forest can reduce edge effects; species that were more abundant near edges in more homogeneous forests were not more abundant near edges in his more heterogeneous old-growth forests. Many forests existing in North America today are relatively homogeneous because of historical timber cutting practices. Thus, edges and heterogeneity created by dispersed small openings in a generally forested landscape may benefit biological diversity and are in need of study.

Fragmentation of Habitats

One problem in determining solutions to effects of habitat disturbance has been the traditional focus in wildlife management on pattern description (e.g., declining numbers of species with area or habitat associations of species) rather than understanding the processes that cause patterns (Gavin 1989, Martin 1992). For example, we often seek to identify the minimum area at which species will occupy habitats to establish management guidelines for maintaining sufficient amounts of critical habitat. Yet, unless we know why species do not exist below a certain area in any given region, we cannot necessarily maintain the habitat conditions required to sustain viable populations of the species, nor can we apply the information across the range of the species. Species are often more abundant in the center of their geographic ranges, in part because the optimum habitat conditions for the species are simply more abundant there (James et al. 1984). In those cases where optimum habitat conditions are more abundant in the center of a species range, the specific habitat conditions required by a species may exist in much smaller fragments, causing area requirements to change over a species range. In addition, optimum microhabitat conditions for any species may be differentially abundant among habitats (e.g., different forest types). As a result, the probability of suitable microhabitat conditions existing within a given area of habitat will differ among these habitat types, causing varying minimum area requirements for species. Hence, geographic differences in minimum area requirements of species are not surprising (Table 1). In some cases (e.g., hooded warbler [*Wilsonia citrina*], scarlet tanager [*Piranga olivacea*], black-and-white warbler [*Mniotilta varia*]) the differences in minimum areas among locations are very large, while in other cases (e.g., yellow-billed cuckoo [*Coccyzus americanus*]), the minimum areas are similar. However, a species may still differ in response to fragmentation even when the minimum areas are small and similar among different geographic locations; for example, the wood thrush (*Hylocichla mustelina*) is sensitive to fragmentation (Blake and Karr 1987, Robbins et al. 1989a) and uses a minimum area of five ha in Illinois (Table 1) and, yet, it was found successfully nesting in trees between houses in Maryland (Brackbill 1958) and New York (Weaver 1939).

The sensitivity of bird species to fragmentation is often attributed to increased nest predation in smaller fragments (Whitcomb et al. 1981, Ambuel and Temple 1983, Wilcove 1985). The basis for this supposition is from artificial nest studies that show greater predation in small than in large forests (Wilcove 1985, Small and Hunter 1988). Artificial nests are subject to a variety of potential biases when comparing among habitats and areas and, thus, may not accurately reflect trends between fragments of differing sizes (Martin 1987). More studies of real nests are needed to establish patterns.

Increased predation rates in small fragments are thought to impact ground- and near-ground-nesting birds the most, because they are commonly argued to suffer the greatest rates of predation in general (Wilcove 1985, Robbins et al. 1989a, 1989b, Terborgh 1989). Higher rates of predation on ground than on off-ground nests have long been assumed, based on a literature review by Ricklefs (1969). Yet, data were pooled across habitat types for his analyses and included different numbers of species per vegetation layer among habitats. Such pooling includes an implicit assumption that patterns of predation on ground versus off-ground species are similar across habitat types. Analyses of a larger data set shows that this assumption is not valid; predation rates were similar between ground and off-ground nests for species nesting in grassland or shrubland habitats, whereas predation rates were lower for ground than for shrub or canopy-nesting species in forest habitats (Martin 1992, 1993). Moreover, three independent data sets from forest habitats showed the same pattern of lowest predation rates on ground-nesting species, although canopy-nesting species may sometimes be similar (Martin 1993). Examination of life history traits (e.g., clutch size, numbers of broods, duration of the nestling period) provides indirect evidence that nest predation, historically, has been less for ground than for off-ground nests (Martin, in preparation). Thus, the long-held assumption that ground-nesting species are most vulnerable to predation appears untrue for forest habitats.

These results call into question the arguments that ground-nesting species are particularly susceptible to population problems from fragmentation because they are most vulnerable to predation. Indeed, such arguments do not explain the population problems and sensitivity to fragmentation shown by canopy-nesting species such as scarlet tanagers, yellow-throated vireos (*Vireo flavifrons*) or cerulean warblers (*Dendroica cerulea*) (*see* Table 1) (Robbins et al. 1989b). The explanation more likely lies in understanding the role of predation on evolution of life history traits that affect reproductive potential and vulnerability to demographic problems. Number of broods per year affects reproductive potential and population vulnerability. Neotropical migrants have been generally classified as single-brooded and, thus, particularly vulnerable to demographic problems (Whitcomb et al. 1981). Yet, species with greater nest predation rates seem to respond by decreasing the number of young and increasing the number of broods (*see* Law 1979, Martin and Li 1992). Neotropical migrants with greater rates of nest predation (e.g., shrub-nesting species, early successional species, sub-canopy species) are often double-brooded (Martin, in preparation). However, the lower predation rates experienced by many ground- and canopy-nesting species in forest habitats is associated with larger clutch sizes (Martin 1988), fewer brood attempts per year (Martin and Li 1992, Martin, in preparation) and higher adult survival (Martin, in preparation). Such data again emphasize the importance of not overgeneralizing patterns and considering Neotropical migrants as a single group, and further indicates that different groups of species may be differentially vulnerable to population disturbance.

Lowered reproductive potential from decreased numbers of broods lowers ability to respond to population perturbations, such as increased nest predation or brown-headed cowbird parasitism, that might arise from fragmentation. Thus, the problem for these species probably is not a greater vulnerability to predation, but rather a lowered ability to compensate for increased mortality; species with lower reproductive potential can have greater susceptibility to extinction (Mertz 1971). Species with greater reproductive potential (e.g., shorter developmental periods and more brood attempts per year) can potentially compensate for increases in mortality. However,

Table 1. Minimum areas (in hectares) of forested habitat islands used by species in different geographic locations.

	New Jersey[a]	Illinois[b]	Maryland[c]	Maryland[d]
Ovenbird	4.0	24.0	6–14	0.8
Scarlet tanager	3.0	16.2	1–5	2.1
White-breasted nuthatch	2.0	28.0	6–14	1.6
Hooded warbler		600.0	1–5	
Acadian flycatcher		24.0	1–5	0.2
	1.2	28.0		11.3
Black-and-white warbler	7.5		>70	208.0
Yellow-throated vireo		6.5	>70	
Kentucky warbler		2.3	6–14	9.3
Wood thrush	0.8	5.1	1–5	0.2
Cerulean warbler		65.0		138.0
Yellow-billed cuckoo	4.0	2.3	1–5	

[a]Galli et al. 1976.
[b]Blake and Karr 1984.
[c]Whitcomb et al. 1981; species presence/absence was listed for ranges of areas as shown.
[d]Robbins et al. 1989a.

species with greater reproductive potential may often have greater annual adult mortality (*see* Martin and Li 1992). Substantial increases in reproductive mortality for such species coupled with high adult mortality can also lead to greater extinction probability (Karr 1990). Thus, either reproductive potential or adult mortality can influence extinction potential, depending on the ecological context (*see* Pimm et al. 1988).

Appropriate conservation plans depend on examining spatial scales larger than the landscape. Local areas where species are more abundant may be ignored in conservation plans because the species is abundant. If attention is focused on the species in geographic areas where it is least common, such locations may reflect areas of marginal habitat or abiotic conditions. Such areas can be important for genetic differentiation, but clearly, maintenance of viable populations of the species is going to be best accomplished by conserving the optimal habitat in the region where the species is most abundant. Examination of species over their entire geographic ranges is necessary for establishing appropriate conservation plans.

Conclusion

Much attention to landscape and fragmentation issues has led to overgeneralization of patterns which can focus attention on inappropriate management actions. For example, creation of openings and edges in forested landscapes may not be detrimental and, in fact, may be beneficial in unnaturally homogeneous habitats. However, increases in local diversity through increased landscape diversity may compromise regional diversity by minimizing habitat conditions needed by species most susceptible to population problems from habitat disturbance. Susceptibility of species to disturbance can vary with habitat requirements and life history influences on reproductive potential, and insufficient information is currently available for such issues.

Over the next decade we need to: (1) identify the specific habitat requirements of species if we are to manage populations before they become threatened or endangered; (2) study the underlying causes of patterns to allow development of management guidelines that attack problems rather than symptoms of problems; (3) study the effects of edge habitat and fragments on reproductive success in different landscape conditions to allow greater caution in our view of the detrimental nature of edges, particularly with regard to forested landscapes; (4) be cautious in our attempts to enhance biological diversity such that we do not maximize local diversity at the expense of diversity at larger geographic scales; (5) carefully consider the impacts of landscape diversification on habitat suitability and population viability within the landscape; and (6) examine the underlying causes of area-sensitivity and demographic problems of species such as nongame birds, including direct study of the life history characteristics of species that affect population vulnerability to disturbance.

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References

Angelstam, P. 1986. Predation on ground-nesting birds' nests in relation to predator densities and habitat edge. Oikos 47:365–373.

Bailey, J. A. 1984. Principles of wildlife management. John Wiley & Sons, NY.

Baxter, W. and C. Wolfe. 1972. The interspersion index as a technique for evaluation of Bobwhite Quail habitat, *in* J. Morrison and J. Lewis, eds., Proc. 1st Nat. Bobwhite Quail Symp. Stillwater, OK.

Blake, J. G. and W. G. Hoppes. 1986. Influence of resource abundance on use of treefall gaps by birds. Auk 103:328–340.

Blake, J. G. and J. R. Karr. 1984. Species composition of bird communities and the conservation benefit of large versus small forests. Biol. Cons. 30:173–187.

Blake, J. G. and J. R. Karr. 1987. Breeding birds of isolated woodlots: Area and habitat relationships. Ecology 68:1724–1734.

Brackbill, H. 1958. Nesting behavior of the Wood Thrush. Wilson Bull. 70:70–79.

Bump, G., R. W. Darrow, F. C. Edminster, and W. F. Crissey. 1947. The Ruffed C = Grouse: Life history, propagation, management. New York St. Dept. Cons., Albany, NY.

Chasko, G. G. and J. E. Gates. 1982. Avian habitat suitability along a transmission-line corridor in an oak-hickory forest region. Wildl. Monogr. 82:1–41.

Crawford, H. S., R. G. Hooper, and R. W. Titterington. 1981. Songbird population response to silvicultural practices in central Appalachian hardwoods. J. Wildl. Manage. 45:680–692.

Denslow, J. S. 1985. Disturbance-mediated coexistence of species. Pages 307–323 *in* S. T. A. Pickett and P. S. White, eds., The ecology of natural disturbance and patch dynamics. Academic Press, Orlando, FL.

Fretwell, S. D. 1972. Populations in a seasonal environment. Princeton Univ. Press, Princeton, NJ. 217 pp.

Galli, A. E., C. F. Leck, and R. T. T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93:356–364.

Gates, J. E. and L. W. Gysel. 1978. Avian nest dispersion and nesting success in field-forest ecotones. Ecology 59:871–883.

Gavin, T. A. 1989. What's wrong with the questions we ask in wildlife research? Wildl. Soc. Bull. 17:345–350.

Giles, R. H., Jr. 1978. Wildlife management. W. H. Freeman and Co., San Francisco, CA.

Graber, J. W., R. R. Graber, and E. L. Kirk. 1983. Illinois birds: Wood warblers. Ill. Nat. Hist. Surv. Biol. Notes 118:1–144.

Holt, S. J. and L. M. Talbot. 1978. New principles for the conservation of wild living resources. Wildl. Monogr. 59:1–33.

James, F. C., R. F. Johnston, N. O. Wamer, G. J. Niemi, and W. J. Boecklen. 1984. The Grinnellian niche of the Wood Thrush. Am. Nat. 124:17–47.

Johnson, R. G. and S. A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. J. Wildl. Manage. 54:106–111.

Johnston, V. R. 1947. Breeding birds of the forest edge in east-central Illinois. Condor 49:45–53.

Johnston, D. W. and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology 37:50–62.

Karr, J. R. 1990. Avian survival rates and the extinction process on Barro Colorado Island, Panama. Cons. Biol. 4:391–397.

Kelker, G. H. 1964. Appraisal of ideas advanced by Aldo Leopold thirty years ago. J. Wildl. Manage. 28:180–185.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecol. Monogr. 14:67–106.

King, R. T. 1938. The essentials of a wildlife range. J. For. 36:457–464.

Knopf, F. L., J. A. Sedgwick, and D. B. Inkley. 1990. Regional correspondence among shrubsteppe bird habitats. Condor 92:45–53.

Law, R. 1979. Optimal life histories under age-specific predation. Am. Nat. 114:399–417.

Leopold, A. 1933. Game management. Charles Scribner Sons, NY.

Martin, T. E. 1987. Artificial nest experiments: Effects of nest appearance and type of predator. Condor 89:925–928.

———. 1988. Nest placement: Implications for selected life-history traits, with special reference to clutch size. Am. Nat. 132:900–910.

———. 1992. Breeding season productivity: What are the appropriate habitat features for manage-

ment? *In* J. M. Hagan and D. W. Johnston, eds., Ecology and conservation of neotropical migratory birds, Smithson. Inst. Press. In press.
———. 1993. Nest predation among vegetation layers and habitat types: Implications for the life history and demographic patterns. Unpubl. manuscript in review.
Martin, T. E. and J. R. Karr. 1986. Patch utilization by migrating birds: Resource oriented? Ornis Scand. 17:165–174.
Martin, T. E. and P. Li. 1992. Life history traits of open- vs cavity-nesting birds. Ecology, in press.
Mertz, D. B. 1971. The mathematical demography of the California Condor population. Am. Nat. 105:437–453.
Newmark, W. D. 1991. Tropical forest fragmentation and the local extinction of understory birds in the eastern Usambara Mountains, Tanzania. Cons. Biol. 5:67–78.
Noon, B. R., D. K. Dawson, D. B. Inkley, C. S. Robbins, and S. H. Anderson. 1980. Consistency in habitat preference of forest bird species. Trans. N. Am. Wildl. Resour. Conf. 45:226–244.
Noss, R. F. 1991. Effects of edge and internal patchiness on avian habitat use in an old-growth Florida hammock. Nat. Areas J. 11:34–47.
Pickett, S. T. A. and P. S. White, eds. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Orlando, FL.
Pimm, S. L., H. L. Jones, and J. Diamond. 1988. On the risk of extinction. Am. Nat. 132:757–785.
Pulliam, H. R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:652–661.
Ratti, J. T. and K. P. Reese. 1988. Preliminary test of the ecological trap hypothesis. J. Wildl. Manage. 52:484–491.
Ricklefs, R. E. 1969. An analysis of nesting mortality in birds. Smithson. Contr. Zool. 9:1–48.
Robbins, C. S., D. K. Dawson, and B. A. Dowell. 1989a. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildl. Monogr. 103:1–34.
Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989b. Population declines in North American birds that migrate to the neotropics. Proc. Natl. Acad. Sci. 86:7658–7662.
Robinson, S. K. 1988. Reappraisal of the costs and benefits of habitat heterogeneity for nongame wildlife. Trans. N. Am. Wildl. Nat. Resour. Conf. 53:145–155.
Robinson, W. L. and E. R. Bolen. 1984. Wildlife ecology and management. Macmillan Publishing Co., NY.
Rodenhouse, N. L. and L. B. Best. 1983. Breeding ecology of Vesper Sparrows in corn and soybean fields. Am. Midl. Nat. 110:265–275.
Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57:773–782.
Small, M. F. and M. L. Hunter. 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia 76:62–64.
Terborgh, J. 1989. Where have all the birds gone? Princeton Univ. Press, Princeton, NJ.
Urban, D. L., R. V. O'Neill, and H. H. Shugart. 1987. Landscape ecology. BioScience 37:119–127.
Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Mange. 47:893–901.
Weaver, F. G. 1939. Studies in the life history of the Wood Thrush. Bird-Banding 10:16–23.
Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on the avifauna of the eastern deciduous forest. Pages 125–205 *in* R. L. Burgess and D. M. Sharpe, eds., Forest Island Dynamics in Man-dominated Landscapes, Springer-Verlag, NY.
Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211–1214.
Yahner, R. H. 1988. Changes in wildlife communities near edges. Cons. Biol. 2:333–339.
Yahner, R. H. and A. L. Wright. 1985. Depredation on artificial ground nests: Effects of edge and plot age. J. Wildl. Mange. 49:508–513.

Temporal Scale Perspectives in Managing Biological Diversity

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Introduction

Our planet is rich with complex and intricate life forms, the biological diversity of Earth. The fundamental questions concerning this biological diversity are simple: How did this richness arise? What can we do to ensure that the processes responsible for this richness will exist in perpetuity? Understanding this complexity begins with broadly categorizing both life and the processes that shape it. At the most basic level, three relatively distinct, yet interacting scales comprise and shape life on Earth: (1) biological scale, ranging from genes to ecosystems; (2) spatial scale, ranging from the local, immediate neighborhood to the landscape or region; and (3) temporal scale, ranging from short-term daily fluctuations to long-term millennial global change. In this paper, I explore the implications of time, the temporal scale perspective, in managing biological diversity. No specific management guidelines or recommendations are offered because every region presents a unique combination of environment, issues and constraints. Instead, my goal is to examine the broad management issues raised by reviewing the effects of time on biological systems, to highlight current limitations in management policy, goals and practices, and to offer suggestions on what I believe will become crucial management issues.

Two basic problems confront this examination of time and biological diversity: our sensory capabilities and semantics. We humans generally fail to perceive all but the most obvious changes over time: "Phenomena unfold on their own appropriate scales of space and time and may be invisible in our myopic world of dimensions assessed by comparison with human height and times metered by human life spans" (Gould 1990). Our lack of these sensory capabilities is compounded by the relationship between temporal and spatial scales: long-term change tends to occur at large spatial scales (Figure 1). We are usually unaware of gradual change over periods of time longer than a few decades, or over areas that are larger than we can directly see.

The term "biodiversity" is currently used by many people, in different ways and for very different purposes. Because of this semantic quagmire, even greater confusion exists over how to practically implement concepts of biodiversity. Unfortunately, the need is too great and the time too short to be stuck in semantic and turf quarrels. Part of this confusion stems from confounding definition with application. Biodiversity can simply, and literally, be defined as the variety of life on planet Earth, and the goal in applying this concept to management is to provide the conditions and processes necessary for sustaining life, in all of its complexity, on Earth.

Time: Types of Change

There are several types of temporal change, each with different causes and resulting effects. Temporal change can be broadly divided into the following categories: cy-

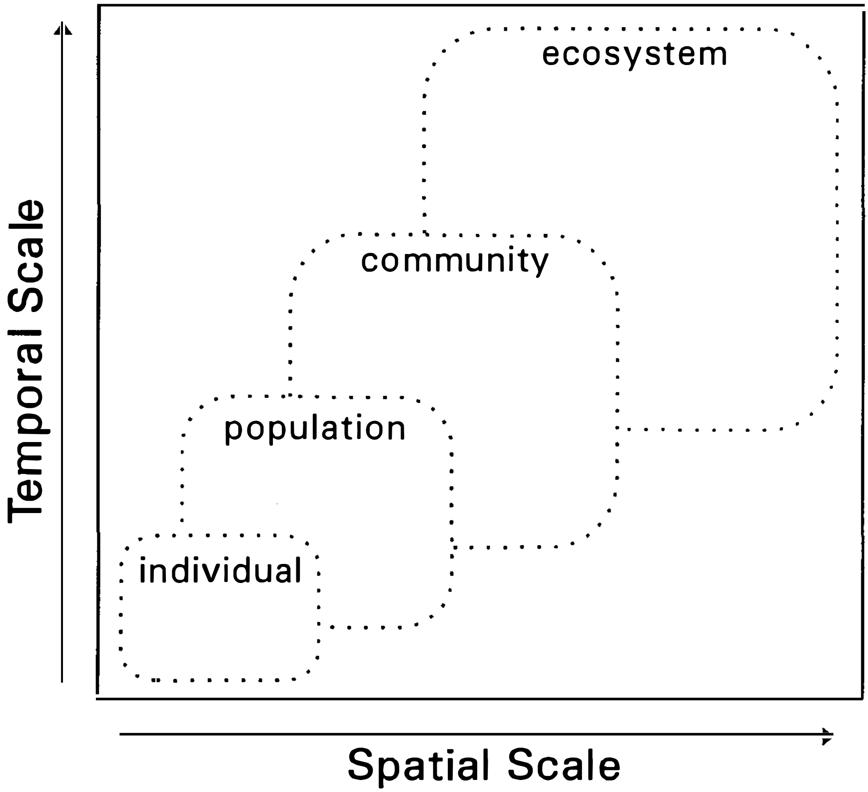

Figure 1. Covariation between spatial and temporal scales. Phenomena that occur at larger spatial scales tend to occur at longer temporal scales. For example, patterns and processes at the level of the individual organism occur at smaller spatial and shorter temporal scales compared to larger spatial and longer temporal scales of the ecosystem.

clical, directional and chaotic. Cyclical change is any change that occurs with regular frequency over a variety of time scales, from daily to seasonal to geological or millennial (Figure 2a). Examples would be daily change in ambient light or temperature, seasonal change in population density or food availability, or millennial change in temperature during different geological periods. Directional change is any consistent increase or decrease of abiotic or biotic environmental factors (Figure 2b). Succession is the best known example of directional change, with changes in characteristics such as species composition, biomass and productivity. Other than autogenic succession, potential causes of directional change include persistent low-level chemical contamination, progressive habitat modification and global warming. Chaotic change is caused by single random (or stochastic) events, such as fire, hurricanes, chemical spills, invasions or introductions of exotic species, or even the movement of individuals to a new area (Figure 2c). Building on the development of chaos theory (Gleich 1987) in mathematics, chaotic change may profoundly affect the character of a community or ecosystem.

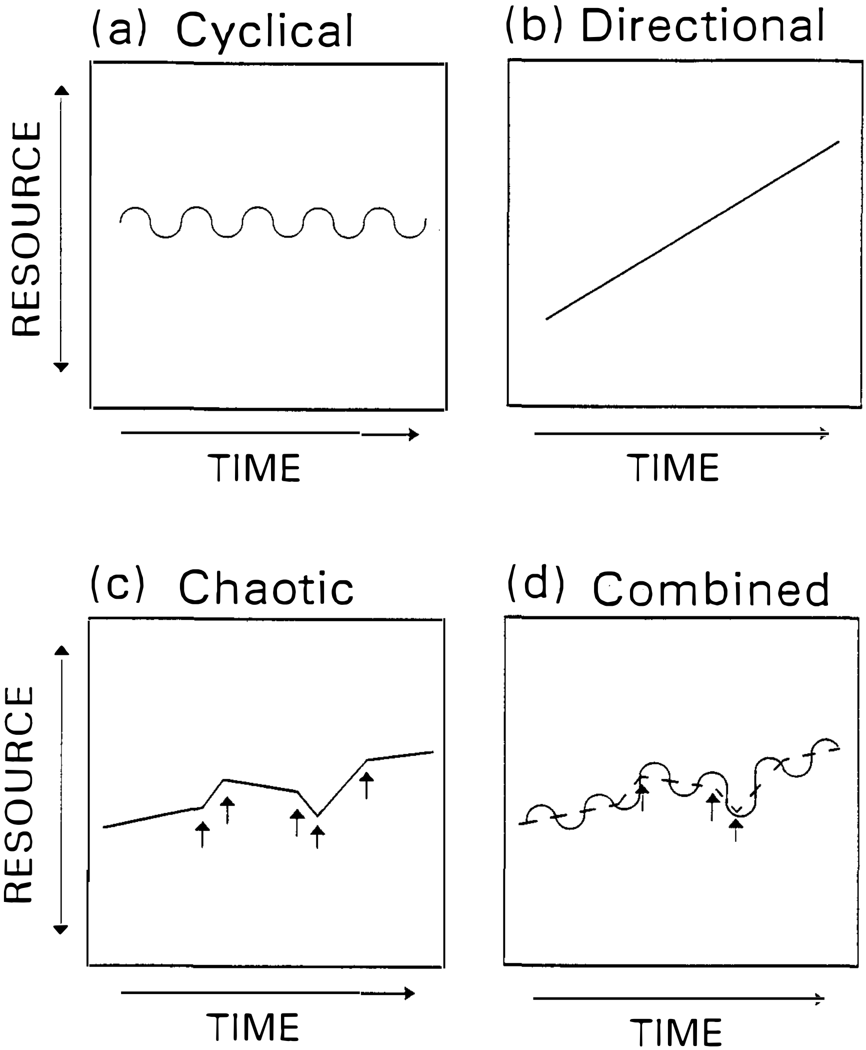

Figure 2. (a) Cyclical change in resource levels over time. The temporal scale could vary from days to thousands of years, while the resource is any parameter or attribute of interest, such as population density, biomass, number of species or rate of nutrient cycling. (b) Directional change in resource levels over time, characterized by any consistent increase or decrease in resource levels. (c) Chaotic change in resource levels over time. Arrows indicate specific random (stochastic) events that alter current resource levels. (d) Combination of cyclical, directional and chaotic change in resource levels over time. The dashed line indicates the general trend of resource levels that change consistently over time, with chaotic events shown by arrows that alter resource levels. The solid line shows the actual resource level as it cycles and is influenced by both directional and chaotic change.

In addition to these categories of change, Ricklefs (1990) suggests four causes of these changes: (1) ''external forcing variables'' such as change in the planet's position causing seasonal change in temperature and moisture; (2) ''natural resonance'' of the system caused by interactions among species and their environment, resulting, for example, in periodic population fluctuations or characteristic disturbance frequencies; (3) interaction among different patterns, for example, availability of food and shelter that vary at different rates, producing unique patterns of temporal change; and (4) random processes and patterns.

The interaction of these types and causes of temporal change (Figure 2d) present significant management challenges. First, it is difficult to discern whether changes in a resource are caused by ''natural'' temporal variation as opposed to changes caused by human activities. Second, the structure and function of the ecosystem we see today is a consequence of cumulative changes in response to stochastic events combined with cyclical and directional variation (Pickett and White 1985), making it difficult to even know what the ''natural'' ecosystem is. After studying several familiar ecosystems such as the African savanna and old-growth forests of the Pacific Northwest, Sprugel (1991) concluded that ''because chance factors and small climatic variation can apparently cause very substantial changes in vegetation, the biota and associated ecosystem processes for any given landscape will vary substantially over any significant time period—and no one variant is more 'natural' than the others.'' This is similar to the concepts of ''multiple stable points'' (May 1977) and ecosystem ''surprise'' (Loucks 1985, Holling 1986). Likewise, from the perspective of thermodynamics, Kay (1991) concluded that ''it is not possible to identify a single organizational state of the system that corresponds to integrity. Instead there would be a range of organizational states for which the ecosystem is considered to have integrity.''

Unfortunately for the natural resource manager, there is no ''balance of nature'' to serve as the model for management, only relatively stable conditions that appear ''stable'' because of our limited human perception. Elton (1930) was among the first to formally recognize that ''the balance of nature does not exist, and perhaps has never existed'' and that the ''resultant confusion is remarkable.'' Similarly, Leopold (1939) commented that ''the 'balance of nature' is a mental image for land and life which grew up before and during the transition to ecological thought. It is commonly employed in describing the biota to laymen, but ecologists among each other accept it only with reservations. . . . Its defects are that there is only one point at which balance occurs, and that balance is normally static.''

Time: Biological and Ecological Effects

Change is a fundamental feature of all biological systems, and everything around us, from adaptations of species to the structure and function of ecosystems, is the result of cumulative change over time. Of necessity, this review focuses on those biological and ecological changes that will likely have a significant impact on current management policy, goals and practices.

Genetics and Evolution

The temporal perspective focuses on change, and arguably the single most important biological process that results from change over time is evolution, a nonrandom change in gene frequencies. Frankel (1974) called attention to our "evolutionary responsibility" that may even "grow into an evolutionary ethic if and when men come to regard other species as an essential part of their own existence." Allowing evolution to continue unfettered by human values is likely the most important responsibility we have to future human generations and to our planet. Recognizing the process of evolution as an end in-and-of itself, Frankel (1974) concluded that "an evolutionary perspective may help to give conservation a permanence which a utilitarian, and even an ecological grounding, fail to provide in men's minds."

Focusing on evolution shifts the management emphasis from single species and resources to the sources of genetic variation and the causes of genetic change within a species, i.e., to the processes that sustain life and provide the context in which evolution occurs. This shift in focus may significantly alter current management practices, in particular, by maintaining: (1) metapopulation structure, a major source of genetic variation; and (2) interactions among species, a major cause of genetic change over time.

A metapopulation is the collection of relatively isolated populations of a species (Gilpin 1988). Populations may be isolated geographically, for example, a fish species inhabiting separate watersheds, or by slight differences in topography or vegetation within a habitat. Although defined spatially, over time the *set* of individual populations may be necessary for continued existence of the species. Wright (1931) initially called attention to the genetic and evolutionary importance of relatively isolated populations, and Wade and Goodnight (1991) experimentally confirmed Wright's theories. Isolated populations may be either a self-sustaining "source" or a non-sustaining "sink" because of different environmental conditions at each site. Pulliam (1988), Pulliam and Danielson (1991), and Howe and Davis (1991) showed the importance of source populations in recolonizing sink populations for the continued existence of a species facing a variety of stochastic and demographic catastrophes.

Source and sink populations likely show genetic differences, since nuclear DNA (Allendorf 1983) and mitochondrial DNA (Avise 1989, Avise and Nelson 1989) studies clearly show genetic differences among populations of a species, reflecting different founding individuals, environmental conditions, cumulative histories, and loss of heterozygosity and allele variation due to genetic drift and inbreeding. Source and sink populations may also differ genetically from one another because source populations are probably under relatively relaxed selection pressures, whereas sink populations probably experience more intense selection pressures. These genetic differences within a metapopulation, combined with movement of individuals among populations, are likely crucial in allowing a species to adapt to a changing environment, especially the accelerated pace of anthropogenic environmental change.

Evolution is a nonrandom change in gene frequencies, and interactions among species, such as predation, mutualism and competition, are important components of natural selection that drive evolutionary change. Typically, the range of biodiversity from genes to ecosystems is presented in a diagram showing how genes make up individuals, individuals make up populations, and so on up the biological hierarchy (Figure 3a). Despite its popularity, this diagram is inaccurate because it fails to show the essential interactions that profoundly affect each of the components. These interactions can be shown in a more realistic, though more complex, view of biodiversity (Figure 3b). This interactive view of biodiversity, for example, shows how

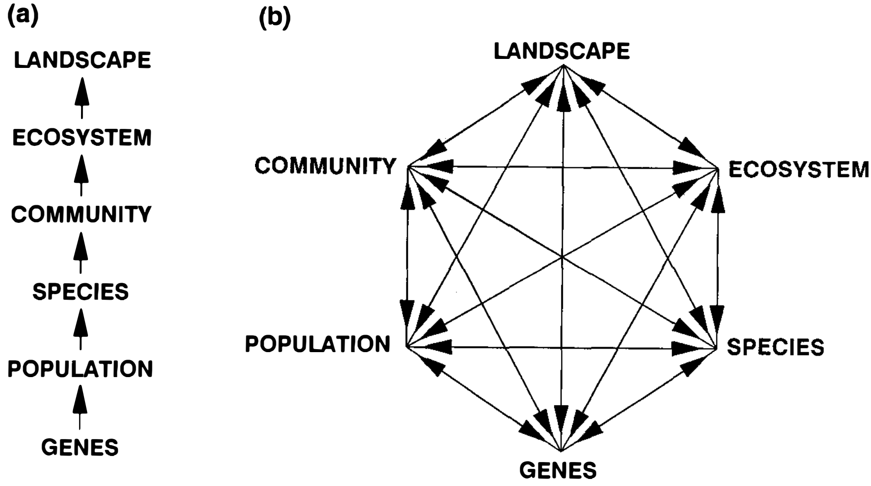

Figure 3. (a) Linear-hierarchical view of the elements of biological diversity, ranging from genes to the landscape. (b) Interactive view of the elements of biological diversity, showing all possible pair-wise combinations of interactions.

predation may affect population density and gene frequencies of the individual species. At the ecosystem level, predation results in energy flow through the food web and creates additional detritus that can be decomposed, with nutrients mobilized and eventually used by plants. Allen and Hoekstra (1990) presented a similar view, showing how these interactions change over time and contribute to the structure and function of the community and ecosystem.

The typical hierarchical view of biodiversity is also flawed because it implies a mechanistic view that ecosystems are merely the sum of their constituent elements, ignoring the patterns and processes that result from these elements interacting with one another (Botkin 1990). Essential ecosystem processes such as decomposition and nutrient cycling, as well as ecosystem services important to people such as the availability of useful natural resources, ultimately result from the interactions among various components of the ecosystem. A fallacy of the mechanistic view is that it implies maintenance of the ecosystem by managing exclusively for the constituent species. Over the short-term, such as a single human life-span, managing for species will likely maintain the appearance of the ecosystem, depending on the longevity of the visibly dominant plants and animals. But over the long-term, the process of evolution and ecosystem services important for people require maintaining the native species as well as the interactions and processes within the ecosystem, requiring a much larger and more complicated management view.

Population Density

The population density of all species changes over time, and it is essential to understand how and why these changes occur because management efforts are often aimed at achieving desired population levels for species of interest, from trees to large mammals. A myriad of factors, both short- and long-term, random and deterministic, influence population growth and density. From the perspective of managing for biological diversity one issue in particular merits discussion: separating natural variation in population density from change caused by human actions. The recent debate over purported declines in amphibian populations (Wake 1991, Peckmann et al. 1991) illustrates the importance of this issue and the range of unanswered questions: How accurate are the data used to infer a change in population density? Are current changes in population density part of the "natural" variation in numbers for that taxon? Can human-caused population changes be separated from "natural" variation? Have human actions altered an environmental factor, e.g., disturbance regime, that only over the long-term will cause population changes, which will then likely appear as "natural" variation? Can altering global temperature regimes or ecosystem processes such as nutrient cycling affect species' populations? Does the population decline of one species signal broader forces acting on the entire ecosystem and all of its species? These questions demand explicit discussion because we manage populations that change over time.

Species Composition

Species composition, or the species present at a site, is currently the principal reason why that site is managed for economic, social, ecological or other values. Species composition at a site depends primarily on whether a species is able to get there, and whether it can survive and reproduce there. In addition, evolutionary processes at a site may subsequently alter the species' composition. Being able to arrive at a particular site depends on the species' vagility and its former geographic range. Whether the species will survive and reproduce depends on the abiotic (physical) and biotic factors (the species that are present and their interactions) at the site that supply needed food, shelter and mate resources.

The species composition at a particular site is not fixed, but changes over both short- and long-term time scales. Over the short-term, dispersal, seasonal migration, disease, hunting, local extinctions, invasions or introductions of exotic species, habitat modification, or other stochastic events can decrease or increase the number and kinds of species at a site. Over the longer-term, species composition can radically change as the environment changes, such as in response to long-term climate change (Tallis 1991). For example, Delcourt and Delcourt (1987) showed how species composition of eastern U.S. forests changed in response to glacial periods. Also, the deletion or addition of a species can cause cascading effects (Terborgh 1988) that ripple throughout the community, while the extirpation of keystone species may have especially profound effects throughout the community (e.g., Brown and Heske 1990).

Abiotic and biotic factors of an environment also change over short- and long-term time frames as a habitat becomes fragmented by roads, development and other management actions that modify the surrounding area, or by being set aside as a park or reserve. Short-term effects of fragmentation may include immediate reduction in population size, severing of dispersal and migration routes, reducing access to food, shelter and mates, and influx of invading, parasitizing or disease-causing species. These short-term effects likely result in the long-term loss of species or "faunal collapse" (Weisbrod 1976, Soulé et al. 1979). This loss of species, or addition of exotic and generalist species, may subsequently alter ecosystem functions such as nutrient cycling (e.g., Vitousek 1986), in turn causing more change in species composition.

Although the number of species in a community may stay relatively constant over time, native species may be replaced by others. Human actions often create disturbances that allow invasion by species that readily inhabit disturbed sites. These may be native opportunistic species or species that are not native to the area, and both may have significant and far-reaching consequences for native biological diversity (Drake et al. 1989). Natural resource managers, and refuge managers in particular, must decide which mix of species is appropriate at each site; merely maintaining the number of species without regard to whether they are native or non-native is unacceptable when managing for biological diversity.

Species composition also changes over time with succession. Regardless of the exact mechanism of directional succession, most sites that are left relatively undisturbed by humans will change markedly over time, not only in species composition, but also in physical factors such as temperature and soil organic matter, and in ecosystem processes such as rates of primary production, decomposition and nutrient cycling.

The Ecosystem

The ecosystem is the context in which individuals derive adequate resources for survival and reproduction, populations grow, and species interact and evolve. In sum, the ecosystem is the stage in which biological diversity develops and is maintained. Ecosystem management offers important benefits (Hunt 1989, Scott et al. 1988, Landres 1992), and although we currently lack legislative mandates and practical knowledge (Johnson and Agee 1988, Clark et al. 1991), the temporal perspective offers important insight on managing ecosystems.

Defining and classifying ecosystems. Conceptually, an ecosystem is the abiotic and biotic components of an environment that interact to produce a flow of energy and a cycling of nutrients. From a management perspective, however, this definition is of limited usefulness for three reasons: temporal change, spatial variation and leaky borders. Over time, the composition, structure and functions (or processes) within an ecosystem change in response to short-term events such as storms or fire, seasonal change in temperature and moisture, and longer-term changes such as succession and climate shifts. Ecosystems are constantly in a state of flux, although our limited human sensory abilities prevent us from observing much of this change. Second, spatial variation in environmental conditions, disturbance history, even the vagaries of species' dispersal influence the composition and structure of a given area. And third, most ecosystems are leaky, that is, certain components leave or enter the area, such as wind-borne seeds, soil particles, mycohrizzal fungal spores, tiny animals and highly vagile larger animals, such as birds or mammals. In addition, the boundary or border of an ecosystem may shift back and forth in response to different environmental factors. The border may also be selectively permeable allowing the exchange of some plants and animals but not others (Wiens et al. 1985). Because of this leakiness, the spatial arrangement of a particular ecosystem within the mosaic or matrix of other habitats strongly influences ecosystem structure and function (Ricklefs et al. 1984).

The net result of temporal and spatial change, and leaky boundaries, is that any given ecosystem will likely vary over time and from one area to another; what we see today at a particular location is the result of cumulative influences and responses over time. This variation means that ecosystems are subjectively defined, both in space and time.

Subjectively defining an ecosystem means that management efforts at holding a particular site at a "dynamic equilibrium," with specific composition and structure, will likely fail. Niering (1987) discussed how the concept of a dynamic equilibrium is intimately tied to the concept of a single climax community at a given site, and how neither concept fits ecological reality. The management implications are clear. Only unambiguous management and assessment goals will allow at least a working definition for the ecosystem of interest and its "normal" or "acceptable" temporal and spatial variation. This definition and "acceptable" variation must be determined for each ecosystem and site, depending on the specific management goals and current knowledge of that environment. Such specificity and knowledge are necessary for determining whether changes in ecosystem structure and function are a result of natural variation or anthropogenic perturbation.

Ecosystem health. The notion of ecosystem health is cited throughout the scientific, management and popular literature. Most natural resource professionals have a general feeling for what a "healthy" ecosystem is, and this notion often forms the basis for subsequent management goals and targets. Leopold (1949) wrote that "a science of land health needs, first of all, a base datum of normality, a picture of how healthy land maintains itself as an organism" and that the "most perfect norm is wilderness." Ecosystems that are relatively unaffected by anthropogenic stresses are essential as controls to compare and understand the effects of perturbation, but what attributes or conditions signal a loss of ecosystem "health"? In addition, there are so few unaffected areas left on the planet, how will the "healthy" norm be established for all the different ecosystem types? Rapport (1989) suggests that "for nature, health is commonly taken to be the absence of detectable symptoms of ecosystem pathology." These symptoms (Rapport 1989) include changes in primary productivity, nutrient cycling, species diversity, stability, prevalence of disease, distribution of species' sizes and the presence of contaminants. Rapport et al. (1985) further propose an "ecosystem-level distress syndrome," analogous to a human physiological stress syndrome.

Despite the intuitive appeal of a human health and disease model, comparing an ecosystem to a human body is a tenuous analogy for several reasons. First, temporal and spatial variation in ecosystem composition, structure and function is the "natural" condition. Therefore, how will a manager of natural resources know if "disease symptoms" result from natural variation or human-caused stresses? Second, unlike a body, small- to large-scale disturbance is a vital part of many ecosystems, necessary for the survival of certain (*e.g.*, fire-adapted or gap-requiring species), and for maintaining environmental heterogeneity necessary for a wide variety of species. Third, an ecosystem is a collection of individual species exploiting each other opportunistically. In contrast, the components of a body are internally coordinated and strongly dependent on one another. And last, a human "health"' model assumes that ecosystems are in a "dynamic equilibrium," i.e., there is a "normal" composition, structure and function for a given ecosystem type, and that the ecosystem will bounce back to this ''normal'' condition after a stress is relieved. Temporal and spatial variation, and chaotic change dispel the idea that there is a single state to which an ecosystem belongs. The ecosystem we see today is merely a relatively stable set of species resulting from a unique series of events, or a ''physiognomic, historically conditioned mosaic of relatively stable cover types . . .'' (Niering 1987).

The primary risk of using ''health'' as a model to describe ecosystems is that it ignores ecological reality. Similarly, the attempt to define an ecological community as a ''super-organism'' (McIntosh 1985) at first was insightful, but later was discarded after it was shown to be erroneously simplistic. While some type of ecological baseline is crucial to identifying change in an ecosystem, the notion of ecosystem ''health'' is overly simplistic, diverting attention and effort from more effective and pragmatic analyses. Although a ''health'' model of ecosystems will likely persist because of tradition, management personnel must recognize the limitations of this model and its anthropocentric assumptions and value judgements.

Time: Management Implications

We can't manage time, but we can manage specific resources, species and maybe even ecosystems. Although necessary for the long-term maintenance of evolution, ecosystem processes, biological diversity, and natural resources and services that provide commodity and amenity values to people, incorporating the temporal perspective into management will require fundamental changes in current policies and practices. In particular, current management goals and targets may be unrealistic over the long-term because they are based on a static or dynamic equilibrium view of natural resources. Instead, goals and targets need to be considered ''moving targets'' that change as environmental conditions and social values change (Koch and Kennedy 1991). The following issues will likely become significant concerns when the temporal perspective is incorporated into management plans and actions.

Managing Ecosystems and Processes

Managing for biological diversity requires managing for the ecosystem and the processes that sustain life on this planet (Hansen et al. 1991). We currently know little about the long-term processes that sustain an ecosystem and the species that are part of it, other than the fundamental importance of soil, primary and secondary production, energy flow through the food web, decomposition, and nutrient cycling. Current management efforts focus on maintaining populations of species and setting aside habitat areas. But this is surely insufficient for maintaining the ecosystem and the processes that sustain it over the long-term. But how is a process managed? Is it sufficient to manage for the components of the ecosystem and assume that the flow of energy and cycling of nutrients will follow? At this point, we simply don't have the answers.

In addition, whether an ecosystem is in equilibrium (i.e., is relatively constant or cyclic) or is chaotic (i.e., it changes in response to abiotic and biotic changes) has important policy implications (Holling 1987). The equilibrium view of ecosystems currently pervades management policy and goals. Under this view, the ecosystem can be disturbed, modified and natural resources extracted and, given sufficient time, this ecosystem will ''heal'' itself back to its former state. In contrast, if the ecosystem responds to cyclical, directional and chaotic changes, then human activities may fundamentally alter the structure and function of the ecosystem, and the ecosystem will not ''heal'' itself, but move to a new, relatively stable state that may or may not provide ecosystem services and other values desired by people.

Managing Natural Resources Over Time

Implicit in managing for the ecosystem is recognizing and allowing short- and long-term temporal variation in the abundance and distribution of natural resources. There are several implications of allowing this variation.

Metapopulations. Management plans that maintain a single population of a species, or several populations with no means for dispersal among them, will likely result in extinction of that species because of natural and human threats to these populations. For the long-term persistence of a species, the metapopulation must be maintained. This requires identifying and maintaining isolated populations of a species, and dispersal capabilities among these populations that allow for migration, recolonization and gene flow.

Succession. Classification of ecosystem types, habitats and communities needs to reflect successional age. Currently, most management plans assume ''climax'' vegetation based on potential site characteristics. For example, Kuchler's Potential Natural Vegetation maps are commonly used by natural resource management agencies. A successional sere is a unique combination of plants, animals and ecological processes that may present unique management concerns, such as a rare or endangered species that exists only in a particular sere. In these cases, is it appropriate for natural resource managers to modify natural succession to maintain an intermediate sere? What if that area would eventually become habitat for endangered species, or provide other important amenity values? Land managers need to explicitly discuss the criteria used in making these decisions, and their long-term impact.

Managing for native biological diversity requires maintaining the array of successional seres typically occurring in a landscape. In general, two extreme options are available to maintain such an array: keep sites at their particular successional stages, for example, with techniques discussed by Luken (1990), or allow individual sites to change over time that, from a regional perspective, yield a ''shifting mosaic'' of successional seres. Maintaining sites at a fixed point along the successional continuum will likely be difficult and costly, while allowing sites to change requires a regional perspective and long-term planning. Neither option will be easy to implement, likely resulting in a mix of management strategies depending on the landscape and management goals.

Cumulative and regional effects. Cumulative and region-wide effects need to be incorporated into the management process. Managing for biological diversity requires assessing each management action in the context of previous actions, planned future actions and actions on adjacent lands. Actions taken in isolation, without regard to cumulative and regional effects, can steadily erode biological diversity. This erosion typically takes place as relatively small, isolated events that, taken individually, do not appear to affect the larger area. But from a regional, long-term perspective, these isolated events may add up to a significant reduction in biological diversity.

Which biodiversity? Natural resource managers must decide whether they will let the species composition at a site change over time, or attempt to maintain the composition at a particular point in time. Both decisions will be difficult to implement.

If managers decide to let species composition change over time, they must then determine which changes are acceptable. For convenience, agents of change can be classified as internal or external. Change caused by internal processes, for example, ''normal'' successional change, may be acceptable, but change induced by invasion of an exotic species, i.e., an external agent, may not be acceptable. Also, change induced by effluent or air or water pollution may or may not be acceptable, depending on a host of factors. But what if an internal change makes the system more susceptible to external threats? Or, what if an external factor accelerates or alters an internal change? How much will it cost to protect the site from external factors? If an invading species or pollution changes the species composition, should the site be abandoned, even if it once represented a unique or valuable resource? Although extremely difficult to answer, explicitly addressing these and other questions allows formal discussion that must serve as the starting point for management actions.

In contrast to letting species composition change, if managers decide to maintain the composition at a particular point in time, two difficult questions arise. Which point in time? How will this static system be maintained in the face of internal and external change?

Monitoring

Given the temporal variation inherent in all ecosystems, and that there is no ''balance of nature,'' monitoring is essential to determine whether changes are ''natural'' or human-caused. Monitoring that simply collects traditional data is insufficient to determine cause-and-effect changes. Instead, a comprehensive monitoring effort is needed that constantly tests hypotheses about the factors influencing the ecosystem. This is ''successive refinement'' (Gauch 1982), or the ''muddling-through'' approach (Bailey 1982, McNab 1983) to ''adaptive management'' (Holling 1978), in which the data and resulting conclusions refine and improve the monitoring process and consequent management actions.

All managers make decisions in the face of much uncertainty because limited time and funding prevent gathering all the data and other needed information. Therefore, communication between managers and researchers is essential in determining the necessary and sufficient data that generate practical information useful for management.

Because the temporal perspective takes a long-term view, the current practice of using high-trophic level avian or mammalian carnivores to monitor ecological conditions is questionable. Such ''indicator'' or ''umbrella'' species are used on the assumption that their large home ranges likely include all of the resources needed by all of the other species using that ecosystem or habitat. While umbrella species may be an expedient short-term surrogate for monitoring the ecosystem, their ability to serve this role for the long-term is conceptually inappropriate and empirically unsupported (Landres et al. 1988, Landres 1992).

Long-term Planning and Agency Coordination

The temporal perspective spans both the short- and long-term. Management agencies typically use a 3- to 10-year planning horizon, and given current fiscal cycles and shifting political influences, even a 10-year time-frame may be unrealistically long-term. Managing for biological diversity will likely require even longer planning horizons, based on the exact goals of management and the landscape under consideration. For example, if an ecosystem is fire-dependent, agency planning should be for the time period as long as the typical disturbance cycle or regime. Achieving stable funding for this length of time, however, will be difficult at best.

In addition, planning and coordination among various agencies is necessary to maintain regional ecosystems and landscapes. Such cooperation is difficult (Sax and Keiter 1987), but recent agreements among the U.S. Fish and Wildlife Service, Forest Service, and Park Service in the Yellowstone and other regions show that interagency cooperation is possible.

Setting Priorities

The perspective of time also demands prioritizing action and funding. Some species and ecosystems are under greater threat of extinction than others and merit priority funding and action. Given the limited funding, personnel and time available for action, it is essential to develop a ranking or priority system enabling management personnel to best direct their efforts. For ecosystems, such a system might include current area and distribution, current and potential threats, evolutionary uniqueness, contribution to surrounding ecosystems, and ecosystem services important to humans. A similar priority system might be developed for individual species.

Such an endeavor is fraught with questions and value judgements, leading down a slippery and scary slope in which human value judgements weigh more than biological and ecological value. But given the extremely limited resources available to maintain the planet's biological diversity, developing such a ranking system is essential.

Obstacles in Managing for Biological Diversity

There are many obstacles that will prevent or slow development of strategies for managing for biological diversity, including lack of clear legislative mandates, lack of information on ecosystems, lack of pristine ecosystems to serve as reference areas, lack of funding, opposing agency mandates, lack of perceived benefits and political interference in biological decisions. Cairns (1990) lists additional barriers to "integrated environmental management," including turf territoriality and related lack of mutual trust, an attitude of resistance to change in general and to certain new ideas in particular, inability to compromise, and lack of leadership. All of these obstacles need to be explicitly recognized; some can be easily overcome, while others, based on attitudes and tradition, will change only slowly and require extensive effort.

Summary

This paper explores the implications of time in managing biological diversity. How does time affect biological systems? How does time affect our management of natural resources? What issues will likely become significant management concerns when the perspective of time is taken into account?

Significant management implications result from examining the effect of time on biological systems. First, there is no "balance of nature," therefore, management goals must be considered "moving targets" that change as environmental conditions and social values change. Second, a management approach is needed that emphasizes ecosystem-level interactions and processes, as well as individual species. Third, because of temporal variation in the abundance and distribution of natural resources, management plans need to account for metapopulation structure, succession, cumulative and region-wide effects, and changing species composition. Fourth, monitoring is necessary to determine whether changes are "natural" or human-caused, and the use of indicator species in most cases is inappropriate to assess changes in an ecosystem. Fifth, long-term planning and agency coordination is necessary for natural resources that vary over temporal and spatial scales. And sixth, given limited funding and personnel, a ranking or priority system is likely necessary to maximize the effects of management actions.

Managing our biological diversity will be an unprecedented challenge. We're just starting to ask the right questions; we're just now developing the conceptual framework; we lack data and funding, and traditional ways change slowly. The reward of managing for biological diversity is maintaining our planet's biological heritage; the question that remains is: Is there sufficient time?

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References

Allen, T. F. H. and T. W. Hoekstra. 1990. The confusion between scale-defined levels and conventional levels of organization in ecology. J. Vegetation Science 1:5–12.

Allendorf, F. W. 1983. Isolation, gene flow, and genetic differentiation among populations. Pages 51–65 *in* C. M. Schonewald-Cox, S. M. Chambers, B. MacBryde, L. Thomas, eds., Genetics and conservation: A reference for managing wild animal and plant populations, Benjamin-Cummings Publ. Co., Menlo Park, CA.

Avise, J. C. 1989. A role for molecular genetics in the recognition and conservation of endangered species. Trends in Evolution and Ecology 4:279–281.

Avise, J. C. and W. S. Nelson. 1989. Molecular genetic relationships of the extinct dusky seaside sparrow. Science 243:646–648.

Bailey, J. A. 1982. Implications of "muddling through" for wildlife management. Wildl. Soc. Bull. 10:363–369.

Botkin, D. B. 1990. Discordant harmonies: A new ecology for the twenty-first century. Oxford Univ. Press, New York, NY.

Brown, J. H. and E. J. Heske. 1990. Control of a desert-grassland transition by a keystone rodent guild. Science 250:1705–1707.

Cairns, J., Jr. 1990. Gauging the cumulative effects of developmental activities on complex ecosystems. Pages 239–256 *in* J. G. Gosselink, L. C. Lee, T. A. Muir, eds., Ecological processes and cumulative impacts: Illustrated by bottomland hardwood wetland ecosystems, Lewis Publishers, Chelsea, MI.

Clark, T. W., E. D. Amato, D. G. Whittemore, and A. H. Harvey. 1991. Policy and programs for ecosystem management in the Greater Yellowstone Ecosystem: An analysis. Conserv. Biology 5:412–422.

Delcourt, P. A. and H. R. Delcourt. 1987. Long-term forest dynamics of the temperate zone. A case study of Late-Quaternary forests in eastern North America. Springer-Verlag, New York, NY.

Drake, J. A., H. A. Mooney, F. diCastri, R. H. Groves, F. J. Kruger, M. Rejmanek and M. Williamson, eds. 1989. Biological invasions: A global perspective. Scope 37. John Wiley & Sons, New York, NY.

Elton, C. 1930. Animal ecology and evolution. Oxford Univ. Press, New York, NY.

Frankel, O. H. 1974. Genetic conservation: Our evolutionary responsibility. Genetics 99:53–65.

Gauch, H. G., Jr. 1982. Multivariate analysis in community ecology. Cambridge Studies in Ecology. Cambridge Univ. Press, New York, NY.

Gilpin, M. E. 1988. Spatial structure and population vulnerability. Pages 125–140 *in* M. E. Soule, ed., Viable populations for conservation. Cambridge Univ. Press, Cambridge, England.

Gleick, J. 1987. Chaos: Making a new science. Penguin Books, New York, NY.

Gould, S. J. 1990. The Golden Rule—a proper scale for our environmental crisis. Natural History 9/90:24–30.

Hansen, A. J., T. A. Spies, F. J. Swanson, and J. L. Ohmann. 1991. Conserving biodiversity in managed forests. BioScience 41:382–392.

Holling, C. S. 1978. Adaptive environmental assessment and management. John Wiley & Sons, New York, NY.

———. 1986. The resilience of terrestrial ecosystems: Local surprise and global change. Pages 292–320 *in* W. M. Clark, R. E. Munn, eds., Sustainable development in the biosphere, Oxford Univ. Press, Oxford, England.

———. 1987. Simplifying the complex: The paradigms of ecological function and structure. European J. Operational Research 30:139–146.

Howe, R. W. and G. J. Davis. 1991. The demographic significance of "sink" populations. Biological Conserv. 57:239–255.

Hunt, C. E. 1989. Creating an endangered ecosystems act. Endangered Species Update 6:1–5.

Kay, J. J. 1991. A nonequilibrium thermodynamic framework for discussing ecosystem integrity. Environ. Manage. 15:483–495.

Koch, H. E. and J. J. Kennedy. 1991. Multiple-use forestry for social values. Ambio 20:330–333.

Landres, P. B. 1992. Ecological indicators: Panacea or liability? *In* D. H. McKenzie, D. E. Hyatt, V. J. McDonald, eds., Ecological indicators. Vol. 2. Elsevier Applied Scientific Publishers, Amsterdam, The Netherlands. In press.

Landres, P. B., J. Verner, and J. W. Thomas. 1988. Ecological uses of vertebrate indicator species: A critique. Conserv. Biology 2:316–328.

Leopold, A. 1939. A biotic view of land. *In* S. L. Flader and J. B. Callicott. 1991. The river of the mother of God and other essays by Aldo Leopold. Univ. Wisconsin Press, Madison.

———. 1949. A sand county almanac. Oxford Univ. Press, New York. 226 pp.

Loucks, O. L. 1985. Looking for surprise in managing stressed ecosystems. BioScience 35:428–432.

Luken, J. O. 1990. Directing ecological succession. Chapman and Hall, New York, NY.

May, R. M. 1977. Thresholds and break points in ecosystems with a multiplicity of stable points. Nature 269:471–477.

McIntosh, R. P. 1985. The background of ecology: Concept and theory. Cambridge Univ. Press, England.

McNab, J. 1983. Wildlife management as scientific experimentation. Wildl. Soc. Bull. 11:397–401.

Niering, W. A. 1987. Vegetation dynamics (succession and climax) in relation to plant community management. Conserv. Biology 1:287–295.

Peckmann, J. H. K., D. E. Scott, R. D. Semlitsch, J. P. Caldwell, L. J. Vitt, and J. W. Gibbons. 1991. Declining amphibian populations: The problem of separating human impacts from natural fluctuations. Science 253:892–895.

Pickett, S. T. A. and P. S. White, eds. 1985. Ecology of natural disturbance and patch dynamics. Academic Press, New York, NY.

Pulliam, H. R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:652–661.

Pulliam, H. R. and B. J. Danielson. 1991. Sources, sinks, and habitat selection: A landscape perspective on population dynamics. Am. Nat. 137(Supplement):S50–S66.

Rapport, D. J. 1989. What constitutes ecosystem health? Perspectives in Biology and Medicine 3:120–132.

Rapport, D. J., H. A. Regier, and T. C. Hutchinson. 1985. Ecosystem behaviour under stress. Am. Nat. 125:617–640.

Ricklefs, R. E. 1990. Scaling pattern and process in marine ecosystems. Pages 169–178 *in* K. Sherman, L. M. Alexander, B. D. Gold, eds., Large marine ecosystems: Patterns, processes, and yields, Am. Assoc. Advancement of Science, Washington, D.C.

Ricklefs, R. E., Z. Naveh, and R. E. Turner. 1984. Conservation of ecological processes. Commission on Ecology Papers Number 8. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Sax, J. L. and Keiter, R. B. 1987. Glacier National park and its neighbors: A study of federal interagency relations. Ecology Law Quarterly 14:207–263.

Scott, J. M., B. Csuti, K. Smith, J. E. Estes, and J. Caicco. 1988. Beyond endangered species: An integrated conservation strategy for the preservation of biological diversity. Endangered Species Update 5:43–48.

Soulé, M. E., B. A. Wilcox, and C. Holtby. 1979. Benign neglect: A model of faunal collapse in the game reserves of East Africa. Biological Conserv. 15:259–272.

Sprugel, D. G. 1991. Disturbance, equilibrium, and environmental variability: What is "natural" vegetation in a changing environment? Biological Conserv. 58:1–18.

Tallis, J. H. 1991. Plant community history: Long-term changes in plant distribution and diversity. Chapman and Hall, London, England.

Terborgh, J. 1988. The big things that run the world—a sequel to E. O. Wilson. Conserv. Biology 2:402–403.

Vitousek, P. M. 1986. Biological invasions and ecosystem properties: Can species make a difference? Pages 163–176 *in* H. A. Mooney and J. A. Drake, eds., Ecology of biological invasions of North America and Hawaii, Springer-Verlag, New York, NY.

Wade, M. J. and C. J. Goodnight. 1991. Wright's Shifting Balance Theory: An experimental study. Science 253:1,015–1,018.

Wake, D. B. 1991. Declining amphibian populations. Science 253:860.

Weisbrod, A. R. 1976. Insularity and mammal species number in two national parks. Pages 83–87 *in* M. Linn, ed., Proceedings of the First Conference on Scientific Research in National Parks, U.S. Dept. Interior, Washington, D.C.

Wiens, J. A., C. S. Crawford and J. R. Gosz. 1985. Boundary dynamics: conceptual framework for studying landscape ecosystems. Oikos 45:421–427.

Wright, S. 1931. Evolution in Mendelian populations. Genetics 16:97–159.

Conserving Biological Diversity in Sustainable Ecological Systems

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Introduction

Raven (1990:770–773) recently wrote that we should view "the future only with great trepidation," a "beautiful world is a diverse one when we have the luxury of enjoying it," and "sustainability and preservation of biodiversity are two sides of the same coin." Trepidation reflects that about 95 million people are added to the earth each year—a billion before the end of the decade. Problems of human poverty, environmental pollution, global warming and species loss will continue. The luxury of enjoying a diverse world is illustrated by the fact that poor people of the world are asked to fulfill wishes (i.e., conserve biological diversity) of rich people living in distant lands. A growing number of scientists (Lubehenco et al. 1991), authors (Brown et al. 1991) and professionals, industries, and conservation organizations (Watkins 1992) consider sustainability the answer to these issues and to conservation of biological diversity.

Sustainability provides the diversity needed to keep all ecological systems functioning and healthy, the diversity required for crops and other products for an acceptable standard of living, and the diversity adequate to meet stewardship responsibilities for an aesthetic environment. Leopold (1933) long ago recognized the importance of sustainability. He wrote, "Game Management is the art of making land produce sustained annual crops of wild game." Later, Leopold (1966a) noted that "American conservation is, I fear, still concerned for the most part with show pieces. We have not yet learned to think in terms of cogs and wheels." Cogs and wheels are the natural processes that occur within ecological systems. Revisiting the wisdom of Leopold—natural processes and sustainability—within an ecological hierarchy is an holistic framework for wildlife management and conservation of biological diversity.

Conservation of biological diversity is among foremost current challenges in resource management (Wilson 1988). This is especially important on public lands in North America (Keystone Center 1991). Existing private, state and federal efforts to conserve biological diversity are not adequate, and the loss of components of biological diversity is increasing (Keystone Center 1991:1). Worldwide protected areas, e.g., parks, refuges and nature preserves, constitute less than 3 percent of the world's surface. Some conservation groups and scientists suggest such areas or "hotshots" of diversity underlie a strategy for conservation of biological diversity (Roberts 1988). Counter to this approach is the recognition that most species neither live in pristine areas nor are most pristine areas adequate in size and composition to maintain viable populations. Today, most ecosystems differ markedly from natural conditions and no longer reflect the evolutionary environment for many species. Control of fire and other alterations of natural processes have markedly influenced the structure, function and composition of most ecological systems whether in lands set aside for a specific purpose or managed for multiple use.

Understanding natural processes is important to maintain and/or restore natural ecological systems and viability of species and communities associated with these systems (Lubchenco et al. 1991). Needed is a strategy to conserve biological diversity built on natural processes (Botkin 1990), an ecological hierarchy (Samson and Knopf 1982), and leading to sustainability of ecological systems. This paper describes such a strategy.

Natural Processes

An ecological system at any scale has three fundamental parameters—composition, structure and function. Composition is the diversity of elements, e.g., plant and animal species. All species, vertebrate and invertebrate, below ground and above ground, terrestrial and acquatic, are inextricably woven to and dependent upon ecological processes that may differ in space and time. An example of the interdependency in the coniferous forests of the Northern Rocky Mountains in Bicknell's geranium (*Geranium bicknelli*). A natural process—the crown replacement—provides ash needed for seeds of Bicknel's geranium to germinate. The seed bank then lays dormant till another crown replacement fire—approximately 250 years. In the Midwest, the recovery plan for survival of the endangered Kirkland's warbler (*Dendroica kirtlandii*) calls for creation of 38,000 acres of habitat by prescribed fire (replacing natural fire) to regenerate jack-pine (*Pinus banksiana*) stands.'' Maclean et al. (1983) note that redirected (by man) frequency of fire in the northern boreal forest over a 50-year interval reduced the diversity, stability and biomass of interacting species including both herbivores and carnivores. A similar decrease in diversity, stability and biomass over a 50-year period is evident in the boundary waters area of northern Minnesota, the result of cumulative effects (including fire control) by man (Cole 1988). The adaptive history of most species in virtually all ecosystems is linked to natural, periodic disturbances. Compilations of species regeneration strategies are available by Kozlowski and Ahlgren (1974), Bormann and Likens (1979), Oliver (1981), and Pickett and White (1985), among others.

Structure in an ecological system is the arrangement of natural elements, e.g., pattern in and juxtaposition of habitat types and other landscape features. Community structure and even composition in western coniferous forests change without periodic occurrence of certain natural processes such as fire (Figure 1). Historically, frequent, small-scale fires created open, single-layer coniferous forests on south-facing slopes. Control of fire and subsequent fuel accumulation on south-facing slopes has lead to an alternative landscape pattern in fire—stand replacement fire—natural to north-facing slopes. The impact is development of forest patches similar in structure whether on south- or north-facing slopes—a loss of natural diversity at the community level. Disturbance does affect community characteristics such as richness (Denslow 1985), dominance and structure (Brokow 1985) in forest (Turner 1987), grassland (Risser 1988), and other communities (Picket and White 1985). Loss of disturbance leads to biosimplification.

The composition and structure of western coniferous ecosystems is closely linked to fire (Knight 1987). H. B. Ayers, U.S. Geological Survey, described the structure and composition of the coniferous forests in northern Montana during his surveys in 1898 and 1899, the approximate time of European settlement. The lodgepole pine (*P. contorta*), subalpine fir (*Abies lasiocarpa*) and Engleman spruce (*Picea Englemanni*) forests (now in the Bob Marshall Wilderness Area) described by Ayers,

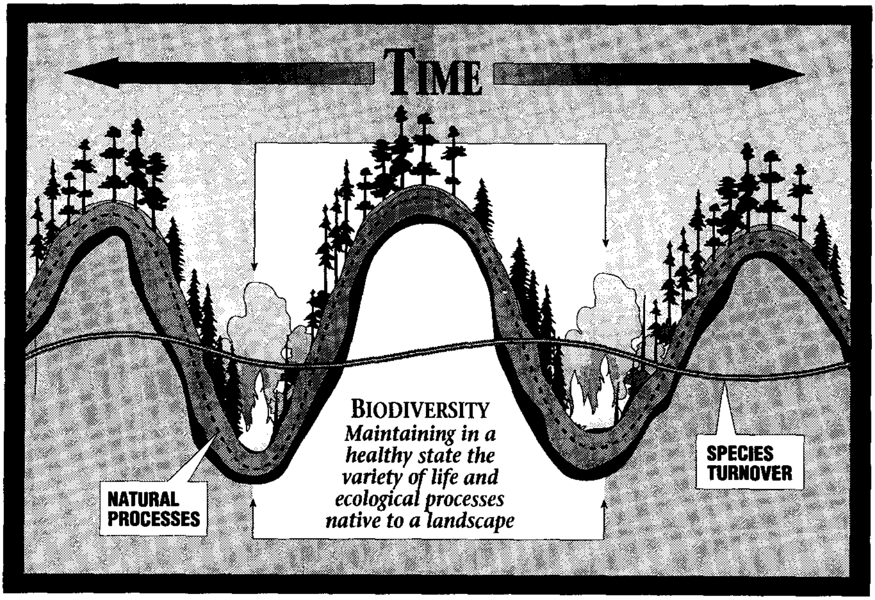

Figure 1. Conservation of biological diversity is to maintain, over time, the variety of life and the ecological processes native to a particular landscape.

largely young forests of samplings (31 percent), seedlings (10 percent) and recent burns (20 percent), differ from the present mature (36 percent) and old growth (14 percent)—a marked change in forest ecosystem structure and composition for a major preserve in the United States. Restoring such areas will require patterns in fire occurrence characteristic to pre-European settlement. Another example is in the Klamath Province of California where fire plays a major role in forest dynamics. Natural fire, largely low intensity ground fire and because of patterns in fuel, wind and other factors, created a mosaic of forest patches differing in age, size and arrangement (Pace 1991). Fire suppression, for a nearly century, has led to increases in fuel, large catastrophic fires and biosimplification of the Klamath province forests. Detrimental effects of suppressed natural disturbance is reported in other ecological systems (Mutch 1970, Conner and Day 1976, Odum et al. 1987).

Through time, beaver ponds come and go, forests come and go, and so on as the result of natural processes—the function in ecological systems, flow of species, energy, material and so on (Figure 2). Through time, species assemblages, including invertebrates, vertebrates and plants, change as forests and other communities come and go and so on, although species number may remain relatively constant. Natural processes over time and space interact to generate patterns in diversity, including those at the community and ecosystem level that, in turn, change over space and time. Understanding what regulates biological diversity, e.g., natural processes, is central to conservation of that biological diversity.

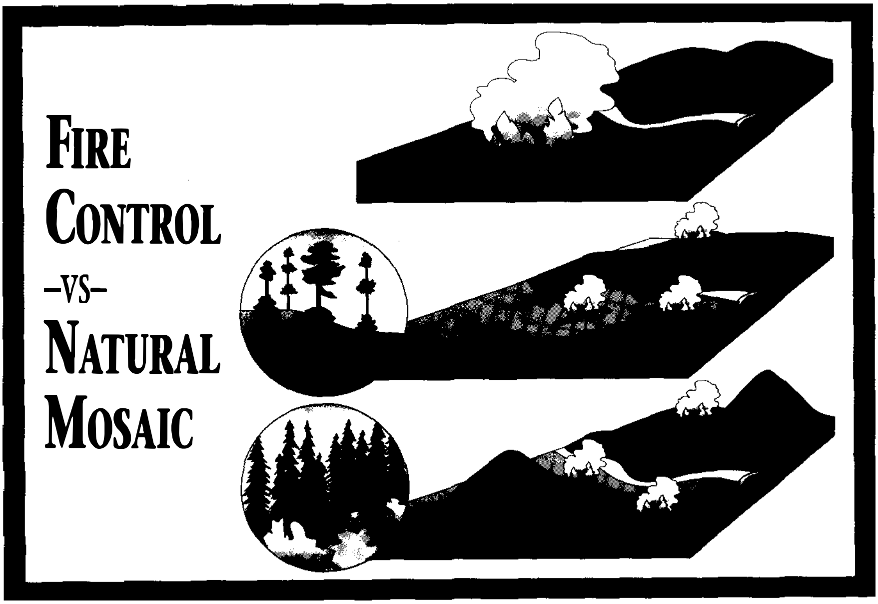

Figure 2. Control of a natural process has lead to biosimplification of forested landscapes in the western United States.

An Ecological Hierarchy

Three key characteristics of an ecological hierarchy are useful in the conservation of biological diversity. First, biota within a particular broad area are more homogeneous than between adjacent areas. Second, patterns in distribution hold for many kinds of organisms. Third, evolutionary influences, e.g., barriers and natural processes characteristic to a particular landscape, are important.

Since Sclater (1858), Darwin (1859) and Wallace (1876), naturalists and scientists have divided the world's land masses into hierarchial regions based largely on patterns in the distribution of terrestrial plants and animals. In the United States, C. H. Merriam, J. Grinnell ad L. R. Dice are among those that delineated life zones and other close relationships between geographical and ecological attributes of the environment and patterns in plant and animal distribution. Recent more detailed regionalization efforts include that of Kuckler (1970), Bailey (1985) and Omernik (1987).

A major threat to biotic integrity of North America and worldwide are exotics and those species transplanted beyond their native ranges (Mooney and Drake 1986, Culatta 1991). Among numerous examples is purple loosestriff (*Lythrum salicaria*), a species native to Europe and now threatening water ways across the United States. Range expansion by the exotic zebra mussel (*Dreissena polymorpha*) now threatens the fate of the North American bivalve fauna. An example among many of the effects of species transplanted beyond their native range is the decline of native brook trout (*Salvelinus fontinalis*) populations in the eastern United States. Competition from rainbow trout (*Oncorhynchus gairdneri*) introduced from the west is considered important to the declines observed in brook trout populations. Conversely, declines in westslope cutthroat (*Oncorynchus clarki lewisi*) and bull trout (*Salvelinus confluentus*) populations are thought to be the result of fish introduced from the eastern United States and Europe.

Ratcliff (1986) and others (e.g., Austin and Margules 1986) forcefully argue that the concept of diversity is only of value when applied to species historically characteristic to a particular area (Figure 3). And, Harris and Atkins (1991:121) state, "we must reduce our emphasis on wildlife *per se*, which includes free ranging species, and increase our focus on the native fauna assemblages that distinguish one region from another"—an important characteristic to an ecological hierarchy offered to managers a decade ago (Samson and Knopf 1982).

In dealing with the conservation of biological diversity, managers are challenged in finding common ground. For example, the Province of British Columbia has developed a comprehensive ecological hierarchy for the management of forested lands and wildlife (Demarchi 1988). The U.S. Fish and Wildlife Service GAP biodiversity program is giving serious consideration to the ecological hierarchy developed by Bailey (1985) or that proposed by Omernik (1987). The neotropical migrant initiative supported by several federal agencies, state conservation departments and conservation organizations has adopted the biome as mapped by John Aldrich of the U.S. Fish and Wildlife Service. The Environmental Protection Agency has developed an ecological hierarchy for surface waters (Hughes and Larson 1988). The issue is

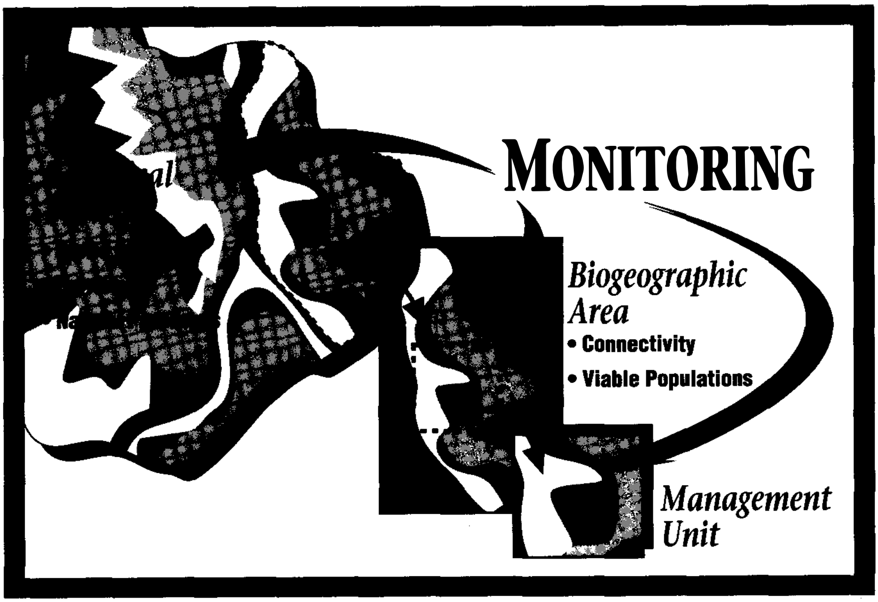

Figure 3. An hypothetical ecological hierarchy. Key issues in the conservation of biodiversity at each level of the hierarchy are noted.

neither the need nor importance of an ecological hierarchy—that is clear in their use in recent initiatives and programs—but one that holds for many kinds of organisms.

An early goal of the development of biogeographic regions was to identify barriers that blocked the interchange of organisms between adjacent regions (Brown and Gipson 1985). This goal remains useful to the conservation of biological diversity (Figure 3). Barriers to dispersal over time are the most significant factor in the evolution of endemics and in development of regional assemblages of plants and animals (Darlington 1978, Brown and Gipson 1985). A recent example is the fragmentation of the Great Plains—once an important barrier to forest dwelling birds—that has lead to the mixing and subsequent hybridization of certain eastern and western birds, such as the yellow- and red-shafted flickers and the Baltimore and bullock's orioles (Sibley and Short 1950). Such hybridization led the American Ornithologists Union to combine the different forms into the northern flicker (*Colaptes auratus*) and northern oriole (*Icterus galbula*), respectively. Had the prairies remained intact and the riparian corridors not allowed to develop, these distinctive populations probably would have diverged into separate species. The work by Knopf (1986) in northeastern Colorado demonstrates both the concept of the corridor as defined by Simpson (1936) and loss of biodiversity as the result of corridors.

The concept of an ecological hierarchy (Figure 3) is evident in several case histories and an opportunity. Evidence suggests that a habitat size-dependency exists for neotropical migrants in the eastern deciduous forest (Wilcove 1985) and in some large bodied avian species that are permanent residents on prairies (Samson 1981a) and forests (Fritz 1979). Fragmentation of habitats at the local level has led to declines in the distribution and numbers of habitat size-dependent species. Minimizing practices promoting site-dependent species in order to reverse regional and national population declines (Samson 1980b, Samson and Knopf 1982). Resource managers must recognize that site or stand management should depend on knowledge about the composition of ecological systems on a broader scale (Samson and Knopf 1982).

Historically, natural disturbance regimes in conjunction with patterns in erosion and sedimentary layering tended to make natural corridors long and narrow (Godron and Formann 1983). Such corridors provided an element of connectivity to the landscape. Many habitats in today's landscapes may be isolated by agriculture, highways or other impacts of man. The loss of long, narrow natural corridors that accompanied man's activities has lead to concerns over population viability, genetic interchange among subpopulations and travel for some species.

Balancing the corridor-dependent loss or gain to biological diversity is one of scale (Figure 3). A significant threat to the long term survival of the spotted owl (*Strix occidentallis*) is the barred owl (*S. varia*). The barred owl, benefitting from the fragmentation of a natural barrier—the contiguous boreal forest—has expanded its range westward. Some conservation groups recently suggested that public lands in the western United States be managed to benefit the barred owl. Assisting the expansion of the barred owl range through such activities at the management unit level will only contribute to the future demise of the spotted owl, a national issue in conservation. On the other hand, corridors connecting similar biotas within an ecoregion, e.g., the southeastern United States or the Klamath province of California, is considered to be significant to the viability of some species, particularly wide ranging carnivores (Harris and Atkins 1991, Pace 1991). Managers and interested public, particularly conservation groups, must balance their recommendations to implement corridors based on scale.

Nearly all authors call for monitoring of land management activities relative to the conservation of biodiversity (Figure 3). Monitoring by land management agencies, for the most part, involves use of management indicator species (MIS)—species thought to respond in some way to management activities. MIS are subject to much criticism (Landres et al. 1988) with little or no ecological thought involved in their selection.

Consider an opportunity to monitor the conservation of biological diversity based on a matrix with an ecological hierarchy (i.e., ecoregion, province and management unit) on one axis and the three fundamental parameters to an ecological system (i.e., composition, structure and function) on the other. Within this monitoring matrix, turnover in species composition could be the management indicator in the ecoregion-composition cell, nutrient cycling in the province-function cell, an index to the natural distribution of habitat patches in the province-structure cell. A low turnover rate—one that approximates natural turnover rates in species composition—could serve as the objective in management for biological diversity and the standard in monitoring for biological diversity. Selection of forest pathogens, indicies to frequency of disturbance, unique structural features such as fens or seeps and so on could monitor persistence of composition, structure and function at the management unit level. Such an approach through an ecological hierarchy would be a step forward in monitoring to ensure that all cogs and wheels at all temporal and geographic scales are conserved.

Sustainability

Imagine the future western United States waterways characterized by purple loosetrife, the zebra muscle and carp (*Cyprinus carpio*), uplands by exotic spotted knapweed (*Centourea cyanus*), barren hillsides with frequent mud slides—the result of fire control leading to cataclysmic fire beyond those observed in 1988—and the air filled with African tiger mosquitos (*Aedes albopictus*). Such changes would be no more than another chapter in the global homogenization of biota as already experienced in the Mediterranean climate regions of the world (Mooney and Drake 1986). Assuming this is not the diverse, healthy and beautiful future environment we seek, how then do land managers in a realistic and meaningful way determine the desired future condition for a diverse and beautiful North American landscape?

First, biological diversity is the variety of life (Keystone 1991). Do we invest heavily in inventory of the variety of life as recommended by some to conserve biological diversity, a difficult task given the fact that 50 to 70 percent of all species are below ground, difficult to inventory and most are even yet to be described (Raen 1990)? Or, do we focus on detecting patterns in the variety of life and their critical ecological and evolutionary determinants as a means to conserve diversity—an expensive and long-term commitment in research (Lubchenco et al. 1991)? What is the basis to define the variety of life—the biota characteristic to today's highly modified landscape with an ever growing number of exotics and invasive species or the biota characteristic of the pre-intensive settlement by man?

What then is realistically attainable to the manager to conserve the variety of life? A response requires answers to three basic questions (Sharpe et al. 1987). What is the distribution of pre-intensive settlement vegetation by major species and how does this relate to the distribution of sites? Have particular sites been altered or lost? How does the distribution of species compare to their presettlement pattern? Comparison of historic to current provides an indication by species and site distribution of those habitats lost, both in terms of quantity and quality. There are two underlying assumptions. First, patterns in pre-intensive settlement vegetation reflect the adaptive history of the biota characteristic to that ecological system and second, pre-intensive settlement habitats were adequate in terms of quantity and quality to maintain a full set of species characteristic to that landscape.

There are several advantages to the approach. Comparison of the pre-intensive settlement vegetation to present provides an indication of what habitats have increased or declined in an area. There is little question that carefully designed inventory and/or longterm research is preferred as the basis to estimate the variety of life within an area. However, neither the funding nor the time required for either is currently available yet the loss of biological diversity continues. This approach does provide a point in time aiding in the validation of an ever growing number of landscape and succession models that predict past and future patterns in disturbance and the resultant landscapes. The information is readily available. Records of early surveyors working for the U.S. Geological Survey are an example of both detailed and relatively reliable information. And, the approach provides a framework for the desired future condition that emphasizes composition and structure native to an ecological system.

Second, biodiversity is ecological processes (Keystone 1991). Understanding the role of biodiversity in natural processes and how ecological processes shape patterns of diversity is central to sustainability of all ecological systems (Lubcheko et al. 1991) and the conservation of biodiversity (National Science Board 1989). Natural processes vary in time and space, yet, over the millennia, provide the adaptive history within which species have evolved, communities have formed and ecological systems emerged. These natural processes vary from ecoregion to ecoregion and, to a certain extent, have served as a criteria in the delineation of broad scale ecological units. An example is the temperate rainforest in southeast Alaska and British Columbia—an ecological system characterized by lack of fire but frequent low intensity windthrow (Samson et al. 1989). In contrast, fire, often intense and broad scale, was a significant influence in maintaining the original tall grass prairie (Weaver 1968). Characterization of the natural processes characteristic to each ecoregion in North America could serve as an important second step in the conservation of biological diversity.

Third, restoring and or maintaining the diversity needed to sustain all ecosystems is essential to cope with problems of global warming, acid precipitation, desertification, long term soil productivity and the viability of select species. Overcoming these and a myriad of other issues related to biological diversity requires an approach both understood by managers and within the economic limits of their respective programs whether at the national or local level.

Managing for sustainable ecological systems to conserve biodiversity includes the restoration of damaged ecological systems (Lubcheko et al. 1991). The fragmentation of natural ecological systems and inherent ecological processes has had a profound effect on the world's biodiversity (Wilson 1988). Specifically, the spread and abundance of species (Wilcove et al. 1986), assembly of communities and ecosystems (Burgess and Sharpe 1981), and the ability of those communities and ecosystems to survive stress such as global warming (Botkin 1991). Control of a natural process, for example, fire, has provided set aside areas—even large ones such as the Bob Marshall Wilderness Area—and the managed landscape alternate pathways to a landscape unlike that evident in the adaptive history of species characteristic to that landscape. The ''nature-knows-best'' or let the landscape alone view is not an acceptable basis for the ecology of the 21st century (Bodkin 1991), nor is wilderness (Noss 1991) without active management a useful paradigm for the conservation of biological diversity.

The third step for the manager to conserve biological diversity is depicted in Figure 4. Restoration, control of natural processes and economics, to the manager, are interrelated. Costs of investments, both in personnel and funding, are high in either the restoration or control of natural processes (such as wildfire). Ecological systems in need of restoration rarely exhibit natural patterns in disturbance nor do those that have been modified through management such as fire control. Some will even argue that we have reached the limit in our technical abilities, personnel and funding to control fires in the western United States and the cataclysmic fires of 1988 are only a precursor to larger fires in the future. Change in the way we conduct land management is needed.

Classic land management has often been very much of a trial-and-error and expensive enterprise and often with great social debate. In assessing current resource management in North America we should consider the human social value of sustainability as best stated by Leopold (1966b) when he wrote, ''A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community.'' Recognizing the significance of natural patterns (figures 1 and 2) in the distribution of biota through an ecological hierarchy (Figure 3) and encouraging natural processes through active and economically wise management (Figure 4) can contribute to the integrity and stability of the biotic community.

A ''beautiful world is a diverse one when we have the luxury of enjoying it'' (Raven 1991:770). There is a growing economic school of analysis that suggests environmentally unsound practices tend to be economically unsound (Liepert and Simonis 1988). A recent and palatable economic argument for the conservation of biodiversity by Hecht and Cockburn (1990) suggests a new economic order and biodiversity go hand-in-hand, at least in the tropics. The link between poverty, inequality and environmental degradation in third world nations has begun to acknowledge that development without ecological sustainability is, at best, contradictory (Brown et al. 1991). The world conservation strategy (International Union for Conservation of Nature and Natural Resources 1980) encourages member nations to develop conservation plans within the context of sustainable development. Planning for resource management in North America should proceed on a similar course if we are to conserve the beauty of the biotic community.

Summary

For two hundred or more years, growth in economic as well as recreational wealth in the United States has drawn heavily on public lands for food, fiber, and other goods and services. In turn, these same public lands now depend on active management by man for their future and survival. Providing support for this survival

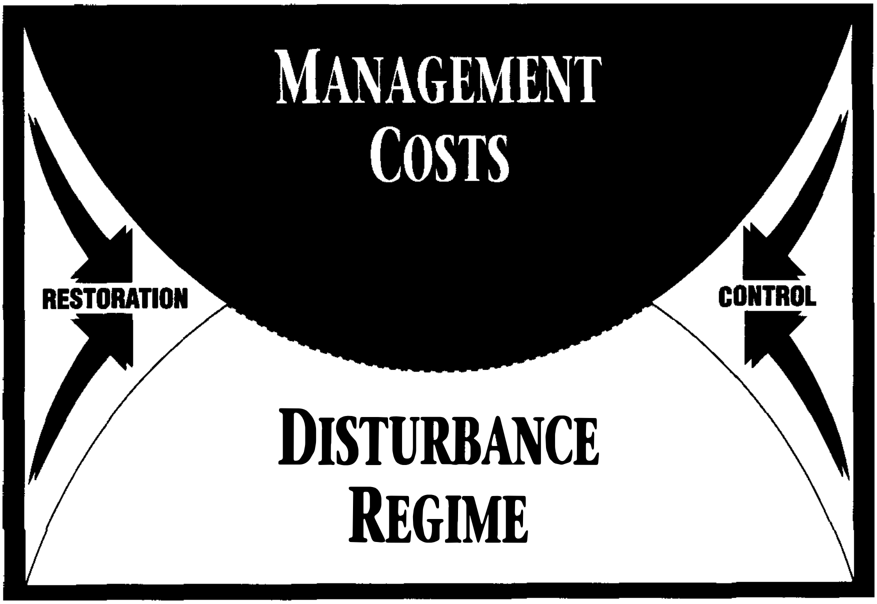

Figure 4. Effective and efficient management for the conservation of biological diversity is to maintain natural processes versus investments in restoration or control of natural processes.

will compete with education, economic growth, long term health care and a host of other problems facing this and other countries.

Many unanswered questions remain in the conservation of biological diversity. What scientific methodology should be used? There is no consensus nor is there direction available today for the conservation of biodiversity (Erwin 1991). What temporal scale or time frame do we use—today's highly modified landscape or yesterday's pre-intensive settlement that reflects a natural setting and the process-dependent adaptive history of thousands of species? Even more important, what are priorities in conservation of biodiversity? Today, considerable effort—both in terms of funding and resources—is currently directed toward forested ecosystems, yet most grasslands and other less species-rich habitats are either under represented in conservation strategies or are extinct.

If we rely exclusively on old approaches and solutions, we not only resign a leadership role but also fail to adequately conserve biodiversity. A new paradigm for the conservation of biodiversity is needed that must occupy new ground. This new paradigm must direct impact(s) of an ever growing human presence on earth, establish limits for all ecological processes whether they influence the survival of Bicknell's geranium or global warming, yet provide for goods and services needed for future health and stability in all human cultures. There is hope and a growing awareness that many issues in the conservation of biodiversity require consideration of multiple resources, multiple ecological systems and large spatial scales in both human-dominated and natural ecosystems (Council on Environmental Quality 1991).

The approach presented in this paper is a managerial framework for the conservation of biological diversity. It is built around three steps.

1. Emphasize natural processes. It is important to emphasize that a ''natural'' community is not one reached after a long period without large scale disturbance (fire, windthrow, etc.), but several communities are ''natural'' for any site at any given time (Sprugel 1991). Failure to accept the role of change has and will continue to produce destructive, undesirable results—specifically an increase in biosimplification and loss of biodiversity. Only by understanding how nature works, (e.g., natural processes) and applying how nature works—active management—will biodiversity be maintained.
2. An ecological hierarchy. Conserving biological diversity is to maintain in a healthy state the variety of life native to a landscape as well as those ecological processes characteristic to that landscape (Wilcove and Samson 1987). Comparison of pre-intensive settlement to current landscapes with a hierarchy (whether it be Bailey's, Omernik's or Kuchler's) could for the first time identify those elements in native composition that have increased, remained stable or experienced significant declines—priorities in the conservation of biological diversity. Decision makers and the public including conservation groups should realize that management must be based on what we know about all geographic scales, including identifying factors contributing to declines in biological diversity.
3. Sustainability. Biological diversity is not an outcome of wise land and resource management. Biological diversity is the single most significant influence leading to healthy ecological systems and wise resource management. We must work to have biological diversity viewed not as of interest of the favored few or scientific community alone, but biological diversity is needed to produce goods and services for all nations, impact issues such as global warming and acid precipitation, and essential to a healthy environment for all humanity. This will be the desired future condition of the landscape if we are successful in the conservation of biological diversity.

References

Austin, M. P. and C. R. Margules. 1986. Assessing representativeness. Pages 46–67 *in* M. B. Usher, ed., Wildlife conservation and evaluation. Chapman and Hall, London.

Bailey, R. G. 1985. The factor of scale in ecosystem mapping. Environ. manage. 4:271–276.

Bormann, R. S. and G. E. Lichens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, NY. 373 pp.

Botkin, D. B. 1990. Discordant harmonies. A new ecology for the twenty-first century. Oxford Univ. Press, NY. 241 pp.

Brokow, N. V. L. 1985. Treefalls, regrowth, and community structure in tropical forests. Pages 53–71 *in* S. T. A. Picket and P. S. White, eds., The ecology of natural disturbance and patch dynamics. Academic Press, Inc., NY.

Brown, L. R., C. Flavin, and S. Postal. 1991. Saving the planet. How to shape an environmentally sustainable global economy. W. W. Norton and Co., NY. 224 pp.

Brown, J. H. and A. C. Gipson. 1983. Biogeography. C. V. Mosby Co., St. Louis, MO. 643 pp.

Cole, G. F. 1988. Changes in interacting species with disturbance. Environ. Manage. 11:257–264.

Conner, W. H. and J. W. Day. 1976. Productivity and composition of a bald cypress-water tupelo site and a bottomland hardwood site in a Louisiana swamp. Amer. J. Bot. 63:1354–1364.

Council on Environmental Quality. 1991. Environmental Quality. 21st Ann. Rep. Council on Environ. Qual., Washington, D.C. 418 pp.

Culatta, E. 1991. Biological immigrants under fire. Science 254:1444–1449.

Darwin, C. 1859. On the origin of species by means of natural selection, or the preservation of favored races in the struggle for life. Facsimile edition. E. Mayr, ed., Harvard University Press, Cambridge, MA. 281 pp.
Darlington, P. J., Jr. 1966. Zoogeography: The geographical distribution of animals. John Wiley and Sons, Inc., NY. 675 pp.
Demarchi, D. A. 1988. Ecoregions of British Columbia. British Columbia Ministry of Environment, Wildl. Branch, Victoria, B. C. Map (1:2,000,000).
Denslow, J. S. 1985. Disturbance-mediated coexistence of species. Pages 307–324 *in* S. T. A. Picket and P. S. White, eds., The ecology of natural disturbance and patch dynamics. Academic Press, Inc., NY.
Erwin, T. L. 1991. An evolutionary basis for conservation strategies. Science 253:750–752.
Fritz, R. S. 1979. Consequences of insular population structure: Distribution and extinction of spruce grouse populations in the Andirondack Mountains. Oecologia 42:57–65.
Godron, M. and R. T. T. Forman. 1983. Landscape and modification and changing ecological characteristics. Pages. 12–47 *in* H. A. Mooney and M. Gordon, eds., Disturbance and ecosystems. Springer-Verlag, NY.
Harris, L. D. and K. Atkins. 1991. Faunal movement corridors in Florida. Pages 117–134 *in* W. E. Hudson, ed., Landscape linkages and Biodiversity. Island Press, Covelo, CA.
Hecht, S. and A. Cockburn. 1990. The fate of the forest: Developers, destroyers, and defenders of the Amazon. Harper Perennial, NY.
Hughes, R. M. and D. P. Larson. 1988. Ecoregions: An approach to surface water protection. Water Pollut. Control Fed. 60:487–493.
International Union for Conservation of Nature and Natural Resources. 1980. World Conservation Strategy. Gland, Switzerland. 107 pp.
Keystone Center. 1991. Final Consensus Report of the Keystone Policy Dialogue on Biological Diversity on Federal Lands. The Keystone Center, Keystone, CO. 96 pp.
Knight, D. H. 1987. Parasites, lightning, and the vegetation mosaic in wilderness landscapes. Pages 59–101 *in* M. G. Turner, ed., Landscape heterogeneity and disturbance. Springer-Verlag, NY.
Knopf, F. L. 1986. Changing landscapes and the cosmopolitism of the eastern Colorado avifauna. Wildl. Soc. Bull. 14:132–142.
Kozlowski, T. T. and C. E. Ahlgren. 1974. Fire and ecosystems. Academic Press, NY. 542 pp.
Kuckler, A. W. 1970. Potential natural vegetation. Map (scale 1:7,500,000). Pages 89–91 in The Natural Atlas of the United States of America. U.S. Geological Survey, Washington, D.C.
Landres, P. B., J. R. Verner, and J. W. Thomas. 1988. Ecological uses of vetebrate indicators species: A critique. Conserv. Biol. 4:316–329.
Liepert, C. and U. E. Simonis. 1988. Int. J. Soc. Econ. 15:37.
Leopold, A. 1933. Game Management, Charles Scribner Sons, NY. 481 pp.
———. 1966a. The Round River. Pages 175–187 in A Sand County almanac, Oxford Univ. Press. NY.
———. 1966b. Natural history. Pages 118–194 in A Sand County almanac, Oxford Univ. Press, NY.
Lubchenco, J., A. M. Olson, L. B. Brubaker, S. C. Carpenter, M. M. Holland, S. P. Hubbell, S. A. Levin, J. A. MacMahon, P. A. Matson, J. M. Melillo, H. A. Mooney, C. H. Peterson, H. R. Pulliam, L. A. Real, P. J. Regal, and P. G. Risser. 1991. The sustainable-biosphere initiative: An ecological research agenda. Ecology 72:371–412.
MacLean, D. A., S. J. Woodley, M. G. Weber, and R. W. Wein. 1983. Fire and nutrient cycling. Pages 111–132 in R. W. Wein and D. A. Maclean, eds., The role of fire in northern circumpolar ecosystems. John Wiley and Sons, NY.
Mooney, H. A. and J. Drake, eds. 1986. Ecology of biological invasions of North America and Hawaii. Springer-Verlag, NY. 419 pp.
Mutch, R. W. 1970. Wildland fires and ecosystems—a hypothesis. Ecology 51:1046–1051.
National Science Board. 1989. Loss of biological diversity: A global crises requiring national and international solutions. Nat. Sci. Found., Washington, DC. 96 pp.
Noss, R. F. 1991. Sustainability and wilderness. Conserv. Biol. 5:120–122.
Odum, W. E., T. S. Smith, III, and R. Dolan. 1987. Suppression of natural disturbance: Long-term ecological change on the outer banks of North Carolina. Pages 123–135 in M. G. Turner, ed., Landscape heterogeneity and disturbance. Springer-Verlag, NY.
Oliver, C. D. 1981. Forest development in North America following major disturbance. For. Ecol. Manage. 3:153–168.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Annals Amer. Geogr. 77:118–124.
Pace, F. 1991. The Klamath corridors: Preserving biodiversity in the Klamath National Forest. Pages 105–116 in W. Hudson, ed., Island Press, Covelo, CA.
Picket, S. T. A. and P. S. White, eds. 1985. The ecology of natural disturbance and patch dynamics. Academic Press, Inc. NY. 291 pp.
Ratcliff, D. A. 1976. Selection of important areas for conservation in Great Briton: The Nature Conservancy Council's approach. Pages 136–159 *in* M. B. Usher, ed., Wildlife Conservation Evaluation. Chapman and Hall, London.
Raven, P. H. 1990. The politics of preserving biodiversity. BioScience 40:769–774.
Risser, P. G. 1988. Diversity in and among grasslands. Pages 176–180 *in* E. O. Wilson, ed., Biodiversity. Nat. Acad Sci. Press, Washington, D.C.
Roberts, L. 1988. Hard Choices ahead on biodiversity. Science 241:1759–1761.
Samson, F. B. 1980a. Island biogeography and the conservation of prairie birds. Proc. N. Amer. Prairie Conf. 7:293–305.
———. 1980b. Island biogeography and the conservation of nongame birds. Trans. N. Am. Wildl. Natur. Resour. Conf. 45:245–251.
Samson, F. B. and F. L. Knopf. 1982. In search of a diversity ethic for wildlife management. Trans. N. Am. Wildl. and Nat. Resour. Conf. 47:421–431.
Samson, F. B., P. Alaback, J. Christner, T DeMeo, A. Doyle, J. Martin, J. McKibben, M. Orme, L. Suring, K. Thompson, B. G. Wilson, D. A. Anderson, R. W. Flynn, J. W. Schoen, L. G. Shea and J. L. Franklin. 1989. Conservation of rain forests in southeast Alaska: Report of a working group. Trans. N. Am. Wildl. Natur. Resour. Conf. 54:121–133.
Sclater, P. L. 1858. On the general geographical distribution of the members of the class Aves. Zool. J. Linn. Soc. 2:130–145.
Sharpe, D. M., G. R. Gunterspergen, C. P. Dunn, L. A. Leitner, and F. Stearns. 1987. Vegetation in a southern Wisconsin agriculture landscape. Pages 137–158. *In* M. G. Turner, ed., Landscape heterogeneity and disturbance. Springer-Verlag, NY.
Sibley, C. C. and L. L. Short, Jr. 1959. Hybridization in the buntings of the Great Plains. Auk 76:443–463.
Simpson, G. G. 1936. Data on the relationships of local and continental mammalian faunas. J. Palontol. 10:410–414.
Sprugel, D. G. 1991. Disturbance, equilibrium and environmental variability: What is ''natural'' vegetation in a changing environment. Biol. Conserv. 58:1–18.
Turner, M. G. 1987. Landscape heterogeneity and disturbance. Springer-Verlag, NY. 239 pp.
Wallace, A. R. 1876. The geographical distribution of animals. MacMillan, London. 588 pp.
Watkins, T. H. 1991. The business of forests. The Wilderness. Winter 8–9.
Weaver, J. E. 1968. Prairie plants and their environment. Univ. Nebraska Press, Lincoln. 276 pp.
Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211–1214.
Wilcove, D. S. and F. B. Samson. 1987. Innovation wildlife management: Listening to Leopold. Trans. N. Am. Wildl. Natur. Resour. Conf. 52:321–329.
Wilcove, D. S., C. H. McCellan, and A. P. Dobson. 1986. Habitat fragmentation in the temperate zone. Pages 237–256 in M. E. Soule, ed., Conservation Biology. Sinauer Assoc., Sunderland, MA.
Wilson, E. O., ed. 1988. Biodiversity. National Academy Press, Washington, D.C. 521 pp.

The International Component of Managing Biological Diversity

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Introduction

Biological diversity, in its simplest form, is the totality of species occupying a given area. A more comprehensive definition would include the interactions of each species with the communities and ecosystems of which it is a part. Over the past decade, we have heard increasingly about biological diversity, largely because of its threatened loss on a global scale (Wilson and Peter 1988). The primary threat to biodiversity stems from the increasingly rapid loss and degradation of natural habitats. In some instances, entire biotas are lost. In other areas, habitats are disturbed, and species are affected to varying degrees.

The loss of biological diversity on any scale, local or global, engenders concern for several reasons. First, certain species often are economically important as sources of timber, food, medicines or other products (Myers 1984, Bird 1991). Conservative estimates put the number of extant species at about 5 million (Wilson 1988). Yet only about 28 percent (1.4 million) of these species have been described (Wilson 1988), so there are at least another 3.6 million about which we know nothing. Others suggest that species numbers could reach as high as 30 million (Erwin 1988). Regardless of the actual number, clearly many species will be lost before we determine if and how they may directly benefit the human population.

Most species provide, in addition, important indirect benefits. Species combine to form communities and thus are important in the environments of other organisms as prey, predators, parasites, competitors, pollinators and dispersers (*see* Wilson 1987, Terborgh 1988). They are equally important in the maintenance of watersheds, fertile soils and balance in the atmosphere (*see* Dickinson 1987, Anderson and Spencer 1991). Finally, species, both individually and collectively as habitats and communities, have an aesthetic value that contributes to the pleasure and psychological well-being of humans above and beyond the tangible benefits that they may provide (Ehrenfeld 1988).

With recognition by the public of the value of biological diversity, politicians and governments have become increasingly aware of the environment, incorporating into national agendas habitat protection and maintenance and wildlife management programs that will help to retain diversity. Most of these programs deal only with problems and practices at local or national levels. Yet, maintenance of biological diversity, even on a local scale, is clearly an international problem. For example, the causes of habitat degradation in any area are not always locally generated. Air and water pollution, including acidified precipitation and human-generated carbon dioxide, move easily across international boundaries (French 1990), and biological pests ride from country to country on contaminated agricultural or other products

(Drake et al. 1989). At the same time, many of the species that comprise the biological diversity that a country wishes to conserve cross borders naturally, migrating or dispersing freely across international boundaries.

In the present paper, I examine the international component of the biological diversity of the United States. I include an overview of the organisms involved, with a focus on migratory birds, and brief summaries of the countries and habitats important to these animals, and the threats to which they may be exposed. I then describe ways in which scientists and managers from the United States can contribute at international levels to the management of these organisms and, thereby, the maintenance of biodiversity in this country. In particular, I will stress protection of undisturbed habitats, enhancement of habitats converted to other uses, and interactions with counterparts and colleagues in other countries.

International Components of Biodiversity of the United States

Non-avian Species

Animals native to the United States that cross international borders include insects and most classes of vertebrates. Although insect migrants, in general, are not common (Orr 1970), one outstanding example is the monarch butterfly (*Danaus plexippus*). Individuals from populations breeding in the eastern United States spend up to five months a year in the high elevation forests of southern Mexico (Urquhart and Urquhart 1976, Brower et al. 1977).

A number of fish species migrate (e.g., eel, species of Atlantic and Pacific salmon, sturgeon [Jones 1968, Lee et al. 1980]), travelling between fresh and salt water. Although these fishes generally do not "enter" other countries, they often occupy an oceanic no-man's land where they may be affected by oil spills and other pollution, and subjected to environmentally unsound fishing practices.

Six of the seven species of marine turtles occur in North America or its coastal waters, and the breeding ranges of four include United States beaches (Ernst and Barbour 1989). These forms suffer from the same degradation of their aquatic environments as do fishes and also are subject to over-exploitation for food and commercial purposes, and to harmful fishing techniques (National Research Council 1990).

North American mammals that travel to other countries fall primarily into two groups, marine mammals and bats. Fifty-six species of pinnipeds, cetaceans and manatee move among waters of the United States, other countries and the open ocean (Burt and Grossenheider 1976). All are exposed to environmental pollution, and many, especially whales, may be harvested in excess. Although migratory behavior and wintering ranges of bats are not well known, probably 11 species breeding in North America migrate to Mexico (Nowak and Paradiso 1983, D. E. Wilson personal communication: 1992).

Despite their diversity, non-avian organisms that move between the United States and other countries represent only a small component of the biodiversity of the United States. For example, the turtles comprise a mere 2.2 percent of the reptiles that are found there (Collins 1990). About 18 percent of the native mammals of the United States (bats about 3 percent; marine mammals approximately 15 percent) are included (Burt and Grossenheider 1976). Together, the reptiles and mammals represent less than 5 percent of the native vertebrates (summed from Burt and Grossenheider 1976, Rappole et al. 1983, Collins 1990), excluding fishes, found in the United States. By far, the most commonly migratory members of the fauna of the United States are the birds.

Nearctic Migrant Birds

Of the approximately 650 species that breed in the United States, 332, or more than 50 percent, spend from three to six months each year in migration or on wintering grounds in countries to the south (Rappole et al. 1983). (For consistency, "winter" and "wintering" denote the north temperate winter, although some birds may be present on "wintering grounds" during the local summer season.) These migrant birds alone represent nearly one-quarter (approximately 22 percent) of the vertebrate (excluding fishes) biodiversity of the United States.

The avifauna of each country of Central and South America and the Caribbean (hereafter, Latin America) includes some species of wintering nearctic migrants, although species representation decreases toward the south (Rappole et al. 1983). For example, 313 species of North American migrants have been recorded from Mexico, 222 from Central America, 161 from various Caribbean islands and 112 from South America. Rappole et al. (1983) listed 19 political/geographic entities with more than 100 species of migrants, including four countries (Mexico, Guatemala, Honduras, Panama) with 200 or more.

Nevertheless, the distribution of migrant species among countries is not uniform. Thus, one cannot assume that a country with more species is necessarily more important than one with few. Shorebirds, for example, tend to migrate particularly long distances. The breeding and wintering grounds often are connected by a few small stop-over areas where birds accumulate fat reserves essential for flying non-stop to the next, significantly distant resting point (Myers et al. 1987). Few, if any, alternative sites exist (Senner and Howe 1984), so the loss of one small area in a single country can have devastating effects on populations of many species.

It is difficult to determine the relative importance of habitats on the wintering grounds, because the habitat distributions of many species are poorly known, and because some species occupy more than one habitat, although in relatively different frequencies (Hutto 1980, Lynch 1989). Nevertheless, some migratory species probably winter in every major habitat type in Latin America (Rappole et al. 1983).

Threats. At present, many of the migratory bird species that breed in North America appear to be experiencing population declines (Faaborg and Arendt 1989, Howe et al. 1989, Robbins et al. 1989, Terborgh 1989). The causes of decline are undoubtedly multiple, operate in breeding, migration and wintering areas, and vary in importance with each species (Askins et al. 1990). On breeding grounds, habitat fragmentation, and associated increases in nest predation and cowbird parasitism are probably the most important factors (*see* Whitcomb et al. 1981, Lynch and Whigham 1984, Terborgh 1989). Loss or degradation of habitat is of greatest significance during migration and on wintering grounds (*see* Rappole et al. 1983, Terborgh 1989).

All natural habitats in Latin America are being degraded (*see* Selcraig 1991) or destroyed at unprecedented rates, but especially tropical forest (Myers 1989, 1991, FAO/UNEP 1991). Current projections suggest that, by the turn of the century, only remnants of forest will remain in Mexico, Central America and the Caribbean, with forests in other countries severely reduced. Other types of habitat, especially grassland

and wetland, are equally threatened (*see* Rappole et al. 1983, Scott and Carbonell 1986). Even if habitat loss is not at present a primary factor in the decline of every species of nearctic migrant, if losses continue at present rates, it soon will be. Clearly, any program directed toward the preservation of biodiversity must deal with the maintenance of migratory species year round, in all portions of their ranges.

Solutions

Solutions to the many environmental problems that exist today are myriad. They differ generally in approach (e.g., environmental education, habitat protection, sustainable development, ecotourism), duration (workshops versus graduate training) and cost (habitat protection versus reclamation). All have merit in specific situations, and, ultimately, all will be part of the global program for the maintenance of biodiversity. However, in the next 10 years, some must take precedence, if only to provide time for the others to have an impact.

The major international threats to North American biodiversity at this juncture are degradation (disturbance and pollution) and loss of marine and terrestrial habitats. Therefore, protection of undisturbed habitats of special importance, enhancement of those habitats already converted to other uses and management of species in disturbed areas must be given top priority. As marine problems are outside my area of experience, I will confine my remarks to terrestrial areas that comprise the countries through which migrant species pass during migration, as well as those in which they winter.

Habitat Protection

The call for habitat protection as a cornerstone of wildlife management and conservation programs is not new (*see* Leopold 1949). Recently, however, there has been a shift toward use (rather than protection) of habitats and ecosystems, but in an enduring, renewable way—''sustainable development'' (Lebel and Kane 1989, Schreckenberg and Hadley 1991). Such practices, although important components of any resource management program, cannot eliminate the need for truly protected areas, for two reasons. First, sustainable development, except in terms of limited extractive reserves, can damage habitats and affect the well-being of some species (Johns 1988). Second, such extractive reserves are viable only at low human population densities (Fearnside 1989, Terborgh 1991, Salafsky et al. 1992). The Latin American population is currently increasing at a rate of 2.1 percent per year (Central America, 2.5 percent; Caribbean, 1.8 percent; South America, 1.9 percent), with no sign of abating, particularly given that a significant portion of the population in these areas (36 percent for Latin America) is under 15 years of age (Population Reference Bureau 1991). In many areas, especially those including habitats most suitable for agriculture, limited sustainable development can only be an interim stage on the road to complete habitat utilization.

Protection of areas of undisturbed habitat of sufficient size to maintain a major portion of the world's biodiversity, or even of United States' biodiversity, will require the concerted efforts of politicians, economists, sociologists and conservation organizations, as well as scientists and managers. In fact, there are a number of unique ways in which managers and scientists can contribute to this process, through research and interactions with counterparts in other countries.

Research

A great deal of basic information is necessary for the design and execution of any successful program of habitat and species protection. Below, I describe three areas of research of top priority for the management of biological diversity.

Area evaluation and habitat needs. Most fundamentally, habitats available for protection must be identified and evaluated, and their importance to the organisms in question (e.g., migratory birds) determined. Without this information, it is impossible to set priorities among different sites, since, realistically, it will be impossible to protect everything. Secondly, we must have this information to insure that the areas protected actually provide appropriate habitats for the species involved. For example, Terborgh (1989) suggested that Canada Warblers (*Wilsonia canadensis*) segregate elevationally by sex on their wintering grounds in Ecuador. Likewise, males and females of several species of warblers segregate by habitat on the wintering grounds (Lopez Ornat and Greenberg 1990). Obviously, in both instances, parks or reserves to protect these species must deal with the needs of both sexes.

Local species. Another way in which research can contribute at the international level to maintenance of biodiversity in the United States is by focusing on local species whose habitats are shared by nearctic migrants during migration and winter. This will, of course, provide information on the interaction between wintering and resident species, and may ultimately contribute to our ability to manage such species in these habitats.

Of even greater significance is the part that work on local species may play in the preservation of habitats used by migrants. Customarily, we refer to most migrants as "North American" or "United States" species, and, frequently, one hears or sees reference to problems with "our birds" or other migrant organisms. Yet, as I indicated above, *our birds* spend three to six months each year in *other* countries. This provincial view, as well as associated pressures often exerted by institutions in the United States on governments in other countries to save habitats, has, unfortunately, been counterproductive in some instances. Too frequently, governments, conservation groups and individuals from other countries also have come to view the migrants as "North American birds," and, therefore, as a "North American problem."

Yet, because conservation is often largely a political and economic issue, local residents and governments must strongly support a particular protection or management scheme for it to be successful. By carrying out research dealing with habitats, species and issues of particular *local* relevance, we may be better able to demonstrate to residents the ways in which wise management practices benefit them, as opposed to being important only to the interests of the United States. We may also promote the protection or wise use of habitats important to species that migrate from North America.

The Monteverde Cloud Forest Preserve, covering about 26,000 acres (10,520 ha), was created to protect an area of undisturbed montane cloud and wet forest and the organisms that occupy it. Species of particular interest were the Resplendent Quetzal (*Pharomachrus mocinno*), Three-wattled Bellbird (*Procnias tricarunculata*) and Golden Toad (*Bufo periglenes*), none of which is found in the United States (Frost 1985, Stiles and Skutch 1989). In addition, however, some 49 species of birds from North America migrate through or winter in the area (Stiles 1983).

Likewise, the Mapimí Biosphere Reserve in north-central Mexico (NE Durango) was created largely to protect habitat of the endangered Bolson Tortoise (*Gopherus flavomarginatus*) (Bury et al. 1988). Happily, 74 species of wintering or migrating birds (a major portion from the United States) also use the area (Thiollay 1981).

It is highly unlikely that either of these sites, or many others in Latin America, would have been preserved solely under the impetus of protecting wintering areas of nearctic migrants from the United States. Clearly, it is essential that we take advantage of whatever reasons may be available to protect habitats. Ultimately, this will benefit all species, including migrants, that use these areas.

Habitat enhancement. It is clear that regardless of all conservation efforts, much or most of the habitat occupied by migrating and wintering species from North America will be developed to some degree. Thus, it is critical that we identify types and methods of exploitation that will have the least effect on habitats and the organisms they contain. We must also develop means of enhancing or restoring disturbed habitats to maximize their suitability for organisms displaced from their natural areas. For example, Lynch (1989) showed that several species of nearctic migrants winter in both forest and early second growth, but at significantly lower numbers in the disturbed habitats. It is important to determine if there are ways of enhancing the disturbed areas to mitigate these effects.

Habitats can be enhanced by increasing food availability or mimicking conditions in undisturbed habitats. For example, at present, we are working in southern Mexico, to identify the species of fruits used by forest-dwelling wintering migrants. Although most North American migrants are largely insectivorous during the breeding season, many (e.g., several species of warblers, tanagers, thrushes) eat large quantities of fruit during the winter or prior to the spring migration (M. S. Foster personal observations). Once the important plants are identified, their suitability for use as ornamentals or shade trees around dwellings, as living fence posts, or for windrows between fields can be determined. Such habitat ''islands'' in areas of extensive cultivation can increase habitat use by birds substantially.

Collaboration

Finally, I would like to mention collaboration with colleagues in countries through which organisms migrate and in which they winter. Although scientists and managers from North America will be closely involved in efforts to protect, enhance or restore habitats in these countries, ultimately, to be successful, programs must be designed and operated by individuals in the countries in question.

Unfortunately, resources in many of these countries, both human and economic, are severely limited. Trained scientists and managers are few, and they often lack basic equipment needed to carry out field studies, access to current literature, and even funds to travel and live in the study area. Because of the speed with which habitats and biodiversity are being lost, protection and management programs cannot wait until sufficient resources become available locally. There is a clear need for involvement from North America, through cooperative research and management projects with host country colleagues and students. In addition to efforts to protect species important to North American biodiversity, a major focus of these projects must be to assist counterparts in achieving their own environmental goals.

Conclusions

The maintenance of United States biodiversity is clearly an international issue: more than 25 percent of the species of non-piscine vertebrates of the United States migrate to countries in Latin America or enter marine waters adjacent to them; and habitats in these areas that are used by migrants are being degraded and destroyed at unprecedented rates. Scientists and managers from the United States can contribute to efforts to counter this threat through research that (1) identifies priority areas for migrant species for protection; (2) determines habitat and other requirements of migrant species during migration and on their wintering grounds as a basis of habitat enhancement; (3) focuses on habitats, species and issues of *local* importance as a means of generating local support for habitat protection; and (4) involves local colleagues and assists them in the realization of their environmental goals.

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References

Anderson, J. M. and T. Spencer. 1991. Carbon, nutrient and water balances of tropical rain forest ecosystems subject to disturbance: Management implications and research proposals. MAB Digest 7. UNESCO, Paris. 95 pp.

Askins, R. A., J. F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Current Ornithol. 7:1–57.

Bird, C. 1991. Medicines from the rainforest. New Scientist 131:34–39.

Brower, L. P., W. Calvert, L. E. Hedrick, and J. Christian. 1977. Biological observations on an overwintering colony of monarch butterflies (*Danaus plexippus*, Danaidae) in Mexico. J. Lepidopterists' Soc. 31:232–242.

Burt, W. H. and R. P. Grossenheider. 1976. A field guide to the mammals. 3rd ed. Houghton Mifflin, Boston, MA. 284 pp.

Bury, R. B., D. J. Morafka, and C. J. McCoy. 1988. Distribution, abundance and status of the Bolson tortoise. Ann. Carnegie Mus. 57:5–30.

Collins, J. T. 1990. Standard common and current scientific names for North American amphibians and reptiles. 3rd ed. Soc. Study Amphib. Rept. Herp. Circ. no. 19. 41 pp.

Dickinson, R. E., ed. 1987. The geophysiology of Amazonia. John Wiley & Sons, NY. 526 pp.

Drake, J. A., H. A. Mooney, F. di Castri, R. H. Groves, F. J. Kruger, M. Rejmánek, and M. Williamson. 1989. Biological Invasions a global perspective. John Wiley & Sons, NY. 525 pp.

Ehrenfeld, D. 1988. Why put a value on biodiversity? Pages 212–216 *in* E. O. Wilson and F. M. Peters, eds., Biodiversity. Nat. Acad. Press, Washington, D.C. 521 pp.

Ernst, C. H. and R. W. Barbour. 1989. Turtles of the world. Smithson. Inst. Press, Washington, D.C. 313 pp.

Erwin, T. L. 1988. The tropical forest canopy. Pages 123–129 *in* E. O. Wilson and F. M. Peters, eds., Biodiversity. Nat. Acad. Press, Washington, D.C. 521 pp.

Faaborg, J. and W. J. Arendt. 1989. Long-term declines in winter resident warblers in a Puerto Rican dry forest. Am. Birds 43:1226–1230.
FAO/UNEP. 1991. Interim report on forest resources assessment 1990. Food and Agriculture Organization of the United Nations, Liaison Office/Americas, Washington, D.C. 2 pp.
Fearnside, P. M. 1989. Extractive reserves in Brazilian Amazonia. BioScience 39:387–393.
French, H. F. 1990. Clearing the air: A global agenda. World-watch paper 94. Worldwatch Inst., Washington, D.C. 54 pp.
Frost, D. R., ed. 1985. Amphibian species of the world. Allen Press and Assoc. Syst. Coll. Lawrence, Kansas. 732 pp.
Howe, M. A., P. H. Geissler, and B. A. Harrington. 1989. Population trends of North American shorebirds based on the international shorebird survey. Biol. Conserv. 49:185–199.
Hutto, R. L. 1980. Winter habitat distribution of migratory land birds in western Mexico, with special reference to small foliage-gleaning insectivores. Pages 181–203 *in* A. Keast and E. S. Morton, eds., Migrant birds in the neotropics. Smithson. Inst. Press, Washington, D.C. 576 pp.
Johns, A. D. 1988. Effects of "selective" timber extraction on rain forest structure and composition and some consequences for frugivores and folivores. Biotropica 20:31–37.
Jones, F. R. H. 1968. Fish migration. Edward Arnold, London, England. 325 pp.
Lebel, G. G. and H. Kane. 1989. Sustainable development. Global Tomorrow Coalition, Washington, D.C. 69 pp.
Lee, D. S., C. R. Gilbert, C. H. Hocutt, R. E. Jenkins, D. E. McAllister, and J. R. Stauffer, Jr. 1980. Atlas of North American freshwater fishes. North Carolina Biol. Surv. Publ. no. 1980–12. 854 pp.
Leopold, A. 1949. A sand county almanac. Oxford, NY. 226 pp.
Lopez Ornat, A. and R. Greenberg. 1990. Sexual segregation by habitat in migratory warblers in Quintana Roo, Mexico, Auk 107:539–543.
Lynch, J. F. 1989. Distribution of overwintering nearctic migrants in the Yucatan Peninsula. I: General patterns of occurrence. Condor 91:515–544.
Lynch, J. F. and D. F. Whigham. 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. Biol. Conserv. 28:287–324.
Myers, J. P., R. I. G. Morrison, P. Z. Antas, B. A. Harrington, T. E. Lovejoy, M. Sallaberry, S. E. Senner, and A. Tarak. 1987. Conservation strategy for migratory species. Amer. Scientist 75:19–26.
Myers, N. 1984. The primary source. Norton, NY. 399 pp.
———. 1989. Deforestation rates in tropical forests and their climatic implications. Friends of the Earth, London, England. 116 pp.
———. 1991. Tropical deforestation: The latest situation. BioScience 41:282.
National Research Council (U.S.), Committee on Sea Turtle Conservation. 1990. Decline of sea turtles, causes and prevention. Nat. Acad. Press, Washington, D.C. 259 pp.
Nowak, R. M. and J. L. Paradiso. 1983. Walker's mammals of the world. 4th ed., vol. I. John Hopkins Univ. Press, Baltimore, Maryland. 568 pp.
Orr, R. T. 1970. Animals in migration. Macmillan, NY. 303 pp.
Population Reference Bureau. 1991. 1991 World population data sheet. Population Reference Bureau, Washington, D.C.
Rappole, J. H., E. S. Morton, T. E. Lovejoy, and J. L. Ruos. 1983. Nearctic avian migrants in the neotropics. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C. 646 pp.
Robbins, C. S., J. R. Sauer, R. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. Proc. Natl. Acad. Sci. 86:7658–7662.
Salafsky, N., B. L. Dugelby, and J. W. Terborgh. 1992. Can extractive reserves save the rain forest? Conserv. Biol. in press.
Schreckenberg, K. and M. Hadley, eds. 1991. Economic and ecological sustainability of tropical rain forest management. MAB Digest 8. UNESCO, Paris. 100 pp.
Scott, D. A. and M. Carbonell, comps. 1986. A directory of neotropical wetlands. IUCN, Cambridge, England and IWRB, Slimbridge, England. 684 pp.
Selcraig, B. 1991. Costa Rica's lethal harvest. Internatl. Wildl. 21:21–24.
Senner, S. E. and M. A. Howe. 1984. Conservation of nearctic shorebirds. Behav. Marine Organisms 5:379–421.
Stiles, F. G. 1983. Checklist of birds. Pages 530–544 *in* D. H. Janzen, ed., Costa Rican natural history. Univ. Chicago Press, Chicago, IL. 816 pp.

Stiles, F. G. and A. F. Skutch. 1989. A guide to the birds of Costa Rica. Comstock, Ithaca, NY. 511 pp.

Terborgh, J. 1988. The big things that run the world—A sequel to E. O. Wilson. Conserv. Biol. 2:402–403.

———. 1989. Where have all the birds gone? Princeton Univ. Press, Princeton, NJ. 207 pp.

———. 1991. Diversity and the tropical rain forest. W. H. Freeman, NY. 242 pp.

Thiollay, J. M. 1981. Structure and seasonal changes of bird population (sic) in a desert scrub of northern Mexico. Pages 143–167 *in* R. Barbault and G. Halffter, eds., Ecology of the Chihuahuan desert. Inst. Ecologia, México, D. F. 167 pp.

Urquhart, F. A. and N. R. Urquhart. 1976. The overwintering site of the eastern population of the monarch butterfly (*Danaus p. plexippus*; Danaidae) in southern Mexico. J. Lepidopterists' Soc. 330:153–158.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of eastern deciduous forest. Pages 125–205 *in* R. L. Burgess and D. M. Sharpe, eds., Forest island dynamics in man-dominated landscapes. Springer-Verlag, NY. 310 pp.

Wilson, E. O. 1987. The little things that run the world (The importance and conservation of invertebrates). Conserv. Biol. 1:344–346.

———. 1988. The current state of biological diversity. Pages 3–18 *in* E. O. Wilson and F. M. Peters, eds., Biodiversity. Nat. Acad. Press, Washington, D.C. 521 pp.

Wilson, E. O. and F. M. Peter, eds. 1988. Biodiversity. Nat. Acad. Press, Washington, D.C. 521 pp.

Faunal Mixing, Faunal Integrity, and the Biopolitical Template for Diversity Conservation

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Introduction

Conservation biologists are striving to protect a diversity of habitats and species in the increasingly altered landscapes of North America, primarily by protecting samples of the biota in natural preserves. Information on species richness has repeatedly been offered as the foundation for planning acquisitions of land for natural preserves (Pickett and Thompson 1978, Miller and White 1986, Schonewald-Cox and Bayless 1986), and geographical patterns of faunal richness are currently being mapped to identify sites for acquisition (Scott et al. 1987). At many locations, however, local species assemblages have been augmented drastically by the addition of new species from contiguous or distant sites. Shifts in the composition of native biological diversity often go undetected in augmented faunas and, compounded regionally, such changes in composition can lead to declines in regionally unique (i.e., endemic) species. Unfortunately, augmented faunas are viewed by the public and local agency personnel as indicative of good wildlife conservation. In this paper, I define faunal mixing as a significant conservation issue and propose that future conservation of the faunal integrity of North America requires enhanced coordination among natural resource agencies.

A Simple Example: Urban Birds in the Desert

The avifaunas of deserts, such as the Sonoran Desert in southeastern Arizona, contain many species unique to the United States. Urbanization alters native landscapes, especially in deserts. The created landscapes of urbanized deserts are more akin to forest edge communities than to native associations. For example, the city of Tucson has grown to cover more than 400 km^2 since 1900. The consequences of urbanization of the desert landscape and its avian assemblage were described by Emlen (1974), who noted that 12 of the 21 indigenous species of the local desert fauna were absent from a residential urban area. The total number of individuals and total avian biomass increased 26 times in Tucson, with desert species representing only 5 percent of the individuals of that assemblage. The drastically augmented urban avifauna is 95 percent synthetic, reflecting primarily the domination of three native, alien species (inca dove [*Scardafella inca*], black-chinned hummingbird [*Archilochus alexandri*], and northern cardinal [*Cardinalis cardinalis*]) and two exotics from Europe (house sparrow [*Passer domesticus*] and European starling [*Sturnus vulgaris*]).

The Obvious Example: Exotics on Islands

Oceanic islands have held a special fascination for zoogeographers, who speculate freely about rates of organismal invasion and colonization. Contemporary faunas on islands, however, are more a prôduct of human meddling than of dispersal capabilities and survival rates of individual species.

An exotic, especially an exotic predator, on an island can disrupt a long-isolated fauna. Domestic cats (*Felis domesticus*) introduced on many oceanic islands and the contemporary spread of brown tree snakes (*Boiga irregularis*) across the South Pacific (Marshall 1985, Fritts 1988) are familiar examples. Besides exotic predators, the introduction of species for aesthetic or economic reasons has destroyed many island faunas. The import of species into an endemic fauna was particularly devastating to the Hawaiian Islands, where introduction of more than 150 species of birds since 1869 doubled the size of the island avifauna (Berger 1980).

Massive floral and faunal introductions into an island ecosystem like the Hawaiian Islands illustrate the ecological complexity that faunal mixing can interject into conservation issues (Ralph and van Riper 1985, Scott et al. 1987, Leopold and Mueller-Dombois 1989). Endemic island species account for 93 percent of all avian extinctions (King 1980) and 67 percent of documented plant and animal extinctions (351 of 518) in the United States since 1620 (Opler 1977). An astonishing 33 percent of native Hawaiian birds present in 1600 are extinct (Temple 1985) and another 27 species are currently listed as endangered or threatened on the islands (U.S. Fish and Wildlife Service 1989). Yet, one can argue that the created fauna of the Hawaiian Islands is arithmetically more diverse and more attractive today than ever in the past (Brown 1989). At present, the chances of conserving a semblance of a native Hawaiian fauna are dismal at best.

The Imposing Example: Aliens Across Continents

Mixing of continental biotas has been equally disastrous, but more subtle. Geographical ranges of species are constantly changing in response to climatic changes, evolution, major natural and anthropogenic disturbances, and inter-specific interactions. Rarely (e.g., Verner and Rothstein 1985), however, do biologists address the regional consequences to the native biotic assemblage of range expansions by species. The largest native vegetative climax in North America is the grasslands of the central plains, which cover $\sim 1.5x10^6$ km^2 (17 percent of the continent). Native Americans and early immigrants along the Oregon Trail saw a steppe (then called the "Great American Desert") with immense herds of grazing ungulates in a complex vertebrate assemblage including large predators, rodents, reptiles, and birds (generally adapted to conditions at differently grazed sites). The integrity of this biogeographic province has been greatly compromised with modern settlement (Knopf 1988). The eastern prairies, for example, are extensively plowed and fragmented by forests that were planted as wind shelters for homes, soils, and crops and to enhance wildlife habitats. As a result, many species of eastern forest birds now occur predictably on the eastern Great Plains (Anderson 1971, Martin 1981, Knopf 1986). The number of forest species expanding onto and across the plains far exceeds the few native prairie species such as the black-footed ferret (*Mustela nigrens*), gray wolf (*Canis lupus*), and mountain plover (*Charadrius montanus*) that are already extirpated or declining on the prairies.

Mixing of the continental fauna is most drastic where water management practices have encouraged vegetative succession on the steppe landscape. Riparian vegetation provides habitat for more vertebrate species than other vegetative associations in western North America (Knopf et al. 1988) and provides a dispersal corridor enabling vertebrates that use shrub and woodland habitats to move across watersheds (Knopf 1985). The anthropogenic development of riparian vegetation across the plains has resulted in many species moving westward (Knopf and Scott 1990). Virtually 90 percent of the 82 breeding bird species predictably present each spring on the steppe of eastern Colorado was not present in 1900 (Knopf 1986) and local communities are currently dominated by ecological generalists of forest edges (Finch 1989). The central Great Plains, which were a major isolating agent in speciation of North American forest birds during the last 10,000 years (Mengel 1970), has become a local showplace for conservation of forest birds in recent years (Knopf 1986). Water management practices have broadened local avifaunal diversity more profoundly and much faster (80–90 years) with subtle changes on the western Great Plains than centuries of active ''faunal meddling'' with the avifauna of the Hawaiian Islands.

Tempering Species Richness in Conservation Planning

The accelerated expansions of ranges of North American (and exotic) species has created faunas more diverse than historically present at most locales. Whether the invasions result in the substitution of a few species as in Arizona, a doubling of the fauna as on Hawaii, or the virtual creation of a new, rich fauna as in Colorado, faunal mixing is a dilemma for biologists dedicated to protecting the integrity of native, endemic faunas. This dilemma is the essence of the dichotomy between preserving the biological diversity of North America (''conservation biology'') and enhancing vertebrate populations (traditional wildlife management).

Traditional policies of natural resource agencies favor the spread of ecological-generalist species across landscapes. Most popular game species in North America are characteristic of early successional stages, and most respond favorably to the presence of vegetative edges (Leopold 1933). States are in charge of game management, but federal agencies such as the U.S. Forest Service and the Bureau of Land Management have historically joined states in designing vegetative conversions of native landscapes into habitats that favor target game species. With rising interest in the conservation of nongame species in the early 1970s, agencies realized that maximizing edges provide habitats for more species of wildlife than are common in unbroken forest landscapes (Hamilton and Noble 1975, Thomas et al. 1979, Strelke and Dickson 1980, Harris 1988). Thus, the development of ecotones to raise the number of species on a landscape was conveniently compatible with existing management objectives for many game species and other consumptive uses of public lands. Just as significant, enhancing species richness was proffered as the most economic approach to conservation of nongame because it did the most good for the most species with the fewest dollars.

Enhancing species richness through fragmentation in landscapes is no longer favored (Harris 1984, Wilcove 1988b) and growing evidence suggests that increasing the quantity of edge can harm, notably, the composition of bird communities (Robbins

1979, Ambuel and Temple 1983, Blake and Karr 1984). Species invading fragmented landscapes bring new biotic interactions into a local vertebrate assemblage (Brittingham and Temple 1983, Wilcove 1985, Small and Hunte 1988) and ultimately shift the composition of that assemblage. Area-sensitive bird species of eastern forests tend to be insectivorous, neotropical migrants of the forest interior (Whitcomb et al. 1981, Wilcove 1988a); declines of these species seem attributable more to changes in habitats on breeding grounds than in wintering areas (Holmes and Sherry 1988, Hutto 1988). Ecological consequences of such species substitutions are masked in management that focuses purely on species richness (Balda 1975, Verner 1986, Martin 1992). Loss of a stenotopic species goes undetected if a widely distributed, generalist species invades the area simultaneously. Contemporary research (Temple 1986, Robbins et al. 1989) is striving to define the forest patch size that provides habitats for viable populations of all species at a location, but field research is still focused primarily on single taxonomic groups. Ecologists rarely weigh the ecological value of viable species populations across taxonomic lines (e.g., a salamander versus an ungulate) which, when combined with an emphasis upon species richness within taxonomic lines, raises serious doubts about the scientific credibility of most of the literature on biological diversity (Hunt 1991).

In retrospect, the ecologist's fascination with the mathematical theory of local diversity measures (Pielou 1975) became divorced from the reality of conservation issues. Wiens (1977, 1983) argued that vertebrate communities are relatively disorganized assemblages of species driven by unpredictable, irregular events (i.e., "ecological crunches") rather than highly organized, interacting, stable entities as previously believed. This view of local faunas as dynamic assemblages rather than structured communities is the ecological paradigm for faunal mixing.

Confusion along Corridors

Landscape corridors, especially along streams, offer various ecological advantages to stream and upland faunas by modulating water and mineral nutrient fluxes, reducing sedimentation rates in streams, and providing strips of habitat for vertebrates to move across landscapes (Forman 1983). Management currently promotes the protection of corridors in landscape networks (Forman and Godron 1981, Hudson 1991). Corridors have been advocated to connect disjunct patches of available habitat to enhance population expansion and genetic mixing of the endangered Florida panther (*Felis concolor coryi*) (Simberloff and Cox 1987) and to raise local species richness of riparian birds in the Southwest (Johnson 1989).

Evidence from the Great Plains, however, indicates that emphasizing riparian corridors in a landscape network may confound conservation of unique species in a region. A riparian corridor across an entire watershed, such as the Platte River headwaters, facilitates dispersal of vertebrates as indicated by avian assemblages that are regionally twice as similar among riparian versus among upland sites (Knopf 1985). But because upland vegetative communities differ profoundly in areas of extreme topographic relief (as in much of western North America), birds from one upland community generally do not use riparian vegetation as a travel corridor to distant patches of habitat. A native steppe bird such as the grasshopper sparrow (*Ammodramus savannarum*) does not use the riparian forest as an avenue to new habitats in the montane shrub transition zone, nor will the green-tailed towhee (*Pipilo* *chlorurus*) move down from the shrub transitions into grasslands. Neither species uses riparian vegetation at all.

Of the bird species that crossed the Great Plains recently along the riparian corridor of the Platte River, the blue jay (*Cyanocitta cristata*) and brown thrasher (*Toxostoma rufum*) colonized new habitats along the Front Range—but those habitats are suburban, horticultural plantings, not native associations. Of mammals, the least shrew (*Cryptotis parva*) also moved to the Front Range (Armstrong 1972) where it occurs along irrigation ditches and canals with vegetative associations very similar to, and connecting with, riparian ecosystems. Riparian faunas are assemblages of primarily ecological generalists in highly linearized forests across a gradient (Knopf 1992). Rather than facilitate movement of native species to potential habitat patches, riparian corridors, in this case, fostered the ingress by species historically alien to the region. The uncritical promotion of corridors must be viewed as a threat to preserving the integrity of native faunas (Simberloff and Cox 1987), especially at larger spatial scales.

The Political Template for Faunal Mixing

Whereas management of game species has been the historical responsibility of the states and management of migratory birds the responsibility of the U.S. Fish and Wildlife Service, conservation of biological diversity is a relatively new charge to natural resource agencies. Dedicated, major funding for the conservation of nongame (and hence biological diversity) commenced with the Endangered Species Act of 1973 (16 U.S.C. 1531–1543; 87 Stat. 884, as amended). That act directs the U.S. Government to prevent future extinctions through (1) acquiring land, (2) conserving species and their habitats on federal lands, and (3) encouraging states to enact endangered species legislation by authorizing funds for allocation to individual states (Opler 1977). Federal support for nongame species that are not endangered, however, has been poor (Senner 1986, Myers 1989). The Fish and Wildlife Conservation Act of 1980 (commonly referred to as the "Nongame Act"), if it ever is funded, will allocate federal dollars directly to the states. Simultaneously, many states developed their own endangered species/nongame programs, often funded through income tax checkoffs (Cerulean and Fosburgh 1986). To generalize then, most funding decisions for conserving nongame species have been made primarily at the state level, or at least in compliance with state interests.

Returning to the continental riparian example, every state and federal management agency protects or enhances riparian areas on public lands in the West. The number of management offices for such authorities in even the small Platte River drainage can be staggering (Knopf and Scott 1990), with all enhancements being conducted irrespective of whether riparian areas are native to a locale and independent of the faunal mixing issue. Similarly, fragmentation of individual forests really was not recognized as a regional issue until resource specialists realized that entire regions were fragmented from identical practices in contiguous districts of a given forest (Harris 1984).

Endangered species programs have also favored faunal mixing at the continental level. This seeming paradox is easily illustrated with comparisons of the continental distributions of the endangered least Bell's vireo (*Vireo bellii pusillus*) versus the California thrasher (*Toxostoma redivivum*) and tricolored blackbird (*Agelaius tricolor*) in California (Figure 1) or the state endangered southern leopard frog (*Rana sphenocephala*) versus the eastern (Maryland) shrew (*Sorex fontinalis*) with an undetermined status in the Commonwealth of Pennsylvania (Figure 2). In both examples, conservation funding supports relatively widespread species on the edge of their continental range at the expense of regional endemics.

Many species targeted for protection under the Nongame and Endangered Species Acts are victims of the political structuring of conservation funding. Principles of landscape fragmentation apply equally well to fragmentation of conservation actions. Missing is a large-scale perspective of biological diversity for structuring conservation actions within and across biogeographic provinces. Simply stated, biological and political boundaries are askew (Figure 3). Political alignment of conservation decisions with biogeographic provinces (continental biodiversity) should be a primary charge of any national legislation or strategy to protect biological diversity.

Towards a Biological Template for Diversity Conservation

Ten years ago, Samson and Knopf (1982) proposed a direction for conservation of biological diversity by the wildlife management profession. Based on case studies in prairie and montane ecosystems, the authors advocated that the profession: (1) minimize practices promoting site-specific diversity (enhancements); (2) emphasize between-habitat diversity on management units; and (3) implement a step-down (national/regional/local) approach in conservation of biological diversity. The suggestion of an hierarchal approach to decisions, however, is mind boggling considering that many issues cross national, regional and local political boundaries.

One approach to better align management decisions with the conservation of biological diversity is to define regional boundaries of national agencies along the basic floristic provinces of North America (Figure 4). In the United States, every regional jurisdiction of the Fish and Wildlife Service and Forest Service encompasses at least two floristic provinces (Table 1), with the Fish and Wildlife Service's Region Two having responsibilities in 5 of the 10 provinces. Only 13 of the 48 conterminous states are in a single floristic province. Realignment of agencies would profoundly facilitate identification of endemic species and reduce the conflict between conservation of species at the periphery (population "sink") versus at the center (population "source") of their continental distribution. Because most species listed as Category

Figure 1. Continental distributions of Bell's vireo (top), California thrasher (middle), and tricolored blackbird (bottom). The least bell's vireo is an endangered subspecies in the Southwest.

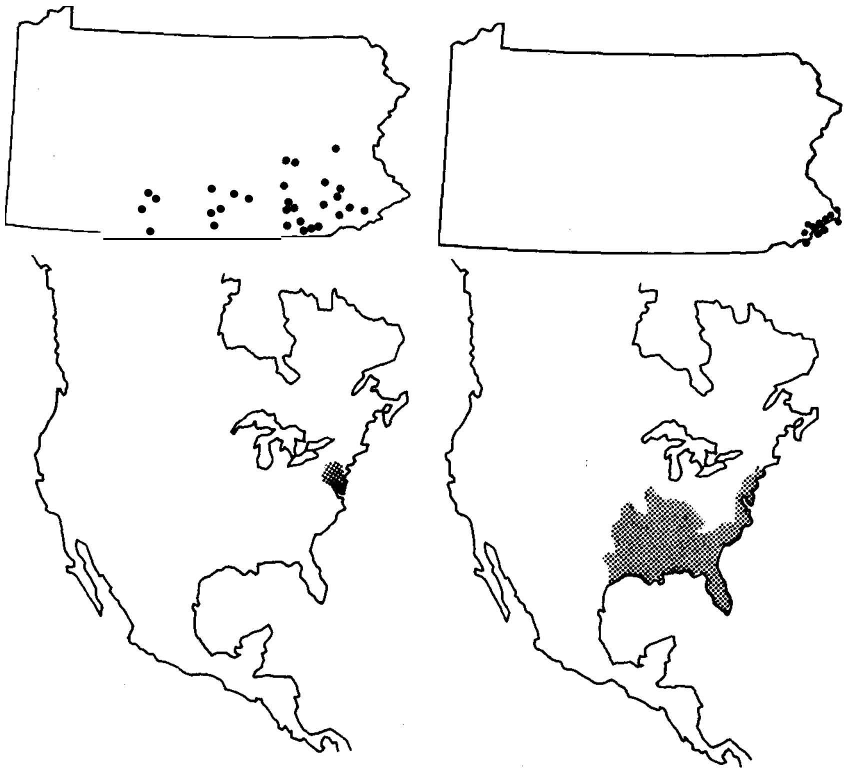

Figure 2. Comparative distributions of the eastern (Maryland) shrew (left) and southern leopard frog (right) in Pennsylvania and the eastern United States. The frog is listed as an endangered species in Pennsylvania, whereas the status of the shrew is "undetermined" (after Genoways and Brenner 1985).

I, Category II, and Threatened or Endangered under the Endangered Species Act are regional endemics, realignment along biogeographic provinces would assure incorporation of information on endemism (Gentry 1986) and, thereby, facilitate identification of species declining towards endangered status.

Aligning diversity conservation with floristic provinces, whether or not accompanied by major administrative reorganizations, demands an interagency forum for defining resource priorities. Such a forum has recently been developed by the North American Waterfowl Management Plan (U.S. Fish and Wildlife Service 1986), which provides a framework for recovery of declining waterfowl populations. A series of joint ventures provide a means for governments, private organizations, and individuals to cooperate in the planning, funding and implementation of projects to conserve waterfowl habitats and populations. The joint ventures, defined biogeographically, assure that the uniqueness of regional complexes is given priority in conservation actions. A "Biological Diversity Management Plan" is needed to provide a biogeographic template for a step-down process to conserve the faunal integrity of North America.

Figure 3. Relative distribution of major political as opposed to biogeographic boundaries of North America.

Given that the objective is to keep organisms from dropping out of ecosystems, conservation of biological diversity must complement the conservation of endangered species. The contribution of a few endangered species to species richness of a locale is negligible, yet endangered species tend to be the evolutionary endemics that make an entire biogeographic region unique when viewed at a continental scale. The current, fragmented approach to diversity conservation promotes the costly, crisis-oriented programs outlined by Ralls and Ballou (1992), while the number of species

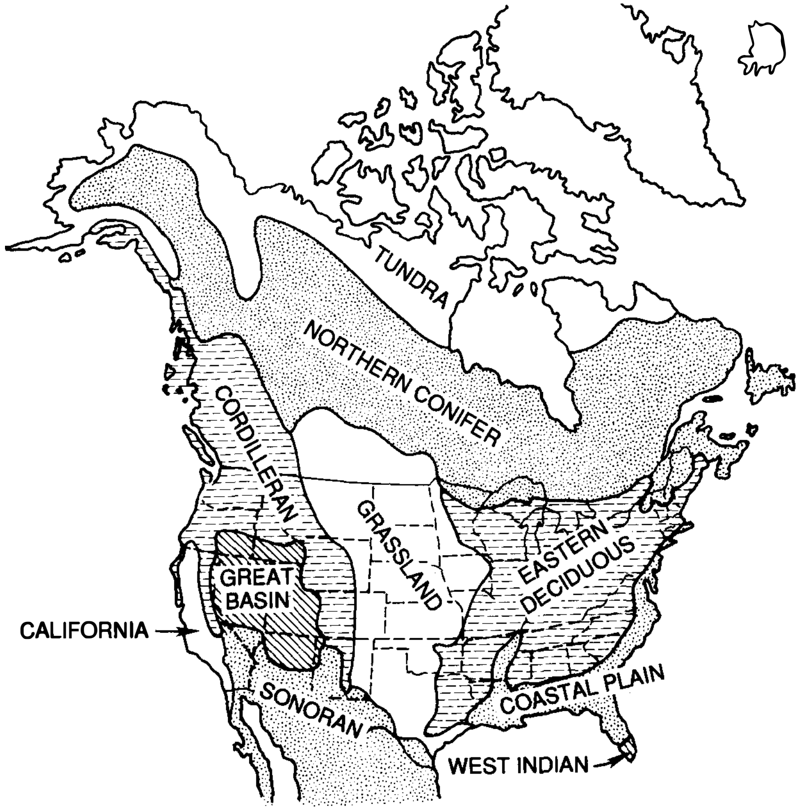

Figure 4. Spatial distribution of the ten floristic provinces of the continental United States and Canada (after Gleason and Cronqist 1964).

Table 1. Number of floristic provinces represented in each of the regional jurisdictions of the U.S. Fish and Wildlife Service and U.S. Forest Service.

Agency region	Floristic provinces	
	Fish and Wildlife Service	Forest Service
1	4	2
2	5	2
3	3	3
4	3	2
5	2	2
6	3	2
7	2	
8		3
9		4
10		2

being upgraded towards endangered status rapidly outstrips the number being delisted. One of their examples was the black-footed ferret, an associate of prairie dog (*Cynomys spp.*) communities in prairie ecosystems. Successful captive breeding of ferrets led to the initial attempts at reintroduction in 1991. This costly endangered species effort, however, ignores the fact that prairie dog populations have declined 98 percent (Marsh 1964) continentally and that three additional faunal endemics (ferruginous hawk [*Buteo regalis*], mountain plover, and swift fox [*Vulpes velox*] associated with prairie dogs are now declining towards threatened or endangered status. Focusing on prairie dogs as regional, keystone species (Simberloff 1988) can provide positive benefits to the conservation of biological diversity (Miller et al. 1990), including four regional endemics, one of which is currently managed at the genetic level of biological resolution. Biogeographic alignment of diversity conservation will bring endangered species issues into a step-down framework that will favor identification of declining endemic species in a proactive, cost-improved effort.

Summary

Despite the extinction of many species and a general decline in the biological diversity of North America, many local faunas contain more species today than historically. Exotic introductions and range expansions of species into altered landscapes have drastically augmented local species richness. Active management of game species and reliance on simplistic information about species richness for nongame conservation continues to encourage faunal mixing at all scales—as will the current emphasis on landscape corridors as a tool to enhance genetic diversity and increase numbers in local populations. The template for faunal mixing, however, is the political structuring of conservation action. The conservation of native biological diversity is a task bigger than agency jurisdictions, and the current trend towards cosmopolitan faunas at the expense of endemic species will continue until information and decisions about biological diversity conform to biogeographic, rather than political, provinces. A series of biogeographically defined joint ventures working across natural resource administrative agencies is proposed to provide a continental, step-down decision process for conserving the faunal integrity of North America.

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References

Ambuel, R. and S. A. Temple. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology 64:1057–1068.

Anderson, B. W. 1971. Man's influence on hybridization in two avian species in South Dakota. Condor 73:34.

Armstrong, D. M. 1972. Distribution of mammals in Colorado. Kansas Mus. Nat. Hist. Mono. 3. Lawrence. 415 pp.

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59–80 *in* D. R. Smith, techn. coord., Symposium on management of forest and range habitats for nongame birds. USDA For. Serv. Gen. Techn. Rept. WO-1.

Berger, A. J. 1980. Hawaiian birdlife. Second edition. Univ. Press Hawaii, Honolulu.

Brittingham, M. C. and S. A. Temple. 1983. Have cowbirds caused forest songbirds to decline? BioScience 33:31–35.

Brown, J. H. 1989. Patterns, modes, and extents of invasions by vertebrates. Pages 85–109 *in* J. A. Drake et al., eds., Biological invasions: A global perspective, John Wiley & Sons Ltd., Somerset, NJ.

Cerulean, S. and W. Fosburgh. 1986. State nongame wildlife programs. Pages 630–656 *in* R. L. DiSilvestro, ed., Audubon Wildl. Rept. Nat. Audubon Soc. New York, NY.

Emlen, J. T. 1974. An urban bird community in Tucson, Arizona: Derivation, structure, and regulation. Condor 76:184–197.

Finch, D. M. 1989. Habitat use and habitat overlap of riparian birds in three elevational zones. Ecology 70:866–880.

Forman, R. T. T. 1983. Corridors in a landscape: Their ecological structure and function. Ekologia (CSSR) 2:375–387.

Forman, R. T. T. and M. Godron. 1981. Patches and structural components for a landscape ecology. BioScience 31:733–740.

Fritts, T. H. 1988. The brown tree snake, *Boiga irregularis*, a threat to Pacific Islands. U.S. Fish and Wildl. Serv. Biol. Rept. 88(31).

Genoways, H. H. and F. J. Brenner. 1985. Species of special concern in Pennsylvania. Carnegie Mus. Nat. Hist. Spec. Publ. No. 11. Pittsburgh, PA.

Gentry, A. H. 1986. Endemism in tropical versus temperate plant communities. Pages 153–181 *in* M. E. Soulé, ed., Conservation Biology, Sinauer Assoc., Inc., Sunderland, MA.

Gleason, H. A. and A. Cronquist. 1964. The natural geography of plants. Columbia Univ. Press, New York, NY.

Hamilton, R. B. and R. E. Noble. 1975. Plant succession and interactions with fauna. Pages 96–114 *in* D. R. Smith, techn. coord., Symposium on management of forest and range habitats for nongame birds. USDA For. Serv. Gen. Tech. Rept. WO-1.

Harris, L. D. 1984. The fragmented forest. Univ. Chicago Press, Chicago, IL.

———. 1988. Edge effects and conservation of biotic diversity. Cons. Biol. 2:330–332.

Holmes, R. T. and T. W. Sherry. 1988. Assessing population trends of New Hampshire forest birds: Local vs. regional patterns. Auk 105:756–768.

Hudson, W. E. 1991. Landscape linkages and biodiversity. Island Press, Covelo, CA. 196 pp.

Hunt, L. O. 1991. Forestry word games: bi•o•di•ver•si•ty. J. Forestry 89(6):39.

Hutto, R. L. 1988. Is tropical deforestation responsible for the reported declines in neotropical migrant populations? Am. Birds 42:375–379.

Johnson, A. S. 1989. The thin green line: Riparian corridors and endangered species in Arizona and New Mexico. Pages 35–46 *in* G. Mackintosh, ed., Preserving communities and corridors. Defenders of Wildlife, Washington, D.C.

King, W. B. 1980. Ecological basis of extinctions in birds. Acta Intern. Ornithol. Congr. 17:905–911.

Knopf, F. L. 1985. Significance of riparian vegetation to breeding birds across an altitudinal cline. Pages 105–111 *in* R. R. Johnson, C. D. Ziebell, D. R. Pattern, P. F. Ffolliot, and R. H. Hamre, techn. coords., Riparian ecosystems and their management: Reconciling conflicting uses. USDA For. Serv. Gen. Tech. Rept. RM-120.

———. 1986. Changing landscapes and the cosmopolitism of the eastern Colorado avifauna. Wildl. Soc. Bull. 14:132–142.

———. 1988. Conservation of steppe birds in North America. Intern. Counc. Bird Preserva. Tech. Publ. 7:27–41.

———. 1992. Conservation of avian diversity in riparian corridors. Bird Cons. 4: In press.

Knopf, F. L. and M. L. Scott. 1990. Altered flows and created landscapes in the Platte River headwaters, 1840–1990. Pages 47–70 *in* J. M. Sweeney, ed., Management of dynamic ecosystems. N. Cent. Sec. The Wildl. Soc., West Lafayette, IN.

Knopf, F. L. R. R. Johnson, T. Rich, F. B. Samson, and R. C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Wilson Bull. 100:272–284.

Leopold, A. 1933. Game management. Charles Scribner Sons, NY.

Marsh, R. E. 1964. Ground squirrels, prairie dogs and marmots as pests on rangelands. Pages 195–

208 in Proc. Conf. Organiza. and Practice Vert. Pest Control. ICI Plant Protection Div., Fernhurst, England.
Marshall, J. T. 1985. Special conservation review. Guam: A problem in avian conservation. Wilson Bull. 97:259–262.
Martin, T. E. 1981. Limitation in small habitat islands: Chance or competition. Auk 98:715–734.
———. 1992. Landscape diversity and biological diversity. Trans. N. Am. Wildl. and Nat. Resour. Conf. 57:current volume.
Mengel, R. M. 1970. The North American Central Plains as an isolating agent in bird speciation. pages 280–340 *in* W. Dort and J. K. Jones, eds., Pleistocene and recent environments of the central Great Plains. Univ. Kansas Press, Lawrence.
Miller, B., C. Wemmer, D. Biggins, and R. Reading. 1990. A proposal to conserve black-footed ferrets and the prairie dog ecosystem. Environ. Manage. 14:763–769.
Miller, R. I. and P. S. White. 1986. Considerations for preserve design based on the distribution of rare plants in Great Smokey Mountain National Park, USA. Environ. Manage. 10:119–124.
Myers, J. P. 1989. Nintendo and other birds. Amer. Birds 43:7–9.
Opler, P. A. 1977. The parade of passing species: A survey of extinctions in the U.S. Sci. Teacher 44(1).
Pickett, S. T. A. and J. N. Thompson. 1978. Patch dynamics and the design of nature reserves. Biol. Cons. 13:27–37.
Pielou, E. C. 1975. Ecological diversity. John Wiley & Sons, NY.
Ralls, K. and J. D. Ballou, 1992. Managing for genetic diversity in captive breeding and reintroduction programs for endangered species. Trans. N. Am. Wildl. and Nat. Resour. Conf. 57:current volume.
Ralph, C. J. and C. van Riper, III. 1985. Historical and current factors affecting Hawaiian native birds. Bird Cons. 2:7–42.
Robbins, C. S. 1979. Effects of forest fragmentation bird populations. Pages 198–212 *in* R. M. DeGraaf and K. E. Evans, eds., Management of north central and northeastern forests for nongame birds. USDA For. Serv. Gen. Tech. Rept. NC–51.
Robbins, C. S., D. K. Dawson, and B. A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic States. Wildl. Monogr. 103:1–34.
Rosenberg, K. V., S. B. Terrill, and G. H. Rosenberg. 1987. Value of suburban habitats to desert riparian birds. Wilson Bull. 99:642–654.
Samson, F. B. and F. L. Knopf. 1982. In search of a diversity ethic for wildlife management. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:421–431.
Schonewald-Cox, C. M. and J. W. Bayless. 1986. The boundary model: A geographical analysis of design and conservation of nature reserves. Biol. Cons. 38:305–322.
Scott, J. M., B. Csuti, J. D. Jacobi, and J. E. Estes. 1987. Species richness: A geographic approach to protecting future biological diversity. BioScience 37:782–788.
Senner, S. E. 1986. Federal research on migratory nongame birds: Is the United States Fish and Wildlife Service doing its job? Am. Birds 40:413–417.
Simberloff, D. 1988. The contribution of population and community biology to conservation science. Annu. Rev. Ecol. and Syst. 19:473–511.
Simberloff, D. and J. Cox. 1987. Consequences and costs of conservation corridors. Cons. Biol. 1:63–71.
Small, M. F. and M. L. Hunter. 1988. Forest fragmentation and avian nest predation in forested landscapes. Oecologia 76:62–64.
Soulé, M. E. 1986. Conservation biology. Sinauer Associates, Inc., Sunderland, MA.
Strelke, W. K. and J. G. Dickson. 1980. Effect of forest clear-cut edge on breeding birds in east Texas. J. Wildl. Manage. 44:559–567.
Temple, S. A. 1985. Why endemic island birds are so vulnerable to extinction. Bird Cons. 2:3–6.
———. 1986. Predicting impacts of habitat fragmentation on forest birds: A comparison of two models. Pages 301–304 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds., Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.
Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Edges. Pages 48–59 in J. W. Thomas, tech. ed., Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington, USDA For. Serv. Handbook 553. Washington, D.C.
U.S. Fish and Wildlife Service. 1986. North American Waterfowl Management Plan. Washington, D.C.
———. 1989. Endangered & threatened wildlife and plants. 50 Congr. Fed. Reg. 17.11.

Verner, J. 1986. Predicting effects of habitat patchiness and fragmentation—the researcher's viewpoint. Pages 327–329 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds., Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

Verner, J. and S. I. Rothstein. 1985. Implications of range expansion into the Sierra Nevada by the parasitic Brown-headed Cowbird. Pages 92–98 *in* N. D. Bradley, ed., State of the Sierra Symposium. Pacific Publ. Co., San Francisco, CA.

Ward, D. B. 1990. How many plant species are native to Florida. The Palmetto 9(4):3–5.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125–205 *in* R. L. Burgess and D. M. Sharpe, eds., Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York, NY.

Wiens, J. A. 1977. On competition and variable environments. Am. Sci. 65:590–597.

———. 1983. Avian community ecology: An iconoclastic view. Pages 355–403 *in* A. H. Brush and G. A. Clark, Jr., ed., Perspectives in ornithology. Cambridge Univ. Press, Cambridge, England.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211–1214.

———. 1988a. Changes in the avifauna of the Great Smokey Mountains: 1947–1983. Wilson Bull. 100:256–271.

———. 1988b. National forests. Policies for the future. Protecting biological diversity, vol. 2. Wilderness Soc. Washington, D.C.

Special Session 6. *Biological Diversity in Aquatic Management*

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Opening Remarks

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Concern for the loss of species and habitats traditionally has focused on diverse terrestrial ecosystems, such as rain forests. Seldom has our attention concentrated on loss of biodiversity in aquatic environments. Perhaps this is because freshwater and marine habitats are more foreign to the human species, and what is out of sight remains out of mind.

In the past few years, however, our concern for the health of aquatic systems has been reawakened. Reports by the American Fisheries Society have shown a 45 percent increase during the past decade in the number of rare freshwater fishes in North America. Major losses of genetic diversity in stocks of West Coast salmon and steelhead have become apparent and have fueled recent listings of salmon populations as endangered or threatened, pursuant to the Endangered Species Act. As with the freshwater mussels, of which 40 percent of North American species are endangered or candidates for federal protection, many species of aquatic invertebrates now are threatened with extinction. According to a report by The Nature Conservancy, species of aquatic animals, from fish to crayfish, are at a much greater risk of extinction in North America than are terrestrial species.

The many problems associated with introductions of non-native species also have focused attention on the aquatic environment. The rapid spread of zebra mussels throughout the Great Lakes, and now into the Mississippi River basin, has heightened our awareness of how quickly introduced species can spread throughout the many interconnected lakes and rivers in North America. In numerous aquatic habitats from the Colorado River to the Great Lakes, introduced species have taken over from native species and now dominate the fauna. Accidental and deliberate introductions of non-native species continue unabated in many areas.

In the following papers, we hope to strengthen interest and concern for the fate of the myriad species in aquatic systems. These papers were presented on March 31, 1992, at a special session of the 57th North American Wildlife and Natural Resources Conference in Charlotte, North Carolina. The purposes of this session were to provide a current review of the status of aquatic resources in marine and freshwaters of North America, discuss the causal factors responsible for the declines, and suggest new management strategies to reverse the loss of our aquatic heritage. The session was cosponsored by the American Fisheries Society and the Wildlife Management Institute.

Introducing the Elements of Biological Diversity in the Aquatic Environment

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Introduction

The aquatic ecosystems of North America contain a rich diversity of flora and fauna that are products of the geologic and evolutionary processes on this continent. This biological diversity, defined as the variety and variability among living organisms and the ecological complexes in which they occur (Office of Technology Assessment 1987), has been under increasing pressure as human population growth and expansion continue to change and degrade the natural landscape. The destruction and modification of biological communities and their habitats have reached crisis proportions here and worldwide, such that the conservation and protection of species and habitats have become major issues facing natural resource managers.

Traditional approaches to preserving wild areas, such as existing national park and wilderness areas, are insufficient to conserve biological diversity. The amount of land protected by national park systems is relatively small, 4.1 percent in the United States and 1.8 percent in Canada. Furthermore, most existing refuges are designed for terrestrial systems and seldom serve the needs of aquatic species, especially those of riverine habitats (Williams 1991). It has become increasingly clear that natural resource specialists must turn to other federal and private lands in their efforts to maintain biological diversity. Yet, many of these areas are managed primarily for commodity production, such as timber, beef or crops.

Maintenance of biological diversity is such an overwhelming task that the effort to sustain communities and ecosystems seems hopeless in the face of advancing civilization (Hunter et al. 1988). We see frequent changes in our hometown landscapes and their waterways resulting from housing developments, shopping malls, roadways and other baggage carried along with economic development. To reflect on this "progress" on a national or global scale is to plunge to depths of despair, particularly for biologists commissioned to conserve and enhance the fish and wildlife resources of states, provinces or countries.

Despite the enormity of the task facing resource managers, it is here in North America that many of the world's best opportunities for protection of biological diversity remain. Large tracts of relatively undisturbed land persist in Canada and Alaska. Approximately 34 percent of the United States is managed by federal agencies, which are influenced by some of the strongest and most progressive resource protection laws, such as the Endangered Species Act, National Environmental Policy Act and Clean Water Act. Furthermore, the general public has demonstrated an increasingly strong interest and concern for environmental issues, resource conservation, and expanding our "ethical community" to non-human species and ecosystems (Nash 1989).

In this paper, we propose to describe briefly the elements of biological diversity in aquatic ecosystems of North America and set the stage for more detailed and descriptive reviews of fauna and habitats in subsequent papers. Our overview will summarize the status of freshwater animals, environmental threats, and discuss the need for information and strategies to protect aquatic ecosystems and their myriad species, primarily in the United States.

Invertebrate Diversity

An exhaustive listing of all freshwater invertebrate groups in North America would require a small tome, because all major phyla of invertebrates, except Echinodermata, have freshwater representatives. The range of complexity, ecology and size, from protozoans to crayfishes, provides evidence of the adaptability of these taxa and their success in North America. Riverine ecosystems account for the highest diversity among aquatic faunal groups of all habitat types because they are more permanent in ecological and evolutionary time scales than most lakes. Typically, a greater heterogeneity of habitats and their associated niches promote the high diversity and ecological complexity recorded in rivers.

Thorp and Covich (1991) estimated the diversity of aquatic invertebrates to be more than 10,000 species within North America, north of Mexico. The diverse, but less well-known, tropical fauna in Mexico would undoubtedly push the total diversity estimate to 20,000 or more species. Compilation of a complete list of species within invertebrate phyla in North America is not yet possible because of several poorly studied phyla of lower invertebrates and such diverse taxa as the midges (Chironomidae) and aquatic beetles (Coleoptera). New species are described annually, and a total head count probably never will be complete.

As judged by the textbooks of Merritt and Cummins (1984), Thorp and Covich (1991), Pennak (1989), and taxon-specific publications (e.g., Bowman and Abele 1982, Turgeon et al. 1988, Burch 1989), the total diversity of identified freshwater invertebrates in North America is approaching 15,000 species. Taxa of the better-studied and larger macroinvertebrates account for nearly 12,600 species, with insects dominating all freshwater systems (Table 1). Although only 3 percent of insects have aquatic or semi-aquatic life stages, representatives of 13 orders reside in aquatic habitats. The insect fauna is dominated by true flies (4,665), beetles (1,640) and caddisflies (1,340), with the other 10 orders contributing roughly 27 percent of the total species. Mollusks are diverse in this north temperate region, and rank among the richest globally (Burch 1989). The freshwater mussels (Unionidae), with 297 species and subspecies in North America (Turgeon et al. 1988), are more speciose on this continent than anywhere else in the world. Other taxa, such as river snails (Pleuroceridae), are particularly diverse, reflecting the geological age and isolation of rivers, particularly in the southeastern United States. Springsnails (Hydrobiidae) are surprisingly diverse in the West and have remained largely unknown until recently

Table 1. Approximate number of species of native freshwater macroinvertebrates in North America, exclusive of Mexico.

Taxon	Number of species[a]
Insecta	
Diptera	4,665
Coleoptera	1,640
Trichoptera	1,340
Lepidoptera	635
Ephemeroptera	575
Plecoptera	550
Odonata	415
Hemiptera	410
Hymenoptera	55
Orthoptera	50
Megaloptera	45
Collembola	30
Neuroptera	10
Crustacea	
Decapoda	335
Ostracoda	300
Copepoda	210
Amphipoda	150
Cladocera	140
Isopoda	130
Eubranchiopoda	70
Mysidacea	5
Mollusca	
Gastropoda	500
Bivalvia	320
Total	12,580

[a]Numbers rounded upward to nearest five species.

(Hershler and Sada 1987, Hershler and Landye 1988, Hershler 1989). Although 90 percent of the subphylum Crustacea are marine, the roughly 10 percent in freshwater are extremely important as prey, predators and detritus processors for nutrient recycling. The benthic and planktonic biomass in many lakes often is dominated by this faunal group (Wetzel 1975).

Vertebrate Diversity

Although fishes are the dominant vertebrates in freshwater, they are not alone. Representatives of all major vertebrate groups, including mammals and birds, occur in aquatic habitats. The herpetofauna is well-represented in the freshwater of North America north of Mexico by 179 native species of amphibians (Smith 1978) and 42 species of turtles (Ernst and Barbour 1972), plus lesser numbers of snakes and crocodilians.

Defining the southern boundary of North America at the southern range of the family Cyprinidae (Rio Misantla in Veracruz and Rio Verde in Oaxaca), Williams and Miller (1990) listed 1,033 species of fishes native to the freshwaters of the continent. These species occur in 51 families and 19 orders. The most diverse families are the minnows (Cyprinidae; 272 species), perches (Percidae; 146), suckers (Catostomidae; 68), killifishes (Cyprinodontidae; 65), livebearers (Poeciliidae; 63), bullhead catfishes (Ictaluridae; 47), salmon and trout (Salmonidae; 47), Mexican livebearers (Goodeidae; 38), and sunfishes (Centrarchidae; 35). Excluding that portion of Mexico encompassed by Williams and Miller (1990), the North American freshwater ichthyofauna includes about 800 species, 790 of which occur in the United States (Page and Burr 1991).

There are vast differences in the distribution of freshwater fishes across North America. Alaska and Canada, while comprising well over half of the land mass, contain only 19 percent of the native freshwater fishes (Briggs 1986). The most diverse fish fauna is found in the geologically stable Mississippi Basin, where the Cyprinidae, Percidae, Catostomidae, Ictaluridae and Centrarchidae predominate. The West contains only about one-fourth as many species as eastern North America, but the fauna is characterized by high levels of endemism (Smith 1981). As with freshwater invertebrates, riverine habitats generally contain a greater diversity of fishes than do lake or pond habitats.

Conservation Status of the Aquatic Fauna

The list of aquatic invertebrates and vertebrates that are federally protected or under consideration for protection (candidates) continues to increase and now totals more than 1,000 taxa (Table 2). Our knowledge of the true status (population sizes, trends and threats) of many invertebrates is so fragmentary that some candidate species are probably undeserving of consideration whereas other species are in jeopardy of extinction but go unrecognized. As judged by the list of rare species, the seemingly better known taxa, such as fishes and mollusks, are those with the higher percentages of protected and candidate species. Of the nearly 790 species of freshwater fishes in the United States (Page and Burr 1991), 260 (33 percent) have been identified as rare. For all of North America, Williams and Miller (1990) considered 28 percent of the native fishes found in freshwaters to be rare or extinct. For mollusks, 325 (40 percent) of the 820 species are federally listed or candidates for protection. Thus,

Table 2. Federally endangered, threatened and candidate species in freshwater ecosystems of the United States.

Taxon	Endangered	Threatened	Candidate[a]	Total
Reptiles	3	4	17	24
Amphibians	6	5	60	71
Fishes	53	34	173	260
Mollusks	46	8	271	325
Insects	13	9	201	223
Crustaceans	8	2	124	134
Total				1,037

[a]Federal Register 56 (225), November 1991.

the numbers of invertebrate species deserving of protection likely are many more than what has been acknowledged.

The North American fish fauna has exhibited significant declines, especially since the 1960s. The number of North American freshwater fishes considered to be endangered, threatened or of special concern by the American Fisheries Society (AFS) has increased from 251 taxa to 364 (+45 percent) during the past decade (Williams et al. 1989). Only 7 of the 251 fishes included in AFS's 1979 list improved enough to be upgraded in the 1989 list. None of the fish improved in status enough to warrant complete removal from the list. In general, the status of aquatic species in the United States appears to be deteriorating faster than that of terrestrial species (Figure 1). Of 221 federally endangered and threatened species with approved recovery plans, only 4 percent of the aquatic species demonstrate an improving trend, according to a report to Congress by the U.S. Fish and Wildlife Service (1990) and 27 percent are stable, whereas 20 percent of the listed terrestrial species are improving and 36 percent are stable. The present status trend of 24 percent of the listed aquatic species is unknown compared with 11 percent for terrestrial species. At least 40 freshwater fishes have become extinct in North American during the past century, 15 (38 percent) of these since 1970 (Miller et al. 1989).

Threats to Aquatic Faunas in the United States

Environmental threats to aquatic communities, habitats and their functional organization (biological integrity) are as varied as the ecosystems themselves. Coblentz (1990) identified three general categories of anthropogenic perturbations: resource misuse, pollution and exotic species. For the first category, activities such as channelization, water withdrawals, dam construction and other projects that change the natural course, water quantity or habitat suitability for native species are proven threats. Dams have significantly altered faunal assemblages nationwide. The impoundment of the Tennessee River and its major tributaries, which contain 224 native fish taxa and 32 endemic taxa, began in 1936 and resulted in 36 multi-purpose dams

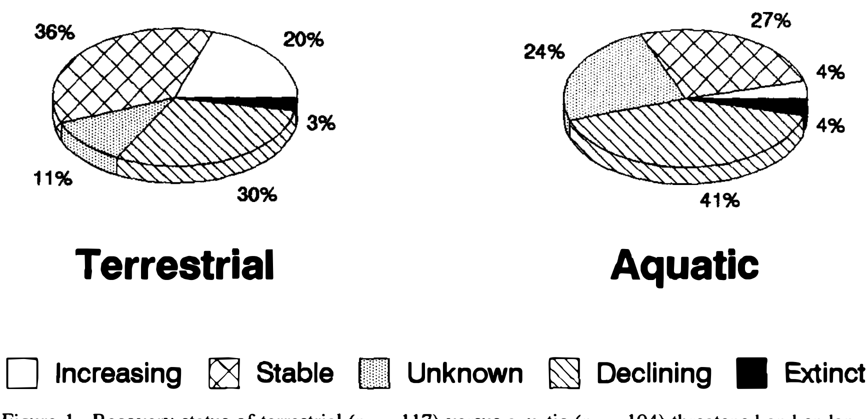

Figure 1. Recovery status of terrestrial (n = 117) versus aquatic (n = 104) threatened and endangered species in the United States. Only those species with approved recovery plans are included (data from U.S. Fish and Wildlife Service 1990).

that eliminated essential habitat for riverine species. Nearly 40 percent of the largest waterways and their associated fauna has been affected by dams (Neves and Angermeier 1990). Downstream tailwaters and upstream reservoirs have been colonized by fewer indigenous species and more introduced species. Similar effects were reported in the Colorado River basin, where 74 percent of native fishes are endemic (Miller 1958). Declines in natives were attributed to high dams with resultant reservoirs and cold tailwaters unsuitable for reproduction of indigenous species. The dam construction era has peaked, but the filling of reservoirs with sediment will create an entirely new set of environmental problems in the next century.

Water pollution problems have plagued us since European settlement and have become progressively worse during this century. Creation of the Environmental Protection Agency in 1970 solidified an environmental improvement policy through the implementation of environmental control legislation. With more than a dozen federal statutes that directly or indirectly relate to aquatic pollution, the tools became available to significantly reduce water quality problems. However, many of society's activities in agriculture, industry and urbanization tend to degrade the biological integrity of aquatic resources, resulting in communities and ecosystems of low resource value (Karr and Dudley 1981). Surveys conducted jointly by the U.S. Environmental Protection Agency and the U.S. Fish and Wildlife Service indicated that degradation of aquatic resources is extensive; 81 percent of fish communities in streams are adversely affected by environmental degradation (Judy et al. 1984). Fisheries experts reported that fish communities in most of our rivers were adversely affected by water withdrawals, reduced water quality and habitat degradation. A nationwide inventory of rivers concluded that only 2 percent of waterways in the conterminous United States are of sufficient quality to justify consideration as a national wild or scenic river (Benke 1990).

The establishment of standards for acceptable effluent discharges and the host of criteria used to identify safe levels of toxicants for release to receiving waters are noteworthy. However, enforcement of federal and state regulations has become a keystone factor in the war on pollution. Too often, the more subtle and insidious effects of nonpoint source pollution from surrounding watersheds, and cumulative impacts of both point and nonpoint problems, go unnoticed by all but the resident fauna. A recent assessment by the U.S. Environmental Protection Agency (1990) indicated that roughly 70 percent of waters provide full beneficial uses, such as drinking water, contact recreation and support of fisheries (Table 3). Limitations or losses of use are caused primarily by siltation, nutrient overload and fecal coliform bacteria. The probable sources of water quality problems for aquatic fauna in streams are principally nonpoint pollution (38 percent), agriculture (30 percent), natural sources (20 percent) and point source pollution (12 percent) (Judy et al. 1984). Recent protocols calling for assessments of biological integrity using such tools as the index of biotic integrity (IBI) with fishes, and the rapid bioassessment protocol (RBP) with invertebrates and fishes, have provided states with a practical means of conducting cost-effective biological assessments of lotic systems (Plafkin et al. 1989, Karr 1991). The trend toward using aquatic communities to define environmental health further strengthens the argument to maintain biological diversity so as to provide standards to evaluate degrees of degradation.

The introduction of non-native aquatic organisms has been so widespread in North America that few natural communities remain unaffected by these species. Negative

Table 3. Assessment of water quality in the conterminous 48 states, territories and jurisdictions of the United States (from U.S. Environmental Protection Agency 1990).

Type of waterbody (percentage assessed)	Beneficial uses (percentage)	Leading causes of degradation (percentage)	Leading sources of degradation (percentage)
Rivers (45)	Full (70)	Siltation (42)	Agriculture (55)
	Partial (20)	Nutrients (27)	Municipal discharge (16)
	None (10)	Fecal coliforms (19)	Habitat modification (13)
Lakes (73)	Full (74)	Nutrients (49)	Agriculture (58)
	Partial (17)	Siltation (25)	Habitat modification (32)
	None (9)	Organics/low DO (25)	Storm sewers/runoff (28)
Estuaries (76)	Full (72)	Nutrients (50)	Municipal discharge (53)
	Partial (22)	Pathogens (48)	Resource extraction (34)
	None (6)	Organics/low DO (29)	Storm sewers/runoff (28)

effects from introductions include displacement of natives through competition, extirpation through predation or disease, and reduction in biodiversity through habitat degradation or change. The greatest problem created by exotics, however, is their persistence in ecological time once they become established. Some exotics have been eradicated or controlled in isolated waterbodies, but the vast majority are uncontrollable (Courtenay and Stauffer 1984). Witness the recent incidental invasion of the zebra mussel (*Dreissena polymorpha*) into the Great Lakes in 1985, and its economic and eventual biological repercussions to that region. Its present expansion into the Mississippi River drainage and then continent-wide will proceed rapidly until its physiological tolerance to environmental conditions sets the boundaries to its distribution. The spread of the asian clam (*Corbicula fluminea*), first discovered in the Columbia River in 1938, also occurred rapidly. It saturated Pacific Coast rivers in the 1940s, reached the Mississippi River system in the 1950s, and now resides in most rivers throughout the southern half of the United States. In some western regions, aquatic communities are dominated by non-native species. Non-native fish stockings and habitat modification have caused most native species to disappear from reservoirs, but, surprisingly, riverine areas also are affected. Only 8 of 28 fish species collected from the Colorado River in Cataract Canyon (Canyonlands National Park) were native (Valdez and Williams 1991). Of 108 species of fishes now known from Nevada, 63 (58 percent) have been introduced (Deacon and Williams 1984). The economic costs of some introduced species, such as the zebra mussels, are becoming known, but the biological costs to indigenous communities and ecosystems are even greater (Minckley and Deacon 1991).

Introduction of the opossum shrimp (*Mysis relicta*) to lakes and reservoirs beyond its native range provides a classic example of an inadequately planned intentional introduction (Nesler and Bergersen 1991). This species was introduced in the 1960s and 1970s throughout the western United States and Canada to improve coldwater fisheries. Subsequent evaluations have documented that this planktivorous predator has out competed gamefish for cladocerans, caused the extirpation of *Daphnia* species and contributed to the collapse of other populations of large cladocerans. The consensus of two symposia on this species was that introductions of *M. relicta* were a mistake, likely to be repeated without careful scrutiny of its complete life history and predatory habits. Similar warnings have been echoed for the introduction of non-native crayfishes, which can distribute new parasites and possibly act as vectors for virulent fish diseases such as IPN or IHN (Unestam 1975).

Conclusions

Although protection of biological diversity is now the rallying cry of conservation biologists, it is the maintenance of biological integrity of communities in lakes and river systems that will sustain the diversity and productivity of our aquatic environments. The preservation of biological integrity has been explicitly identified in federal water quality legislation since the Water Pollution Control Act of 1972 and provides an appropriate goal for regulations intended to protect aquatic ecosystems. Conservation strategies at the species level cannot sustain biodiversity at larger scales; rather, maintenance of species diversity depends on maintenance of community diversity, and so on up the scale of complexity. There is both bottom-up and top-down stability contributed by the "little things" and "big things" that run the world (Wilson 1987, Terborgh 1988), and we must preserve as much of the habitat of the indigenous fauna as possible. The protection of natural ecosystems and their inherent biodiversity is much more cost effective than to attempt recovery of species on the brink of extinction. It is essential, therefore, that we treat the disease rather than suffer from the symptoms; we must become proactive rather than reactive in our planning and management of aquatic resources. Ignorance, poverty, arrogance and profit appear to be driving the wanton destruction of biological resources, particularly those that have no demonstrated utility to humans, such as many invertebrates. Unfortunately, the societal changes required to eliminate the threats to the biological integrity of our freshwater systems are rooted in socio-economic priorities and our notion of "the good life." We must seek a balance; to provide for the consumptive needs of people and to protect the biological integrity of aquatic systems for future generations. Unless and until we teach the public how to modify economic activities for conservation purposes, whatever else we might do in the management of fish and wildlife resources is, in the long run, irrelevant (Leopold 1933).

References

Benke, A. C. 1990. A perspective on America's vanishing streams. J. N. Am. Benthol. Soc. 9:77–88.

Bowman, T. E. and L. G. Abele. 1982. Classification of the recent Crustacea. Pages 1–27 *in* L. G. Abele, ed., The biology of Crustacea, Volume 1. Academic Press, NY.

Briggs, J. C. 1986. Introduction to the zoogeography of North American fishes. Pages 1–16 *in* C. H. Hocutt and E. O. Wiley, eds., The zoogeography of North American freshwater fishes. Wiley and Sons, NY.

Burch, J. B. 1989. North American freshwater snails. Malacological Publ., Hamburg, MI. 365 pp.

Coblentz, B. E. 1990. Exotic organisms: A dilemma for conservation biology. Conserv. Biol. 4:261–265.

Courtenay, W. R., Jr. and J. R. Stauffer, Jr., eds. 1984. Distribution, biology, and management of exotic fishes. Johns Hopkins Univ. Press, Baltimore, MD. 430 pp.

Deacon, J. E. and J. E. Williams. 1984. Annotated list of the fishes of Nevada. Proc. Biol. Soc. Washington. 97:103–118.

Ernst, C. H. and R. W. Barbour. 1972. Turtles of the United States. The Univ. Press Kentucky. 347 pp.

Federal Register. 1991. Endangered and threatened wildlife and plants; animal candidate review for listing as endangered or threatened species, proposed rule. Fed. Reg. 56(225):58804–58836.
Hershler, R. 1989. Springsnails (Gastropoda: Hydrobiidae) of Owens and Amargosa River (exclusive of Ash Meadows) drainages, Death Valley system, California-Nevada. Proc. Biol. Soc. Washington. 102:176–248.
Hershler, R. and J. J. Landye. 1988. Arizona Hydrobiidae (Prosobranchia: Rissoacea). Smithsonian Contri. Zool. 459:1–63.
Hershler, R. and D. W. Sada. 1987. Springsnails (Gastropoda: Hydrobiidae) of Ash Meadows, Amargosa Basin, California-Nevada. Proc. Biol. Soc. Washington. 100:776–843.
Hunter, M. L., Jr., G. L. Jacobson, Jr., and T. Webb, III. 1988. Paleoecology and the coarse-filter approach to maintain biological diversity. Conserv. Biol. 2:375–385.
Judy, R. D., Jr., T. M. Murray, S. C. Svirsky, M. R. Whitworth, and L. S. Ischinger. 1984. 1982 national fisheries survey. Volume 1. FWS/OBS-84/06, U.S. Fish and Wildlife Service, Washington, D.C.
Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecol. Appl. 1(1):66–84.
Karr, J. R. and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environ. Manage. 5:55–68.
Leopold, A. 1933. Game management. Charles Scribner's & Sons, NY. 481 pp.
Merritt, R. W. and K. W. Cummins, eds. 1984. An introduction to the aquatic insects of North America. Second ed. Kendall/Hunt Publ. Co., Dubuque, IA. 722 pp.
Miller, R. R. 1958. Origin and affinities of the freshwater fish fauna of western North America. Pages 187–222 *in* C. L. Hubbs, ed., Zoogeography. Am. Assoc. Adv. Sci. Publ. No. 51.
Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries. 14(6):22–38.
Minckley, W. L. and J. E. Deacon. 1991. Battle against extinction: Native fish management in the American West. Univ. Arizona Press. 517 pp.
Nash, R. F. 1989. The rights of nature. Univ. Wisconsin Press, Madison. 290 pp.
Nesler, T. P. and E. P. Bergersen, eds. 1991. Mysids in fisheries: Hard lessons from headlong introductions. Am. Fish. Soc. Symp. 9, Am. Fish. Soc., Bethesda, MD. 199 pp.
Neves, R. J. and P. L. Angermeier. 1990. Habitat alteration and its effects on native fishes in the upper Tennessee River system, east-central U.S.A. J. Fish Biol. 37(Suppl. A):45–52.
Office of Technology Assessment. 1987. Technologies to maintain biological diversity. OTA–F–330, U.S. Govt. Print. Off., Washington, D.C.
Pennak, R. W. 1989. Fresh-water invertebrates of the United States. Protozoa to Mollusca. Third ed. John Wiley and Sons, Inc., NY. 628 pp.
Page, L. M. and B. M. Barr. 1991. A field guide to freshwater fishes. Houghton Mifflin Co., Boston, MA. 432 pp.
Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. EPA/440/4–89/001, U.S. Environmental Protection Agency, Washington, D.C.
Smith, G. R. 1981. Late Cenozoic freshwater fishes of North America. Ann. Rev. Ecology and Systematics. 12:163–193.
Smith, H. M. 1978. A guide to field identification of amphibians of North America.
Terborgh, J. 1988. The big things that run the world—a sequel to E. O. Wilson. Conserv. Biol. 2:402–403.
Thorp, J. H. and A. P. Covich, eds. 1991. Ecology and classification of North American freshwater invertebrates. Academic Press, NY. 911 pp.
Turgeon, D. D., A. E. Bogan, E. V. Coan, W. K. Emerson, W. G. Lyons, W. L. Pratt, C. F. E. Roper, A. Scheltema, F. G. Thompson, and J. D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada. Am. Fish. Soc. Special Publ. 16, Bethesda, MD. 277 pp.
Unestam, T. 1975. The dangers of introducing new crayfish species. Pages 557–561 *in* J. W. Avanlt, Jr., ed., Freshwater crayfish. Louisiana St. Univ., Baton Rouge.
U.S. Environmental Protection Agency. 1990. National water quality inventory: 1988 report to Congress. EPA 440-4-90-003, Off. Water, Washington, D.C.
U.S. Fish and Wildlife Service. 1990. Report to Congress: Endangered and threatened species recovery program. U.S. Dept. Inter., Washington, D.C. 406 pp.

Valdez, R. A. and R. G. Williams. 1991. Endangered fishes of Cataract Canyon. Proc. Desert Fishes Council. 20(1988):25–26.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia, PA. 743 pp.

Williams, J. E. 1991. Preserves and refuges for native western fishes: History and management. Pages 171–189 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: Native fish management in the American West. Univ. Arizona Press. 517 pp.

Williams, J. E. and R. R. Miller. 1990. Conservation status of the North American fish fauna in fresh water. J. Fish Biol. 37(Suppl. A):79–85.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14(6):2–20.

Wilson, E. O. 1987. The little things that run the world (the importance and conservation of invertebrates). Conserv. Biol. 1:344–346.

Ethical Considerations in Conservation of Biodiversity

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Preface

> *One of the penalties of an ecological education is that one lives alone in a world of wounds. Much of the damage inflicted on land is quite invisible to laymen. An ecologist must either harden his shell and make believe that the consequences of science are none of his business, or he must be the doctor who sees the mark of death in a community that believes itself well and does not want to be told otherwise* (Aldo Leopold [*Round River*] 1953).

I write this paper with a measure of idealism, quickened by the harsh reality of continental species endangerment and extinction. I recognize that tradition and established bureaucracy are not easily overcome. Probably nothing is more intransigent than bureaucracy at the policy making level that takes comfort in the status quo. However, we are now experiencing the gentle breezes that inevitably precede the winds of change, and we would be well advised to heed them. As our profession enters into this new era of assuming responsibilities for biodiversity conservation, we should become dynamic and enthusiastic leaders, not petulant dissenters. I hope that what follows will help to clarify this complex matter.

Introduction

During 1992, at the Western Division and National meetings of the American Fisheries Society, sessions addressed an enormously important issue that perplexes our profession, perhaps best defined in the session titles, Western Division: ''Endangered Fish Conservation and Sport Fisheries: Managing Resources Between a Rock and a Hard Place;'' and National: ''Fisheries Goals for the Year 2000: Biodiversity or Benefits?''

A perceptive reader will detect a burgeoning phenomenon first identified by a prophetic Aldo Leopold (1949:221) a half century ago and described in *A Sand County Almanac*: ''Conservationists are notorious for their dissensions. . . . In each field one group (A) regards the land as soil, and its function as commodity-production; another group (B) regards the land as a biota, and its function as something broader. How much broader is admittedly in a state of doubt and confusion.''

Unfortunately, this dichotomy remains strongly with us today, with the stakes vastly higher in terms of actual and potential loss of biodiversity.

Because of its ramifications, it behooves us to examine the underlying causes of an intriguing mixture of biology, politics and philosophy in an effort to improve overall management direction. The dichotomy is complicated (especially within the states) by budgetary constraints and practices which give lip service to conservation of biodiversity while available financial resources are directed toward conventional management goals. Most state nongame programs are left to survive on ''soft'' and highly unpredictable funding sources, such as tax checkoff revenues (Williams 1986). Having undergone a Group A to Group B conversion about 30 years ago, and about 10 years into my career (Pister 1985, 1987, 1991a), and having spent countless hours pondering this phenomenon, I offer the following observations.

Discussion

In general, we find four distinct groups expressing professional concern over the conservation and integrity of natural biodiversity:

1. University faculty and students who possess a deep appreciation of the ecosystem and recognize the research potential within a biota, and whose professional existence is strongly related to its integrity. Unfortunately, this group seldom takes an active role in biodiversity conservation, assuming that it will be adequately handled under the stewardship mandate of government agencies. Exceptions to this are the more pragmatic university representatives within (and leading) the Society for Conservation Biology, Desert Fishes Council and similar organizations. University researchers are strong supporters of Leopold's Group B.
2. Biologists affiliated with the private sector: The Nature Conservancy, World Resources Institute, Defenders of Wildlife, National Audubon Society, National Wildlife Federation, Environmental Defense Fund, Wildlife Management Institute, etc., and private consulting firms. Established conservation organizations will be strongly supportive of biodiversity concepts (Group B), whereas private consulting firm personnel will largely reflect the business climate in which they operate. A consultant's projects may be as diverse as an aquaculture proposal suggesting importation of a potentially harmful exotic, or a study involving collection and evaluation of data concerning a critically endangered species. Normally, the consultant will not be an advocate, but will simply do a job or supply information to fulfill an obligation to a client.
3. Federal biologists from resource-related agencies: Fish and Wildlife Service, National Park Service, Bureau of Land Management, Environmental Protection Agency, Forest Service, Bureau of Reclamation, Soil Conservation Service, Corps of Engineers, etc. Because management authority for fish and wildlife populations in public waters is normally relegated to the states, federal biologists generally do not become involved in specific management activities, except through cooperative efforts with state agencies. Activity and attitudes relative to biodiversity conservation are determined primarily by basic agency orientation. For instance, a biologist representing the Office of Endangered Species will be disturbed by a Soil Conservation Service proposal to introduce *Tilapia* into a farm pond located within a drainage containing native fishes, or a Corps of Engineers plan to dam a river critical to the existence of a threatened native plant or rare hydrobiid snail.
4. State fish and wildlife agency biologists. Probably the best example of Leopold's A/B dichotomy is found within this group entrusted with the management of most public waters, although it prevails within other agencies as well. Here, we often find a deep philosophical chasm separating biologists sitting at adjoining desks, and with supposedly similar educational and cultural backgrounds. Why, then, does the A/B dichotomy persist?

Possible Causes

It has been my observation that two basic types of biologist are hired by fish and wildlife agencies. First, there are those who develop an early love for fishing and/or hunting and pursue a related career by entering into a fish or wildlife curriculum at a college or university. Major specialty course requirements are supplemented with offerings designed primarily to sharpen technical skills. Foundation courses in the humanities are avoided or minimized, and the student emerges at the bachelor's level better described as trained than educated in the classic sense (Baer 1978, Brown 1987). Such employees have a tendency to remain in Group A throughout their careers. They are technologically competent and, by reflecting agency policy (often with a strong Group A bias), may rise quickly to administrative and policy making levels.

By contrast, there exists another type of student whose broad interest in the life sciences causes him/her to major in biology, zoology, environmental science or some related discipline, often within a Letters and Science curriculum that requires strong grounding in the humanities. During the undergraduate years (usually within the upper division or even in graduate school), the student develops a deep academic interest in fish and/or wildlife and finds that the best way to pursue this interest as a career is within a fish and wildlife agency. In many instances, such a person will gain little or no interest in hunting, fishing or consumptive use of any type. He/she often will be viewed as something of an ''oddball'' by the Old Guard, which finds it difficult to accept the fact that their obligation (moral, if not legal) is to the entire biological resource and not only to a particular political constituency. Almost without exception, this person will identify strongly with Group B and, when looking at his/her co-worker at the next desk, will find that the communication gap is primarily the result of a very different set of values (Baer 1978). The Group A employee will normally devote his/her career primarily to promoting traditional interests in the Department of Fish and Wildlife, whereas the Group B employee's primary concern will be over the fish and wildlife resource per se. There can be a major difference between the two (Williams 1986).

Changing Times

In the March-April 1979 issue of the American Fisheries Society journal *Fisheries*, five administrators representing different perspectives on fisheries education stated their views concerning curriculum structure. It was their consensus 13 years ago that the profession would be well served by a broadening of curricula to include more humanities courses, and that the concept of pursuing a fisheries speciality only at the graduate level should be given serious consideration, as suggested a decade later in the same journal by Oglesby and Krueger (1989). This was before such awesome environmental issues as global warming, acid rain or tropical rainforest destruction had become household terms. Conservation biology as a formal discipline did not yet exist, nor did its corollary term, biodiversity. To emphasize how the world environment has changed, the March-April 1979 issue of *Fisheries* displayed a snail darter (*Percina tanasi*) and the Little Tennessee River on its cover. That was a very different, and very naive, era.

The past decade has underscored the wisdom of the authors. As we conclude the 1990s, then enter very quickly into the next century, we may be certain that the problems presented to us will become increasingly complex and serious, and that each year, as society and technology evolve, the issues requiring considered judgment from fisheries scientists will become increasingly difficult to solve. They will, in all probability, comprise things that we are unable to comprehend or define at this time. It therefore becomes a matter of urgency that our universities not produce graduates whose skills become obsolete almost before they receive their baccalaureates. A broadly based and relatively unspecialized education emphasizing biological principles can accomplish this and, in the process, help to assure that we do not produce what can quickly become outmoded missiles without guidance systems.

During my undergraduate years at Berkeley, following World War II, before the fish and wildlife speciality in higher education became so widespread, I found it perplexing that, as a wildlife conservation student, I could locate in the course list but two offerings in the field of wildlife, and one (Ichthyology) related to fisheries. When I complained to my adviser, A. Starker Leopold, his response was simple and direct: "We intend to educate you here. You can pick up job skills later." I have since learned that it is much simpler to train an educated person than *vice versa*.

Despite the fact that during my entire six years up through the master's degree I studied only Ichthyology (scarcely a fisheries management course) and two wildlife courses, I somehow survived a 38-year career as a fishery biologist charged with conserving the ecological integrity (and managing sport fisheries where appropriate) within about a thousand waters in the eastern Sierra-Desert regions of California. This area currently supports more recreational use than Yellowstone, Grand Canyon and Glacier national parks combined (Federal Energy Regulatory Commission 1986). Doing so involved contending with a diversity of problems totally unknown to me when I began my career, following graduate school in 1952. My direction was provided by a broad grounding in the humanities and ecological principles, and a value structure based on the philosophies of Starker and Aldo Leopold (Pister 1987). Whereas genetic diversity allows a species the best chance of adapting to new and unexpected conditions, in like manner, a broad and less specialized education in the management of natural resources will best prepare our biologists to handle new and unexpected problems.

What Does the Future Portend?

At a 1991 fisheries leadership workshop sponsored by the American Fisheries Society at Snowbird, Utah, Frank Popper, of the Urban Studies Department of Rutgers University, presented a keynote address entitled: "The Return of the American Frontier: Some Implications for Fisheries," which predicted that, during the twenty-first century, large quantities of privately owned or controlled land in the rural West will be abandoned and revert to public or quasi-public holdings. This will result in enlargement and improved buffering of national parks and forests, their state counterparts, and other public lands. He envisioned major growth in businesses devoted to ecological restoration of land damaged by previous extractive uses, as well as a burgeoning ecological tourism industry. All this underscores the observation that society is moving away from its emphasis on consumptive use toward a different component of the biota. We are returning to a frontier that, in Dr. Popper's words (Popper 1991:A–4): "will offer a magnificent, once-in-history opportunity to create (or recreate) extraordinary habitat, for fisheries and for other habitat uses as well. The combined rise of preservation, decline of a great deal of extraction, and emptyingout of much of the Pacific side of North America will present a remarkable chance to undo our past mistakes and neglect. It is not, perhaps, a chance we deserve, but it is no more than a chance—we also have to be willing to act to take advantage of it. If we succeed, the results will be environmentally and economically spectacular, the world's first sustainable-development frontier. If we are not so fortunate, the results will be disastrous, the historically familiar creation of yet another human-induced wasteland."

Signs of this shift are already appearing in the bellwether state of California, which, in 1989, sold 29 percent fewer angling licenses than in 1980, although the state's population increased by more than 7 million during that decade. In 1980, about one in 10 Californians bought a fishing license, for a total of 2.3 million. In 1989, about 1.6 million fishing licenses were sold, or one for every 20 Californians. This concept is clearly illustrated by Figure 1, which presents hypothetical supply and demand curves for fish and wildlife resources as we move into the next century, and underscores the need to conserve biodiversity. Components of the total biota,

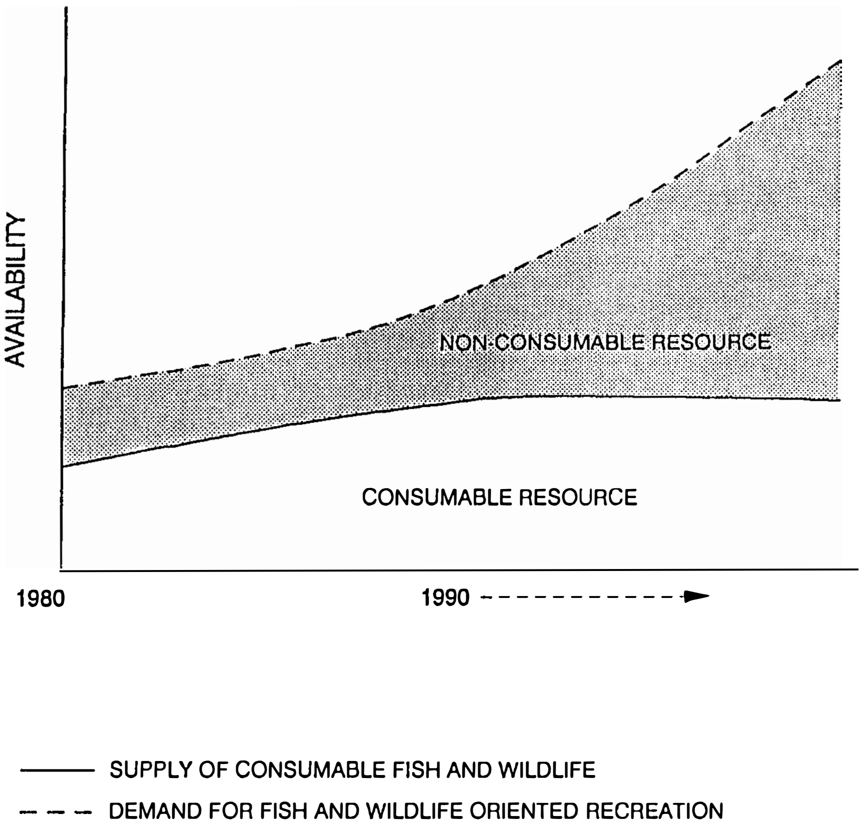

Figure 1. Probable supply and demand trends of North American fish and wildlife resources (adapted from Pister 1991b).

existing in secure habitats, will then essentially comprise a dictionary from which we may write prescriptions for whatever an unquestionably more sophisticated and perceptive society may require (Pister 1976, 1991a, 1991b).

Values and Aquatic Organisms

My fishery values were cemented during a very dramatic afternoon on August 19, 1969, when a graduate student working with me came breathlessly into the office and stated with obvious trepidation that unless we came immediately to the rescue of the only remaining population of the Owens pupfish (*Cyprinodon radiosus*), which was hanging on precariously in a rapidly desiccating, room-sized refugium pond located about eight miles away, we would have an extinct species on our hands (Miller and Pister 1971). In order to do so, however, I would need to cancel a long-planned and highly touted creel census program scheduled for a major reservoir. It was while I was walking back to our pickup truck over rough ground in total darkness later that night, holding the entire world population of an endangered species in two buckets, one in either hand, that the relative values involved really hit me. I wish that everyone working in fisheries science could share a similar experience. It would do much to place our values where they ought to be! Even so, I am still chastised by an occasional individual for concerning myself with ''dickie-fish!'' To repeat: ''One of the penalties of an ecological education is that one lives alone in a world of wounds.''

It disturbs me that any responsible fishery administrator could entertain, for even a moment, a thought of introducing another species in the hope of temporarily making fishing better, if doing so could create even a *minimal* chance of further harming our already seriously depleted native fish fauna (Williams et al. 1989, Miller et al. 1989). Where does the blame lie here? Are our universities producing ecological illiterates without established values, or are ethics of the business world forcing us into doing things we know deep down are wrong? In their quest of immediate management goals, public agencies sometimes commit errors that, if they were made by the general public, could even subject them to prosecution under the law!

Obligations to the Future

A strong point I would make in a discussion of values would be the obligation of the fisheries profession to future generations, emphasizing our moral obligation to life forms other than ourselves (Partridge 1981, Sikora and Barry 1978). An obvious question might be posed as follows: ''Which of the following will aquatic scientists (and society) in the year 2092 be most likely to judge us by: the level of angling success in 1992 in a certain reservoir, or the integrity of the natural aquatic biota that we pass on to them?'' In responding to the demands of the consumptive user we seldom think of the evolutionary history (in progress for billions of years) and precision of the biota we are influencing, often irreversibly and, for all practical purposes, forever. The future requires that fish and wildlife agency personnel become keenly aware of these concepts. Their power to alter and destroy is awesome, if not properly directed.

Bright spots on the horizon. A positive note in recent years has been the accelerated hiring of women as biologists by resource management agencies. It is my impression that women tend to be more sensitive to the mechanisms of the natural world and, as a rule, are far more perceptive than men. It will constitute a major step in the right direction for conservation biology when more women move into administrative positions within their organizations. It has been my observation that women are more likely than men to honor the term "biologist," which presumes understanding and respect for all the complexities and wonder inherent within the ecosystem (Ehrenfeld 1976, 1978, Rolston 1987). As in many parts of society, the fish and wildlife profession has suffered far too long under the almost exclusive domination of males!

Where Do We Go From Here?

Up to this point I have discussed the pragmatic aspects and problems relating to the accomplishment of biodiversity conservation. We need now to direct our efforts toward establishment of a professional ethic that gives it top priority in the planning and budgeting process. To accomplish this, we must hire a generation of fish and wildlife biologists who, with their supervisors, share a deep appreciation of the entire biota and of the evolutionary and ecological relationships that exist within the ecosystem. Gradually then, through an improved funding system for fish and wildlife management agencies and a totally committed and adequate staff to handle this new concept of ecosystem management, we may be able to reverse the downward trends that, even at this early date, reflect a rapidly diminishing aquatic biota (Rolston 1987, Williams et al. 1985, 1989). But before this will be possible, we must employ individuals who are so appreciative and defensive of all forms of life that they would literally work as hard to preserve them as they would a member of their immediate family.

Harvard's Stephen Jay Gould (1991:13) stated this concept with his usual candor: ". . . I also appreciate that we cannot win this battle to save species and environments without forging an emotional bond between ourselves and nature as well—for we will not fight to save what we do not love (but only appreciate in some abstract sense)." This is another way of expressing an observation attributed to the German philosopher Goethe, that "Every man is given only enough strength to accomplish those things of which he is fully convinced of their importance."

Eating Our Cake and Having It, Too!

I wish to emphasize that the preceding does not suggest that we totally discard traditional management programs, which can no doubt continue indefinitely into the future. However, it does presume that, percentage wise, conventional consumptive uses will inevitably decline, and will continually be diluted through loss of habitat (Pister 1976, 1991b) (Figure 1).

Ethical Applications

For thousands of years, since the time of the ancient Greeks, mankind has looked to philosophers to provide direction for societal change, and to lend guidance in defining and establishing meaningful values. In 1979, a new journal appeared covering a field peripheral to the mainstream interests of environmental (and fish and wildlife) biologists, yet destined to play an increasingly important role in the future of an environmentally conscious world. ***Environmental Ethics***, described on its cover as "An interdisciplinary journal devoted to the philosophical aspects of environmental problems,'' brings together writings of philosophers and biologists who detect a strong need for the application of ethical considerations to the causes in which biologists have been engaged for decades, frequently without giving the subject of ethics more than a passing thought. This new emphasis on environmental ethics likely will become one of the most important concepts shaping our destiny as we move into the next century. It will pervade both agency and academe with a philosophy emphasizing what we can do for our fish and wildlife resources, rather than what they can do for us. Contemporary environmental philosophers have already made major contributions in this direction (Callicott 1991, Nash 1989, Rolston 1991).

In a very thoughtful essay concerning conservation of biodiversity, and precipitated by the ongoing Mount Graham red squirrel dilemma, Gould (1990) suggested that we execute a compact with out planet invoking the Golden Rule, a principle utilized by virtually all major religions. Because we cannot ever, in the long run, defeat natural law, and nature holds great power over us, it behooves us to execute such a pact at the earliest possible date. A high priority for the conservation of biodiversity within our profession, which should be a leader in such matters, would constitute a major step in this direction.

Picking up on this same theme, Callicott (1991) proposed a Golden Rule or summary moral maxim of the Leopold Land Ethic: ''A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise'' (Leopold 1949:224–225). From this ethic he derives the following ''commandments:'' ''1) Thou shalt not extirpate species or render them extinct; 2) Thou shalt exercise great caution in introducing exotic species into local ecosystems; 3) Thou shalt exercise great caution in extracting energy from the soil and releasing it into the biota; 4) Thou shalt exercise great caution in damming and polluting watercourses; 5) Thou shalt be especially solicitous of predatory birds and mammals'' (Callicott 1987). Other environmental philosophers show related concerns (*see* Hargrove 1989, Nash 1989, Rolston 1986, 1988). Undeviating adherence to such a set of ''commandments'' as guidance for a new ethic would place our concern over conservation of biodiversity on a firm foundation. It would get us ''off and running.''

Conclusion

During a recent assignment at the Leetown, West Virginia training facility of the U.S. Fish and Wildlife Service, I took an extra day and drove to Thomas Jefferson's home and memorial at Monticello. On his tombstone are inscribed the three lifetime achievements that he wished to be remembered by: ''Author of the Declaration of American Independence, of the statute of Virginia for religious freedom, and father of the University of Virginia.''

It has been said that a politician's main concern is to be reelected, whereas a true statesman devotes his/her efforts to deeper issues of enduring value to future generations. As I read of Jefferson's magnificent accomplishments, I thought of those in past and present elected office who will be remembered for lesser things. The metaphor likewise applies to our stewardship responsibilities, which extend into the eternities.

It is my feeling that if Aldo Leopold were alive today, he would be disturbed by the fact that persons concerned over the well-being of the nation's fish and wildlife resources should be at even minor odds over such a matter as conservation of biodiversity. It is likely that he would reiterate another of his marvellously prophetic statements, made 59 years ago in his classic text: *Game Management* (1933:405): ''There is, in short, a fundamental unity of purpose and method between bird-lovers and sportsmen. Their common task of teaching the public how to modify economic activities for conservation purposes is of infinitely greater importance, and difficulty, than their current differences of opinion over details of legislative and administrative policy. Unless and until the common task is accomplished, the detailed manipulation of laws is in the long run irrelevant.''

Epilogue

In a pointed, but very gentle book, entitled *The Rediscovery of North America*, Barry Lopez (1990) described how Europeans have ravaged North America for 500 years in their relentless pursuit of wealth. The greed and devastation first manifested by Pizarro and Cortes are today repeated in the form of acid precipitation, destruction of old growth forests and loss of biodiversity. In their quest for gold, the Spaniards never became aware of the much greater wealth they were destroying in terms of human culture and natural values. Now, half a millennium later, we need to rediscover our continent, and to become aware of the enormous wealth that, although jeopardized, still remains. This wealth is not gold or treasure, but consists of infinitely more valuable things.

''Some hold that this task is hopeless, that the desire for power and wealth is too strong. Without denying in any way the dark flaws of human nature, I wish politely to disagree. . . . We can say, yes, this happened, and we are ashamed. We repudiate the greed. We recognize and condemn the evil. And we can see how the harm has been perpetrated. But, five hundred years later, we intend to mean something else to the world. . . . We must turn to each other and sense that this is possible'' Lopez (1990).

The dominoes are showing signs of falling, and we must take heed. There could be no finer way to enter into the next millennium than for the North American conservation community to recognize that basing its programs on an ethically sound foundation will inevitably result in the application of sound biological principle and practice.

References

Baer, R. A. 1978. Values in higher education: The crisis and the promise. J. Nat. Assoc. Coll. and Teachers Agric., March 1978, 4–10.

Brown, D. A. 1987. Ethics, science, and environmental regulation. Environmental Ethics 9, 331–349.

Callicott, J. B. 1987. The conceptual foundations of the land ethic. Pages 186–217 *in* J. B. Callicott, ed., Companion to A Sand County Almanac. Univ. Wisconsin Press, Madison. 308 pp.

———. 1991. Conservation ethics and fishery management. Fisheries 16(2):22–28.

Ehrenfeld, D. W. 1976. The conservation of non-resources. Am. Scientist 64:648–656.

———. 1978. The arrogance of humanism. Oxford Univ. Press, London. 286 pp.

Federal Energy Regulatory Commission (FERC), Office of Hydropower Licensing. 1986. Final environmental impact statement, Owens River Basin: Seven hydroelectric projects, California. Docket no. EL85-19-102. FERC, Washington, D.C.

Gould, S. J. 1990. The golden rule—a proper scale for our environmental crisis. Nat. Hist., September 1990, 24–30.

———. 1991. Unenchanted evening. Nat. Hist., September 1991, 4–13.

Hargrove, E. C. 1989. Foundations of environmental ethics. Prentice-Hall, Englewood Cliffs, NJ. 229 pp.
Leopold, A. 1933. Game management. Charles Scribner's Sons, NY. 481 pp.
———. 1949. A sand county almanac and sketches here and there. Oxford Univ. Press, NY. 226 pp.
Leopold, L. B., ed. 1953. Round River: From the journals of Aldo Leopold. Oxford Univ. Press, NY. 173 pp.
Lopez, B. 1990. The rediscovery of North America. The Univ. Kentucky Press, Lexington.
Miller, R. R. and E. P. Pister. 1971. Management of the Owens pupfish, *Cyprinodon radiosus*, in Mono County, California. Trans. Am. Fisheries Soc. 100:502–509.
Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinction in North American fishes during the past century. Fisheries 14(6):22–29, 31–38.
Nash, R. F. 1989. The rights of nature. Univ. Wisconsin Press, Madison. 290 pp.
Oglesby, R. T. and C. C. Krueger. 1989. Undergraduate fisheries education: Technical specialization or broad foundation? Fisheries 14(5):17–21.
Partridge, E., ed. 1981. Responsibilities to future generations. Prometheus Books, Buffalo, NY. 319 pp.
Pister, E. P. 1976. A rationale for the management of nongame fish and wildlife. Fisheries 1(1):11–14.
———. 1985. Desert pupfishes: Reflections on reality, desirability, and conscience. Environmental Biology of Fishes 12:3–12.
———. 1987. A pilgrim's progress from group A to group B. Pages 221–232 J. B. Callicott, ed., *in* Companion to a Sand County Almanac. Univ. Wisconsin Press, Madison. 308 pp.
———. 1990. Desert fishes: An interdisciplinary approach to endangered species conservation in North America. J. Fish Biology (1990) 37 (Supplement A), 183–187.
———. 1991a. Desert Fishes Council: Catalyst for change. Pages 55–68 W. L. Minckley and J. E. Deacon, eds., *in* Battle Against Extinction: Native Fish Management in the American West. Univ. Arizona Press, Tucson. 517 pp.
———. 1991b. Environmental water ethics in the Eastern Sierra. *In* Mono Lake Symposium, Supplement to the Bull. So. California Acad. Sci. 90:20–26.
Popper, F. 1991. The return of the American frontier: Some implications for fisheries. *In* Harville, J. P., ed., Proc. N. Am. Fisheries Leadership Workshop. Am. Fish. Soc., Bethesda, MD. 32 pp.
Popper, D. and F. Popper. 1991. The re-invention of the American frontier. The Amicus J., Summer 1991, 13(3):4–7.
Rolston, H. 1986. Philosophy gone wild: Essays in environmental ethics. Prometheus Books, Buffalo, NY. 269 pp.
———. 1987. Duties to ecosystems. Pages 246–274 J. B. Callicott, ed., *in* Companion to a sand county almanac. Univ. Wisconsin Press, Madison. 308 pp.
———. 1988. Environmental ethics: Duties to and values in the natural world. Temple Univ. Press, Philadelphia, PA. 391 pp.
———. 1991. Fishes in the desert: Paradox and responsibility. Pages 93–108 W. L. Minckley and J. E. Deacon, eds., *in* Battle against extinction: Native fish management in the American West. Univ. Arizona Press, Tucson. 517 pp.
Sikora, R. I. and B. Barry, eds. 1978. Obligations to future generations. Temple Univ. Press, Philadelphia, PA. 250 pp.
Williams, J. E., D. B. Bowman, J. E. Brooks, A. A. Echelle, R. J. Edwards, D. A. Hendrickson, and J. J. Landye. 1985. Endangered aquatic ecosystems in North American deserts, with a list of vanishing fishes of the region. J. Arizona-Nevada Acad. Sciences 20:1–62.
Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America, endangered, threatened, or of special concern: 1989. Fisheries 14(6):2–20.
Williams, T. 1986. Who's managing the wildlife managers? Orion Nature Quart. 5(4):16–23.

Crimes Against Biodiversity: The Lasting Legacy of Fish Introductions

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Introduction

A little over a century ago, the United States was witnessing the origin of what would become an introduction frenzy. Spencer Fullerton Baird was the first Commissioner of the U.S. Fish Commission, the progenitor agency of the Fish and Wildlife Service and the National Marine Fisheries Service. Professor Baird accomplished much in his life, including initiating the most extensive surveys of this nation's fish and fishery resources, an effort that involved leading ichthyologists of that time. He was the creator of the National Museum of Natural History. In his capacity as Commissioner, he did more than anyone in history to advance knowledge of our native fauna (Dall 1915, Adler 1989).

Baird lived in a time when it was recognized that much of our agricultural wealth—farm crops and many farm animals—was of foreign or exotic origin. This increase in species richness through introductions clearly had been beneficial, and this impression carried over into fisheries. Many of the fish surveys initiated by Baird were undertaken to determine how our fish resources could be improved by introductions from abroad or elsewhere in the U.S. (e.g., Jordan 1891). This "improving on nature syndrome" persists a century later in some circles in fishery management and particularly in the expanding aquaculture industry.

Not recognized, then or now, is that most agricultural crops and some farm animals are so far genetically removed from their ancestral origins that they cannot exist on their own without cultivation or husbandry. Furthermore, those crops and animals have no access to ancestral stocks with which they might genetically backcross, thus enhancing chances for feral survival while simultaneously altering gene pools of their ancestors. Introducing organisms that do not require cultivation or husbandry into natural or even disturbed ecosystems is vastly different, and any comparison with agriculture is an "apple and orange" situation.

Under Baird's leadership, the U.S. Fish Commission began large-scale introductions of exotic fishes—among them common carp (*Cyprinus carpio*), ide (*Leuciscus idus*), tench (*Tinca tinca*) and, later, brown trout (*Salmo trutta*). Western native fishes were transplanted in eastern waters, and vice versa. Introductions were made under the guise of improving food resources (Baird 1879), but mostly to enhance sport fishing. This established a precedent from which the federal government has only recently retreated (but in which it remains involved by funding states for such activities) and a pattern followed by state game and fish agencies as they created their own niches of practice and politics.

An Historical Overview

Prior to Baird's involvement, goldfish (*Carassius auratus*) had become established by the 1680s, and an individual first introduced common carp into the Hudson River, New York in the 1830s (DeKay 1842). By World War II, 14 species of exotic fishes had become established in U.S. waters, and now there are at least 70, equivalent to almost 10 percent of the native North American fish fauna north of the U.S./Mexican border. Eighty percent of these were introduced and became established since 1950. Transplants of native species beyond drainages in which they were native have resulted in at least 158 species (perhaps over 200) becoming established in other ecosystems (Courtenay 1991). Collectively, established exotics and transplants are nearly equivalent to 30 percent of the native fish fauna, spread across a large geographic area. Most of the known and suspected transplants and few of the exotics involve sport fishing—intentionally introduced predators, sometimes forage species, or released bait fishes (Courtenay and Taylor 1984). Clearly, species richness—but not necessarily biodiversity—has been increased through introductions.

Alien fishes have become established from a variety of sources—intentional introductions for food, sport and forage purposes, biological control of pests (many of which are also exotic), aquarists getting rid of unwanted pet species or stocking thermal springs to purposefully establish species, discharge of ballast water from intercontinental ships, dumping of bait buckets and unintentional but predictable escapes from aquarium fish culture and aquaculture facilities (Courtenay et al. 1984, 1986, Shelton and Smitherman 1984, Courtenay and Stauffer 1991, Courtenay and Williams in press). Had target waters been more amenable, perhaps another 56 identified species and an unknown number of species in five separate genera, all collected in open U.S. waters, might also have become established. Many of these non-established exotics represent families from which there are established populations of other species. Only one state, Alaska, lacks established exotic fish species.

Effects of Introductions

There is a growing literature of investigations of effects of introduced species on native biota, but comparatively few of these studies are agency-sponsored. Fisheries management agencies have typically regarded an introduction as successful if it seems to fulfill its stated purpose (e.g., to improve a fishery) for a short period of time, with little regard to ecosystem or long-term effects. If declines of native species are noted, declines are blamed on the effects of habitat alterations, such as dams and diversions, providing further justification for introducing supposedly better adapted species. The introduced species, however, are often the final blow to a native biota previously weakened by habitat alterations (Minckley 1991). In the western United States, for example, there is increasing evidence that many native fishes would thrive in reservoirs in the absence of introduced fishes.

Introduced species impact native fishes through predation, a wide spectrum of competitive factors, introduction of diseases and parasites for which native species lack resistance, and hybridization (Deacon 1979, 1988, Courtenay and Stauffer 1984, Hoffman and Schubert 1984, Taylor et al. 1984, Courtenay et al. 1984, Moyle 1986, Moyle et al. 1986, Minckley and Deacon 1991). Hybridization is rare when exotic species are involved, but fairly common with transplants (Phillip et al. 1983, Waples et al. 1990, Benke 1991). Often these impacts require years to several decades to become evident, although negative effects from predators usually occur rapidly. Sometimes introgressive hybridization can be rapid (Echelle and Connor 1989, Johnson and Hubbs 1989), heading one or more species toward extinction.

There is variation in how introduced fishes alter recipient faunas. First, however, it must be recognized that diversity of native fishes differs geographically, the highest occurring in the southeast and diminishing beyond (McAllister et al. 1986). South Florida, for example, like much of the area west of the Rocky Mountains, has few native freshwater species, and the southwestern fish fauna is best described as depauperate (Minckley et al. 1986).

Introduced species having the least effect are often small herbivores, insectivores or omnivores introduced into local drainages in eastern states; the greatest effects result from large predators released almost anywhere. Bait-bucket introductions and releases of aquarium fishes in eastern and midwestern states have enriched faunas of coastal and some inland drainages, probably not without some biotic alteration, but extinctions have not occurred, except through hybridization (Horwitz 1982, Hocutt et al. 1986). Conversely, releases of predatory green sunfish (*Lepomis cyanellus*) into North Carolina streams created major changes in native species (Lemly 1985), and introductions of piscivorous Sacramento squawfish (*Ptychocheilus grandis*) into California's Eel River induced major shifts in resident fishes, with potential to eliminate at least one species from the drainage (Brown and Moyle 1991). Introduction of the sea lamprey (*Petromyzon marinus*) into the western Great Lakes was a costly biological disaster (Fetterolf 1980, Ashworth 1986), perhaps to be equalled or bettered in future years by ecosystem modifications wrought by establishment of zebra mussel (*Dreissena polymorpha*) and other species new to the Great Lakes (Mills et al. in press). Introduced planktivores in lakes, such as alewife (*Alosa pseudoharengus*) in the Great Lakes or mysid shrimp in western lakes, can rival the effects of higher order predators. The greatest disaster from introduction of a predator was the elimination of perhaps up to 200 species of cichlid fishes in Lake Victoria, Africa by the Nile perch (*Lates nilotica*) (Barel et al. 1985).

Those who blame factors other than introductions as direct causes for declines in biodiversity should examine what happened in Clear Lake, California, one of the oldest, large natural lakes in North America. Its native fish fauna consisted of 11 species, with at least 3 endemic to the lake (Moyle 1976b). Over many decades, 16 alien fish species were introduced successfully, and presently there are 21 species there. Although total species richness almost doubled, six native species were extirpated, two of them now globally extinct. While there has been some diversion of streams used for spawning by native lake fishes, these extinctions were most likely caused by introduced predatory centrarchids.

Reservoirs in southeastern states were built in a region with high rainfall and high fish diversity. Riverine species that declined in abundance as reservoirs filled were replaced by introduced predatory fishes to enhance sport fishing. These introductions apparently impacted few native species, and the benefits of new fisheries outweighed negative ones (Courtenay 1990). Sheldon (1988), however, stated that reservoirs serve to isolate fish populations in tributory streams from one another because they are large areas of habitat unfavorable to smaller stream fishes and, in part, because they contain numerous predators. Therefore, when one or more local extinctions occur, colonization from other populations in adjacent tributaries is unlikely, if not impossible. Further, as water quality in eastern and midwestern waters is degraded and habitat is additionally modified, negative effects from species introductions will doubtless increase.

Southwestern reservoirs are in a region with low rainfall and low species diversity. Many sport fishes were introduced, many of them "copy-cat" introductions from eastern successes, and often proved to be extremely damaging to native fishes (Courtenay and Robins 1989). Dam construction on the Colorado River and Rio Grande clearly disrupted life-styles of native fishes, but it is likely that most species would have persisted had predatory species not been introduced (Minckley 1991). These predators are known to consume eggs and young of native species, thus damping or eliminating recruitment in reservoirs and river mainstems. Success of introductions from hatchery programs, designed to restore native fishes, has been reduced significantly through predation by introduced species (Marsh and Brooks 1989). Consequently, nearly all native fishes in the Colorado River and a rapidly increasing number in the Rio Grande drainage are listed as threatened or endangered, many on the verge of extinction (Minckley and Deacon 1991).

The aquarium fish hobby and industry often have denied their involvement in introductions, mostly to avoid restrictive legislation or regulation. The advent of jet cargo aircraft and development of styrofoam shipping containers during the 1950s made massive importations possible, thus greatly increasing the variety of species and numbers of individuals imported (Courtenay and Stauffer 1991). To reduce costs of importation, culture facilities sprang up in southern Florida, southern California and other warm areas. It has been estimated that 80 percent of the aquarium fishes sold in North America were cultured in Florida (Boozer 1973). Ramsey (1985) reported that imports of exotic aquarium fishes into the U.S. amounted to approximately 200 million fish per year of hundreds of species, many undescribed, annually. Courtenay and Stauffer (1991) concluded that more than 50 percent of the exotic fishes established in U.S. waters originated as escapes from aquarium fish culture and releases by hobbyists.

Of the hundreds of fish introductions made in the U.S., how many can be considered as successful? The answer depends whether or not one defines success mainly in terms of economics or angler satisfaction, without considering ecological damage or loss of biodiversity. A substantial percentage of U.S. sport fisheries stems from introduced species, although often the introduced fishes simply replaced other species. Brown trout and rainbow trout (*Oncorhynchus mykiss*), for example, largely have replaced cutthroat trout (*O. clarki*) in interior drainages of western states. Centrarchid basses have replaced squawfishes (*Ptychocheilus* spp.) in many parts of the West, because squawfish are regarded as trashfish by occidental anglers, even though they were highly prized by native Americans and early settlers and are prized today by oriental immigrants. Most transplants of sport fishes into southeastern reservoirs are considered positive and seem to have had little or limited negative effect on native fishes. Nevertheless, transplants of similar species into southwestern reservoirs, although often regarded as positive as well, have had devastating effects on native fishes. Introduced fishes are, for example, a major barrier to recovery of the endangered fish fauna of the lower Colorado River (Minckley 1991). The only introductions likely to have been ecologically neutral were those made into places such as the Salton Sea in southern California, created in the early 20th century when irrigators accidentally assisted diversion of a flooding Colorado River into a dry desert basin, creating a new body of water (Courtenay and Robins 1989).

Biological Realities and Future Management

Introduced species carry a lasting legacy once they become established as reproducing populations and expand their ranges. They are biological pollutants which usually cannot be eliminated. In this respect, they differ from most other forms of environmental modification, which can, with time, be adjusted or corrected. We are not suggesting that all intentional introductions be prohibited, but that they should be strictly controlled and rarely done. Each introduction should be based on careful research and on a rationale that takes into account their potential long-term and regional effects. In particular, it is important to have an evaluation of potential effects of introductions on receiving ecosystems. Introduced piscivores, such as lamprey eels or Pacific salmons in the Great Lakes, can cause major, ecosystem-wide changes within a few years, but introduced species from lower trophic levels can take years to show an effect. Eventually, new configurations of the receiving ecosystems develop, which, in all likelihood, will not be as persistent and resilient as the original configuration of co-evolved species. This ecosystem instability created by introduced species will doubtless keep fishery biologists involved as environmental tinkerers for years to come, but is also likely to result in high variability in catches of fisheries and the constant creation of new threatened and endangered species.

This strongly suggests that a new national ethic needs to be established for introductions, one that is extremely cautious with intentional introductions and very punitive with unauthorized introductions. This ethic should be translated into national legislation to regulate introductions. Such legislation, for example, would make states responsible for damage done outside their borders by a species introduced within a state which then spreads to other states. In the past, the federal government has been largely silent on such issues, even though introductions are clearly an interstate matter. Federal agencies have assisted states in making introductions and, ironically, are often called upon to help solve problems created by introduced species. The result of the absence of a firm national policy is a hodgepodge of often contradictory policies and laws among the states.

The American Fisheries Society has twice adopted policy statements on intentional introductions (Anonymous 1973, Kohler and Courtenay 1986), and has sponsored symposia in which protocols for introductions were developed. Yet no state or federal agency has, to our knowledge, adopted these policies or protocols as their policy. Nevertheless, most states have regulations that essentially prohibit introductions of non-native species without a permit, although enforcement is often minimal. These regulations became necessary because many anglers have the same idea that still pervades some fisheries agencies—that introductions can quickly create a fishery. Thus, California has spent hundreds of thousands of dollars in recent years attempting to eradicate populations of white bass (*Morone chrysops*) and northern pike (*Esox lucius*) established through illegal introductions. Such introductions, made in reservoirs, have tremendous potential to reduce salmonid populations downstream. Utah has twice funded expensive reclamation projects to free a reservoir of bait bucket releases that are certain to be repeated. Bait bucket releases into the Virgin River of Arizona, Nevada and Utah also have contributed to the decline of the endangered woundfin (*Plagopterus argentissimus*); the aggressive, introduced red shiner (*Cyprinella lutrensis*) brought with it an Asiatic tapeworm that now infests the woundfin (Deacon 1988). The tapeworm originated from exotic grass carp (*Ctenopharyngodon idella*), first introduced in Arkansas.

The aquarium industry is also responsible for many destructive introductions. It has proven itself powerful in limiting regulation of its activities, despite the fact that Florida and California have received many introduced fishes that "escaped" from fish farms. The industry has also done little to educate fish hobbyists about the dangers of releasing unwanted aquarium species. Throughout many parts of the U.S., a major exotic aquatic weed, *Hydrilla verticillata*, has become established, largely from discarded aquarium plants. Aquarium fishes, released by hobbyists, contaminate many isolated desert springs to the detriment of native fishes and invertebrates (Courtenay et al. 1986, 1988). Hawaii has finally recognized the problems created by aquarium fishes in its streams and has an active campaign to discourage such releases. An integral part of that campaign is to have pet stores take back any fishes no longer wanted by their owners. Unfortunately, the problems created by the aquarium fish industry have not had much influence on the growing aquaculture industry, which is now seeking reduction of limited regulation it has by fisheries agencies through state and federal legislation that puts it under the jurisdiction of agriculture. These are the same agencies that historically have shown a great reluctance to regulate toxic pesticides under their jurisdiction, resulting in much environmental damage.

Changes clearly are needed. Nearly all "conservation" agencies were created to conserve natural (= native) resources, but their missions have been altered. There is little conservation ethic in many of these agencies and they thrive on "knee-jerk" reactions or "band-aid" corrections to what their narrow training or political influences dictate. Often, however, the problems they try to correct are not of their making, because there are too many special interests demanding and too many agencies managing the same waters for other purposes. Our point is that intentional introductions, because of their inherent and unpredictable dangers, should be the very last management tool used, and only when all other options have failed. The apparent "quick fix" by introductions often leads to future, more expensive problems to ecosystems and management agencies. Using the wrong tool usually damages the product.

Finally, introductions of non-native fishes, from whatever source, are virtually guaranteed to increase at a rapidly escalating rate unless major policy and regulation changes are made. We see no quick, easy fixes because many managers lack the background in ecology to understand our concerns, agencies see no reason to change practices, and commercial and hobby interests have no understanding. This issue really comes down to one question—are short-term, "quick fix" actions taken by agencies and irresponsibility shown by industry and hobbyists more important than the long-term biological costs?

References

Adler, K., ed. 1989. Contributions to the history of herpetology. Soc. Stud. Amphib. Rept., Contrib. Herpetol. 3:1–202.

Anonymous. 1973. Position of the American Fisheries Society on introduction of exotic aquatic species. Trans. Amer. Fish. Soc. 102:274–276.
Ashworth, W. 1986. The late, Great Lakes: An environmental history. Wayne St. Univ. Press, Detroit, MI. 274 pp.
Baird, S. F. 1879. The carp. Pages 40–44 *in* Report of the Commissioner, Rept. U.S. Fish Comm. 1876–77. U.S. Govt. Print. Off., Washington, D.C.
Barel, C. D. N., R. Dorit, P. H. Greenwood, G. Fryer, N. Hughes, P. B. N. Jackson, H Kawanabe, R. H. Lowe-McConnel, M. Nagoshi, A. J. Ribbink, E. Trewavas, F. Witte, and K. Yamoaka. 1985. Destruction of fisheries in Africa's lakes. Nature (London) 315:19–20.
Behnke, R. J. 1991. America's changing fish fauna. Trout (Spring):35–38.
Boozer, D. 1973. Tropical fish farming. Am. Fish Farm. 4(8):4–5.
Brown, L. R. and P. B. Moyle. 1991. Changes in habitat and microhabitat partitioning with an assemblage of stream fishes in response to predation by Sacramento squawfish (*Ptychocheilus grandis*). Can. J. Fish. Aquat. Sci. 48:849–856.
Courtenay, W. R., Jr. 1990. Fish conservation and the enigma of introduced species. Pages 11–20 *in* D. A. Pollard, ed., Introduced and translocated fishes and their ecological effects, Proc. Bur. Rural Res. 8, Canberra, Australia.
———. 1991. Pathways and consequences of the introduction of non-indigenous fishes in the United States. Unpubl. rept. to Off. of Tech. Assess., U.S. Congress. 83 pp.
Courtenay, W. R., Jr., D. A. Hensley, J. N. Taylor, and J. A. McCann. 1986. Distribution of exotic fishes in North America. Pages 675–698 *in* C. H. Hocutt and E. O. Wiley, eds., Zoogeography of North American freshwater fishes. John Wiley & Sons, New York, NY.
Courtenay, W. R., Jr. and C. R. Robins. Fish introductions: Good management, mismanagement, or no management? Rev. Aquat. Sci. 1:159–172.
Courtenay, W. R., Jr. and J. R. Stauffer, Jr., eds. 1984. Distribution, biology, and management of exotic fishes. Johns Hopkins Univ. Press, Baltimore, MD. 430 pp.
Courtenay, W. R., Jr. and J. R. Stauffer, Jr. 1991. The introduced fish problem and the aquarium fish industry. J. World Aquacult. Soc. 21:145–159.
Courtenay, W. R., Jr. and J. N. Taylor. 1984. The exotic ichthyofauna of the contiguous United States, with preliminary observations on intranational transplants. EIFAC Tech. Pap. 42:466–487.
Courtenay, W. R., Jr. and J. D. Williams. In press. Dispersal of exotic species from aquaculture sources, with emphasis on freshwater fishes. *In* A. Rosenfield and R. Mann, eds., Dispersal of living organisms into aquatic ecosystems. Maryland Sea Grant Program, College Park, MD.
Courtenay, W. R., Jr., J. E. Deacon, D. W. Sada, R. C. Allan, and G. L. Vinyard. 1986. Comparative status of fishes along the course of the pluvial White River, Nevada. Southwest. Nat. 30(4):503–524.
Courtenay, W. R., Jr., D. A. Hensley, J. N. Taylor, and J. A. McCann. 1984. Distribution of exotic fishes in the continental United States. Pages 41–77 *in* W. R. Courtenay, Jr. and J. R. Stauffer, Jr., eds., Distribution, biology, and management of exotic fishes. Johns Hopkins Univ. Press, Baltimore, MD.
Courtenay, W. R., Jr., C. R. Robins, R. M. Bailey, and J. E. Deacon. 1988. Records of exotic fishes from Idaho and Wyoming. Great Basin Nat. 47:523–526.
Dall, W. H. 1915. Spencer Fullerton Baird A Biography. J. B. Lippincott, Philadelphia, PA. 462 pp.
Deacon, J. E. 1979. Endangered and threatened fishes of the West. *In* The endangered species: A symposium. Great Basin Nat. Mem. 3:41–64.
———. 1988. The endangered woundfin and water management in the Virgin River, Utah, Arizona, Nevada. Fisheries (Bethesda) 13(1):18–24.
DeKay, J. E. Zoology of New York—IV: Fishes. W. and A. White and J. Visscher, Albany, NY.
Echelle, A. A. and P. J. Connor. 1989. Rapid, geographically extensive genetic introgression after secondary contact between two pupfish species (*Cyprinodon*, Cyprinodontiade). Evol. 43:717–727.
Fetterolf, C. M., Jr. 1980. Why a Great Lakes Fishery Commission and why a Sea Lamprey International Symposium. Can. J. Fish. Aquat. Sci. 37:1588–1593.
Hocutt, C. H., R. E. Jenkins, and J. R. Stauffer, Jr. 1986. Zoogeography of the fishes of the central Appalachians and central Atlantic coastal plain. Pages 161–212 *in* C. H. Hocutt and E. O. Wiley, eds., The zoogeography of North American freshwater fishes. John Wiley & Sons, New York, NY.
Hoffman, G. L. and G. Schubert. 1984. Some parasites and diseases of exotic fish. Pages 233–261

in W. R. Courtenay, Jr. and J. R. Stauffer, Jr., eds., Distribution, biology, and management of exotic fishes. Johns Hopkins Univ. Press, Baltimore, MD.

Horwitz, R. J. 1982. The range and co-occurance of the shiners *Notropis analostanus* and *N. spilopterus* in southeastern Pennsylvania. Proc. Acad. Nat. Sci. Philad. 134:178–193.

Johnson, J. E. and C. Hubbs. 1989. Status and conservation of poeciliid fishes. Pages 301–317 *in* G. K. Meffe and F. F. Snelson, Jr., eds., Ecology and evolution of livebearing fishes (Poeciliidae). Prentice-Hall, Inc., Englewood Cliffs, NJ.

Jordan, D. S. 1891. A reconnaissance of the streams and lakes of the Yellowstone National Park, Wyoming, for the purposes of the U.S. Fish Commission. Bull. U.S. Fish Commiss. 9:41–63.

Kohler, C. C. and W. R. Courtenay, Jr. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries (Bethesda) 11(2):39–42.

Marsh, P. C. and J. E. Brooks. 1989. Predation by ictalurid catfishes as a deterrent to re-establishment of hatchery-reared razorback suckers. Southwest. Nat. 34:188–195.

McAllister, D. E., S. P. Platania, F. W. Schueler, M. E. Baldwin, and D. S. Lee. 1986. Ichthyofaunal patterns on a geographic grid. Pages 17–51 *in* C. H. Hocutt and E. O. Wiley, eds., Zoogeography of North American freshwater fishes. John Wiley & Sons, New York, NY.

Mills, E. L., J. H. Leach, J. T. Carlton, and C. L. Secor. In press. Exotic species in the Great Lakes: A history of biotic crises and anthropogenic introductions. J. Great Lakes Res.

Minckley, W. L. 1991. Native fishes of the Grand Canyon region: An obituary? Pages 124–177 *in* Colorado River ecology and dam management, National Academy Press, Washington, D.C.

Minckley, W. L. and J. E. Deacon, eds. 1991. Battle against extinction. Univ. Ariz. Press. 517 pp.

Minckley, W. L., D. A. Hendrickson, and C. E. Bond. 1986. Geography of western North American fishes: Description and relationships to intracontinental tectonism. Pages 519–613 *in* C. H. Hocutt and E. O. Wiley, eds., Zoogeography of North American freshwater fishes. John Wiley & Sons, New York, NY.

Moyle, P. B. 1976a. Fish introductions in California: History and impact on native fishes. Biol. Conserv. 9:101–118.

———. 1976b. Inland fishes of California. Univ. Calif. Press, Berkeley, CA. 405 pp.

———. 1986. Fish introductions into North America: Patterns and ecological impact. Pages 27–43 *in* H. A. Mooney and J. A. Drake, eds., Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York, NY.

Moyle, P. B. and R. A. Leidy. 1992. Loss of biodiversity in aquatic ecosystems: Evidence from fish faunas. Pages 127–169 *in* P. L. Fiedler and S. Jain, eds., Conservation biology: The theory and practice of nature conservation, preservation, and management. Chapman and Hill, New York, NY.

Moyle, P. B., H. W. Li, and B. A. Barton. 1986. The Frankenstein effect: Impacts of introduced fishes on native fishes in North America. Pages 415–426 *in* R. H. Stroud, ed., Fish culture in fisheries management. American Fisheries Society, Bethesda, MD.

Murphy, B. R. and D. R. Terre. 1984. Genetic conservation of North American walleye stocks: A review of problems and needs. Unpubl. abstract, 114th meeting of Am. Fish. Soc., Ithaca, NY.

Philipp, D. P., W. F. Childers, and G. S. Whitt. 1983. A biochemical genetic evaluation of the northern and Florida subspecies of largemouth bass. Trans. Amer. Fish. Soc. 112:1–20.

Ramsey, J. S. 1985. Sampling aquarium fishes imported by the United States. J. Ala. Acad. Sci. 56:220–245.

Sheldon, A. L. 1988. Conservation of stream fishes: Patterns of diversity, rarity, and risk. Conserv. Biol. 2:149–156.

Shelton, W. L. and O. Smitherman. 1984. Exotic fishes in warmwater aquaculture. Pages 262–301 *in* W. R. Courtenay, Jr. and J. R. Stauffer, Jr., eds., Distribution, biology, and management of exotic fishes. Johns Hopkins Univ. Press, Baltimore, MD.

Taylor, J. N., W. R. Courtenay, Jr., and J. A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pages 322–373 *in* W. R. Courtenay, Jr. and J. R. Stauffer, Jr., eds., Distribution, biology, and management of exotic fishes, Johns Hopkins Univ. Press, Baltimore, MD.

Waples, R. S., G. A. Winans, F. M. Utter, and C. Mahnken. 1990. Genetic approaches to the management of Pacific salmon. Fisheries (Bethesda) 15(5):19–25.

Fisheries Management and Biological Diversity: Problems and Opportunities

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The carp is . . . a stately, good, and very supple fish (Izaak Walton).

Introduction

For all the attention that "biodiversity" has received in recent years, it is remarkable how little of that attention has focused specifically on fresh water ecosystems. The biological diversity of our freshwater ecosystems is, after all, comparable in many ways to that of our terrestrial ecosystems. For example, the number of fish species in North American fresh waters, about 800, is more than the 650 or so North American breeding bird species. The percentage of species at risk of loss, however, is dramatically greater in our aquatic ecosystems than in our terrestrial ones. More than a third (34 percent) of North American fish species are classified by The Nature Conservancy as rare, imperiled, critically imperiled, extinct or possibly extinct (Master 1990). The comparable figure for birds is only 11 percent, for mammals 13 percent, and for reptiles 14 percent. Among other aquatic taxa, the percentage of rare species is even greater. For example, 65 percent of North American crayfish species are classified as rare or worse under the Conservancy's system, as are 73 percent of the unionid mussels (Master 1990).

Equally alarming is the accelerating rate of loss. According to data compiled by the American Fisheries Society (*see* Miller et al. 1989), the rate of extinction of North American fishes has doubled over the course of this century. Between 1900–1950, 13 species or subspecies of North American (including Mexican) fishes became extinct; from 1951 to the present, 28 have vanished.[1] One in every ten North American freshwater mussel species has become extinct in this century (Master 1990).

Despite the highly imperiled state of much of our freshwater biodiversity, few conservation efforts have focused on it. This is starkly revealed in a comparison of the percentages of species in various groupings that are protected by the Endangered Species Act (*see* Table 1). A much smaller percentage of rare aquatic species is protected under the act than is the case for rare terrestrial species. Nor is protection under the act a sure sign of recovery. According to data compiled by the U.S. Fish

[1]We have added the Maryland darter to the list of extinct fishes in Miller et al. (1989), following news reports in 1991 that it had vanished.

Table 1. Status of select animal groups in North America (Master 1990). Percentage of North American species classified as rare, imperiled, critically imperiled, possibly extinct, or extinct by The Nature Conservancy is compared with the percentage listed as endangered or threatened under the Endangered Species Act. A disproportionately small percentage of rare aquatic organisms is also protected under the Endangered Species Act.

Group	Nature Conservancy	Endangered Species Act
Mammals	13	6
Birds	11	5
Reptiles	14	6
Amphibians	28	3
Fishes	34	7
Crayfishes	65	1
Unionid mussels	73	11

and Wildlife Service, efforts to recover listed fish have been no more or less successful than efforts to recover other listed vertebrates. But efforts to recover listed mussels have been a dismal failure relative to other animals (*see* Table 2).

The threats to aquatic biological diversity are many and familiar. They include the physical alteration of aquatic habitats, the indirect impacts of land use within watersheds, chemical pollution, and deliberate or accidental modification of aquatic biota through species introductions or removals. Fishery managers cannot be indifferent to the threats to aquatic biodiversity for four reasons. First, the loss of aquatic biodiversity can redound to the detriment of fishery resources in which managers are most keenly interested. Second, efforts to protect imperiled aquatic biodiversity may constrain fishery management options. Third, various fisheries management practices have contributed to the loss of aquatic biodiversity and continue to do so. And finally, fisheries managers have the expertise and resources needed to reverse the loss of aquatic biodiversity. This paper explores the interface between fisheries management and aquatic biodiversity. Our aim is to examine the role that fisheries management has played, and could, in the future, play, with respect to the conservation of aquatic biological diversity.

Table 2. Population trends of listed species with recovery plans (U.S. Fish and Wildlife Service 1990).

Species	Increasing or stable	Decreasing or extinct	Unknown
All vertebrates (except fishes) versus fishes			
Vertebrates (except fishes)	68	40	22
Fishes	26	12	11
chi-square = 0.812, d.f. = 2, $p > 0.05$			
All vertebrates (except fishes) versus bivalves			
Animals (except bivalves)	101	58	44
Bivalves	1	27	2
chi-square = 42.91, d.f. = 2, $p \ll 0.005$			

Conflicts Between Fisheries Management and Biodiversity Conservation

While the harm to biodiversity resulting from fisheries management practices if often secondary to the impact of water diversion projects, agricultural and industrial pollutants, and other factors, it is harm nonetheless, and in many cases, easily preventable harm. In this section, we focus on three issues: (1) the introduction of species to areas outside their native ranges; (2) the release of hatchery-reared fish; and (3) the use of lead fishing weights.

Species Introductions

Perhaps the single most harmful impact of fisheries management on aquatic biodiversity stems from the introduction of fish into waters outside their natural ranges. Introductions are pervasive and continuing. Moyle et al. (1986) estimated that 25–50 percent of the freshwater fishes caught by anglers in the continental United States are from populations established through introductions. The practice, moreover, is nearly as old as fisheries management itself. Carp, whose virtues Izaak Walton so rapturously extolled, were introduced into the Hudson River in New York in 1831 or 1832, the first documented introduction of an exotic fish into North America (Moyle et al. 1986). Since that time, at least six other foreign species have become established within the coterminous United States following their introduction as game fish, and 53 native species have been moved outside their original U.S. ranges for the same purpose. Another 58 native species have expanded their ranges as a result of releases from bait buckets (*see* Courtenay and Taylor 1984).

If Izaak Walton's enthusiasm for the carp is no longer universally shared, neither is fish introduction in general acclaimed as an unqualified good. Among the environmental costs associated with it is the loss of much native aquatic biodiversity, including the native fishes in many rivers and lakes. In reviewing the causes of the extinctions of North American fish in the past century, Miller et al. (1989) concluded that introduced species were a contributing factor in 68 percent of these extinctions; only habitat loss exceeded species introduction in its frequency as a factor contributing to extinction.

Our own analysis confirms the extent to which game fish introductions are harming endangered aquatic species. As of July 1991, 86 species, subspecies and populations of U.S. fish were listed as threatened or endangered under the Endangered Species Act. Forty-four are threatened to some degree by introduced fishes (Bean 1991). Of these 44 fishes, at least 29 are threatened by species introduced in connection with sport fisheries, including both the deliberate introduction of game fish by fisheries managers and the accidental or deliberate release of bait fish by fishermen (Table 3). Transplanted trout are harming at least 11 listed species through hybridization, predation and competition.

Some researchers (Kaiser 1991, Orchard 1992) have expressed concern that introduced predatory fishes are reducing populations of native amphibians. In informal conversations with us, fisheries experts from five states agreed that there is a correlation between the introduction of game fishes in lakes and subsequent declines in frog populations.

The ecological consequences of species introductions are notoriously difficult to predict. The introduction of a freshwater shrimp in the Flathead River-Lake ecosystem

Table 3. Endangered fishes threatened by introduced game and bait fish.

Endangered fish[a]	State	Introduced species threat[b]	Introduction purpose[c]
Apache trout	Arizona	Competition with non-native fishes, including brook trout, rainbow trout and brown trout; interbreeds with brown trout	Game release
Ash Meadows Amargosa pupfish	Nevada	Predation from largemouth bass	Game release
Beautiful shiner	Nevada	Competition and interbreeding with red shiner	Bait release
Blackside dace	Kentucky and Tennessee	Competition with southern redbelly dace	Bait release
Bonytail chub	California and Nevada	Competition with non-native fishes such as red shiner and redside shiner	Bait release
Clover Valley speckled dace	Nevada	Predation by rainbow trout, bass and sunfish	Game release
Colorado squawfish	Colorado and Utah	Competition and possible parasite transmission from introduced fishes, including red shiner, redside shiner and green sunfish	Bait and game release
Comanche Springs pupfish	Texas	Predation from green sunfish; hybridization with sheepshead minnow	Bait and game release
Desert pupfish	Arizona	Predation from introduced fishes, including tilapia and largemouth bass	Game release
Gila trout	Arizona and New Mexico	Hybridization with non-native trout	Game release
Greenback cutthroat trout	Colorado	Hybridization with rainbow trout, Yellowstone cutthroat trout; competition with brook trout and brown trout	Game release
Independence Valley speckled dace	Nevada	Predation from non-native dace, trout and bass	Bait and game release
Little Kearn golden trout	California	Hybridization with rainbow trout	Game release
Loach minnow	Arizona and New Mexico	Predation from black bullhead, yellow bullhead, channel catfish, flathead catfish, smallmouth bass, largemouth bass, brown trout; competition with red shiner	Bait and game release
June sucker	Utah	Competition with and predation from largemouth bass, black bullhead, channel catfish, carp, white bass and walleye	Game release
Little Colorado spinedace	Arizona	Predation from black bullhead, channel catfish, yellow bullhead, green sunfish, largemouth bass and brown trout; competition with rainbow trout	Game release

Endangered fish[a]	State	Introduced species threat[b]	Introduction purpose[c]
Mohave tui chub	California	Hybridization with arroyo chub; competition for food with more aggressive non-native fishes	Bait and game release
Owens pupfish	California	Predation from largemouth bass	Game release
Owens tui chub	California	Predation from brown trout	Game release
Paharanagat roundtail chub	Nevada	Competition with non-native fishes, including carp	Game release
Paiute cutthroat trout	California	Competition and interbreeding with non-native trout	Game release
Razorback sucker	Colorado and Arizona	Predation by carp, green sunfish, channel catfish, flathead catfish	Game release
Shortnose sucker	California and Oregon	Competition with flathead minnow; predation from yellow perch and possibly bullheads, largemouth bass, crappie, green sunfish and Sacramento perch	Bait and game release
Spikedace	Arizona and New Mexico	Non-native predators and competitors such as rainbow trout, smallmouth bass, channel catfish and red shiner	Bait and game release
Virgin River chub	Arizona, Nevada and Utah	Competition with red shiner; possible parasite transmission too	Bait release
Warner sucker	Oregon	Predation by exotic centrarchid and ictalurid fishes, especially crappie (*Pomoxis* spp.)	Game release
Woundfin	Arizona	Competition with red shiner	Bait release
Yaqui catfish	Arizona	Hybridization with channel catfish and blue catfish	Game release
Yaqui chub	Arizona	Predation from introduced fishes, such as largemouth bass, bluegill, black bullhead, channel catfish and green sunfish	Game and commercial release

[a]All are listed as either threatened or endangered under the Endangered Species Act.
[b]Sources: Endangered Species Technical Bulletin, Lowe et al. (1990).
[c]Sources: Ono et al. (1983); Courtenay and Taylor (1984); Lowe et al. (1990); Page and Burr (1991); U.S. Fish and Wildlife Service (1992); G. Devine (personal communication); Endangered Species Technical Bulletin; Federal Register.

by the State of Montana resulted in an unexpected collapse of zooplankton populations, which, in turn, triggered a dramatic decline of plankton-feeding kokanee salmon (themselves an introduced species). The decline in kokanee, in turn, led to the abandonment of a long-established bald eagle aggregation area that had generated significant local tourism (Spencer et al. 1991). None of these consequences was foreseen.

This, and other examples like it, are fueling second thoughts about the wisdom of further species introduction efforts. Indeed, federal legislation enacted in response to the accidental introduction of the zebra mussel into U.S. waters, the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, establishes a federal interagency task force and charges it, among other things, with developing appropriate policies to address the intentional introduction of nonindigenous aquatic organisms into U.S. waters. Significantly, the scope of the legislation extends not just to what have traditionally been considered "exotic" (i.e., foreign) species but to native species outside their natural range.

Hatcheries

In addition to the impacts of fishery management upon aquatic biodiversity generally, there are potentially deleterious impacts upon the species and stocks of fish that are themselves the targets of management. This is shown most dramatically in the situation now unfolding in the Pacific Northwest. A half a century ago, when the first big hydroelectric dams were being built on the Columbia River, the needs of anadromous fish were very actively considered by engineers and fishery managers alike in the planning for those projects. Referring to plans for hatcheries, fish ladders and other conservation strategies, a committee of the American Fisheries Society (James 1937) concluded that "No possibilities, either biological or engineering, have been overlooked in designing a means to assure perpetuation of the Columbia River salmon."

By one measure, they succeeded: Salmon have been perpetuated in the Columbia River system. But that success was achieved at the cost of the genetic diversity, and, therefore, very likely the resilience, of the wild salmon resource. At least 106 naturally-spawning stocks of salmon, steelhead and sea-run cutthroat trout from the Columbia and other river systems of the Pacific coast have been irretrievably lost; another 159 are sufficiently in peril that they are considered to be at high or moderate risk of extinction and may require protection under the Endangered Species Act (Nehlson et al. 1991). Two stocks, winter run chinook salmon of the Sacramento River and Snake River sockeye salmon, already have been given that protection.

Important as the hydroelectric dams were in creating the problems that Northwest salmon now face, they were not the sole culprits. Many of the "solutions" that the fisheries management profession embraced created their own new set of problems. Hatcheries were constructed to produce huge numbers of fish to offset those lost to the dams. What they produced were genetically similar fish that swamped many genetically distinctive wild runs. Indeed, according to one authority, the only reason wild sockeye salmon still survive in the Snake River is because hatcheries there have failed (D. Chapman personal communication). In the long-term, hatchery programs may pose the greatest single threat facing salmon in the Pacific Northwest (Hilborn 1992).

Commercial harvest strategies also have contributed to the erosion of genetic diversity among this singularly important fishery resource. The salmon fisheries of the Pacific Northwest consist of many different stocks, some relatively abundant and robust, others much less so. Management strategies aimed at maximizing overall fish harvest took advantage of the hatchery stocks' ability to withstand harvest rates that native stocks could not. As a result, fishing pressure itself contributed to the decline of many of these native stocks. The implications for future fisheries management are potentially quite significant. In order to preserve the genetic diversity of wild salmon, harvest strategies may have to be devised that will shift harvest pressure onto strong stocks, particularly hatchery fish, and away from weak, wild stocks. One means of doing so is by marking hatchery fish with fin tags, while replacing lethal capture methods (e.g., gill nets) with live capture methods (e.g, fish traps) that allow release of the wild fish. Such changes are expensive, but technically feasible (D. Chapman personal communication).

Sport fishing also can suffer when hatchery-reared fish are added to natural populations. Introduced fish may disrupt locally adapted gene pools, and behavioral differences between hatchery-bred and native stocks can lead to increased intraspecific aggression (Goodman 1991, Ferguson 1990).

The importance of preserving genetic diversity in fish populations is becoming increasingly apparent to fisheries managers. In some respects, this change in attitude mirrors a similar transformation well underway in forestry. The preservation of genetic diversity in commercially valuable trees is seen by many foresters as an essential part of silviculture (Silen and Doig 1976, Millar 1987), and the planting of monocultures of genetically uniform trees has come under attack.

Lead Sinkers

While the potential problems associated with the use of lead sinkers are only now beginning to surface, we are sufficiently concerned about this issue to bring it to the attention of fisheries managers. In Great Britain, the deaths of numerous mute swans, first noted in 1973, prompted an intensive search for causes. Following a flurry of studies, the deaths were conclusively tied to the ingestion of lead fishing sinkers (Simpson et al. 1979, Birkhead 1981, 1982, Sears 1988, Birkhead and Perrins 1985). In the United States, evidence of a similar problem has come from Pokras' recent study (in press) of common loon mortality in New England. Of 33 adult loons found dead and submitted for autopsy, 19 (57 percent) were determined to have died from ingesting lead fishing sinkers. Although common loons are not on the federal list of endangered and threatened species, they are considered to be a sensitive and declining species throughout much of New England. Given both the popularity of fishing and the toxicity of lead, we would not be surprised to see similar incidents involving other species of birds and aquatic organisms in the future. Anecdotal reports suggest this already is happening.

Legislative efforts to abolish lead sinkers have been strongly opposed by manufacturers of fishing weights. In this respect, the controversy over sinkers parallels the long and bitter debate over lead shot. Only when the problem of poisoned waterfowl and bald eagles had grown too big and obvious to ignore did the U.S. Fish and Wildlife Service restrict the use of lead shot in waterfowl hunting.

The Dingell-Johnson Act: A Missed Opportunity?

When asked why he robbed banks, the infamous Willie Sutton replied, "That's where the money was." With respect to sports fisheries, the "bank" is the Federal Aid in Sport Fish Restoration Act, more commonly known as "Dingell-Johnson." Enacted in 1950 to restore America's degraded sport fisheries, the act is widely perceived to be one of our most successful conservation programs. Hundreds of millions of dollars have been raised to undertake a vast array of projects geared towards restoring, managing and improving sport fisheries in the United States, as well as providing more opportunities for people to enjoy fishing. Yet, despite these efforts, the overall condition of freshwater biodiversity in North America has continued to deteriorate. It is time to ask whether this important act can be used to improve the situation. Doing so is surely in the long-term interests of the sport fishing community.

According to preliminary data complied by the U.S. Fish and Wildlife Service (Table 4), a total of $154.7 million was spent in FY90 under Dingell-Johnson. Of this amount, approximately $18.0 million (11.6 percent) was spent on fish stocking programs, and $14.2 million (9.2 percent) was spent to develop user facilities, such as boat ramps and fishing access sites.

We contacted fisheries managers in 15 states to identify the fish species used in restocking programs. Many were species known to be harmful to various endangered species (Table 3). An additional concern, discussed earlier, is the impact of hatchery strains on wild genotypes. While Dingell-Johnson mandates that a percentage of the funds be spent on user facilities, such facilities are at best neutral to aquatic biodiversity, and may even be harmful if public access leads to bait-bucket introductions of non-indigenous fishes or the deposition of lead sinkers.

Only $4.5 million (2.9 percent) was spent on land acquisition, and much of this may have gone to acquire land for parking lots, campgrounds and hatcheries, as opposed to protecting spawning areas or other sensitive natural habitats. A total of $7.9 million (5.1 percent) was spent on habitat improvement projects.

In contrast, the total federal expenditures that could be identified to species for the conservation of threatened and endangered fishes, clams, and crustaceans was only $11.3 million during the same fiscal year (U.S. Fish and Wildlife Service 1991)—significantly less than Dingell-Johnson expenditures for fish restocking or developing user facilities.[2]

[2]The breakdown for endangered species is as follows: fishes $10,291,000; clams $850,000; and crustaceans $138,300.

Table 4. Expenditures under the Federal Aid in Sport Fish Restoration Act for fiscal year 1990, based on preliminary data supplied by the U.S. Fish and Wildlife Service, Division of Federal Aid.

Expense category	Amount	Percentage of total
Area and facility maintenance	$16,144,169	10.4
Fish stocking development	17,955,029	11.6
User facility development	14,207,691	9.2
Support facility development	512,498	0.3
Investigations	71,504,800	46.2
Aquatic education	3,347,781	2.2
Planning and administration	10,456,138	6.8
Technical guidance	5,724,762	3.7
Land acquisition	4,543,362	2.9
Habitat improvement development	7,874,460	5.1
Impoundment development	2,444,271	1.6
Total	$154,714,961	100.0

This analysis suggests that Dingell-Johnson funds are doing relatively little to prevent the loss of freshwater biodiversity in the United States and, in some cases, may even be exacerbating the problem. The challenge is to make the restoration of sport fisheries part of the restoration of aquatic biodiversity in general. In the long term, the two goals are not only compatible—they are probably inseparable.

Recommendations

Species Introductions

What are responsible policies relating to the intentional introduction of nonindigenous fish or other aquatic organisms into U.S. waters? At a minimum, four needs seem apparent. First, pre-introduction ecological baseline studies are essential in order to ascertain later what the effects of any introduction actually were. Second, those proposing an intentional introduction ought to be made to bear the cost of control efforts or unanticipated damages when an introduction produces unexpected harmful results. Third, follow-up studies are essential to determine not just the success of the introduction, but the impacts it may have had on other resources, especially native biological diversity. Finally, where a proposed introduction has the potential to affect neighboring states, as many aquatic introductions surely do, comity among states and a respect for the right of each state to manage its own native wildlife resources ought to require that potentially affected states concur with the introduction proposal.

Hatcheries and Genetic Diversity

Introduced genes can be as harmful as introduced species, especially when hatchery-bred fish compete with wild populations. Concern over massive restocking programs reflects a growing appreciation for the importance of preserving genetic diversity in wild fish populations. At a time of accelerating environmental change (including the specter of global climate change), the genetic diversity of wild populations may be the key to the long-term survival of many species. Moreover, since patterns of genetic diversity are poorly known for most fish species, fisheries managers should strive to maintain healthy populations of native fishes throughout their natural ranges and to be particularly careful to protect disjunct populations as well as those at the margins of the species' geographical or altitudinal range.

Lead Sinkers

All too rarely are wildlife professionals given the opportunity to correct a problem before it becomes a crisis. Such is the case with lead sinkers. Studies in Great Britain and New England demonstrate the harm to birds from ingesting lead sinkers. Other species could be affected, too. Now is the time for fisheries professionals to push for a ban on the use of lead in fishing sinkers. Further delay will only result in more severe environmental problems and greater resistance from manufacturers. A replay of the prolonged battle that preceded restrictions on the use of lead shot for waterfowl hunting is in no one's best interest.

Dingell-Johnson

The Dingell-Johnson program has made possible tremendous growth in recreational fisheries, but the goal of increasing fishing opportunities has largely supplanted the original aim of sport fish "restoration." In the process, much of the native biological diversity of our aquatic systems has been subjected to still further stress beyond that caused by habitat loss, pollution and other factors. The Dingell-Johnson program would appear to have enormous potential to lead the way toward a new era of fishery management in which much greater sensitivity to conserving the genetic diversity of game fish and the biological diversity of the waters they occupy characterizes decisions about species introductions, use of hatchery fish and other matters. We recommend that the Fish and Wildlife Service assume a more active role in this regard; it should be more than a funnel through which money passes to the states. The Service should encourage and reward state management efforts that seek to marry the two very important conservation objectives of providing ample fishing opportunities and sustaining our rich diversity of aquatic life.

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References

Bean, M. J. 1991. The role of the United States Department of the Interior in nonindigenous species issues. Rept. to the Off. Tech. Assessment. Environmental Defense Fund, Washington, D.C. 86 pp.

Birkhead, M. 1981. How the fishermen kill the swans. New Scientist, April 2.

———. 1982. Causes of mortality in the mute swan *Cygnus olor* on the River Thames. J. Zool., London. 198:15–25.

Birkhead, M. and C. Perrins. 1985. The breeding biology of the mute swan *Cygnus olor* on the River Thames with special reference to lead poisoning. Biol. Conserv. 32:1–11.

Courtenay, W. R., Jr. and J. N. Taylor. 1984. The exotic ichthyofauna of the contiguous United States with preliminary observations on intranational transplants. Pages 466–487 *in* E.I.F.A. Commission Symposium on Stock Enhancement in the Management of Freshwater Fisheries, Budapest, Hungary, May 31–June 2, 1982. E.I.F.A.C. Tech. Pap/Doc Tech CEPCPI 42.

Ferguson, M. M. 1990. The genetic impact of introduced fishes on native species. Can. J. Zool. 68:1053–1057.

Goodman, B. 1991. Keeping anglers happy has a price. BioScience 41:294–299.

Hilborn, R. 1992. Hatcheries and the future of salmon in the Northwest. Fisheries 17(1):5–8.

James, M. C. 1937. Report of the Division of Commercial Fishing presented at the 67th Annual Meeting of the American Fisheries Society *in* Nehlsen, W., J. E. Williams, and J. A. Lichatowich, 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries (Bethesda) 16:4–21.

Kaiser, H. 1991. Declining amphibians. Canadian Assoc. Herpetologists Bull. 5(2):1–4.

Lowe, D. W., J. R. Matthews, and C. J. Moseley, eds. 1990. The official World Wildlife Fund guide to endangered species of North America. Beacham Pub., Washington, D.C. 1180 pp.

Master, L. 1990. The imperiled status of North American aquatic animals. Biodiversity Network News 3:1–8.

Millar, C. 1987. The California forest germplasm conservation project: A case for genetic conservation of temperate tree species. Conservation Biology 1:191–193.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries (Bethesda) 14:22–38.

Moyle, P. B., H. W. Li, and B. A. Barton. 1986. The Frankenstein effect: Impact of introduced fishes on native fishes in North America. Pages 415–426 *in* R. H. Stroud, ed., Fish culture in fisheries management. Am. Fish. Soc., Bethesda, Maryland.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich, 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4–21.

Ono, R. D., J. D. Williams, and A. Wagner. 1983. Vanishing fishes of North America. Stone Wall Press, Washington, D.C. 257 pp.

Orchard, S. A. 1992. Amphibian population declines in British Columbia. *In* C. A. Bishop and K. E. Pettit, eds., Declines in Canadian amphibian populations: Designing a national monitoring strategy. Canadian Wildl. Serv. Occas. paper. In press.

Page, L. M. and B. M. Burr. 1991. A field guide to freshwater fishes. Houghton Mifflin, Boston, MA. 432 pp.

Pokras, M. A. In press. Problems encountered with common loons in New England. J. Zoo and Widl. Med.

Sears, J. 1988. Regional and seasonal variations in lead poisoning in the mute swan *Cygnus olor* in relation to the distribution of lead and lead weights, in the Thames Area, England. Biol. Conserv. 46:115–134.

Silen, R. and I. Doig. 1976. The care and handling of the forest gene pool. Pacific Search 10(8):7–9.

Simpson, V. R., A. E. Hunt, and M. C. French. 1979. Chronic lead poisoning in a herd of mute swans. Environ. Pollut. 18:187–202.

Spencer, C. N., B. R. McClelland, and J. A. Stanford. 1991. Shrimp stocking salmon collapse, and eagle displacement. Cascading interactions in the food web of a large aquatic ecosystem. BioScience 41:14–21.

U.S. Fish and Wildlife Service. 1990. Report to Congress: Endangered and threatened species recovery program. U.S. Govt. Print. Off., Washington, D.C. 406 pp.

———. 1991. Federal and state endangered species expenditures. Fiscal year 1990. U.S. Fish and Wildl. Serv., Washington, D.C.

———. 1992. Final draft biological opinion for the operation of Flaming Gorge dam. U.S. Fish and Wildl. Serv., Denver, CO.

Functional Coastal-marine Biodiversity

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Introduction

This paper focuses on the functional diversity of coastal and marine systems and their differing management and conservation requirements. Biological diversity (i.e., biodiversity) usually has been defined on three levels—genetic, species/population and ecosystem (Office of Technical Assessment [OTA] 1987, Wilson and Peter 1988). The biodiversity of coastal and marine environments is extraordinarily high in all respects, but information on the genetics and species levels is particularly deficient. Even less well understood is the relationship of biodiversity to ecological function (Grassle et al. 1990). This is partly because marine systems are inherently difficult to study and partly because they continue to be "out of sight, out of mind to most people, including most scientists" (Ray and Grassle 1991), despite the fact that marine systems are almost twice as diverse at higher taxonomic levels than terrestrial systems (Ray 1985, May 1988, Grassle et al. 1990).

Biodiversity conservation traditionally has been modelled after terrestrial practices, which have emphasized large, endangered, charismatic species and the prevention of their extinction, most particularly in the tropics (e.g. McNeely et al. 1990). A strongly terrestrial bias continues to be evident in strategy documents (*see* IUCN, UNEP, WWF 1991; WRI, IUCN; UNEP 1992). However, in the marine environment, only a minute portion of the species are large, charismatic or on the verge of extinction. And while terrestrial species increase in diversity and richness from polar to tropical regions, such a gradient is not the case for many marine taxa (e.g., marine mammals) or even for nearshore and beach communities (Dexter 1992).

The functional aspects of biodiversity—terrestrial or marine—have received relatively little attention in conservation circles. Functionally, marine and terrestrial ecosystems exhibit very different time/space scales and responses to change. This is a major reason that the conservation of the biodiversity of marine systems cannot follow terrestrial examples. Thus, there is a need for new paradigms for identifying and conserving our coastal-marine diversity.

Oceanographers and most coastal scientists have long emphasized a functional approach. Steele (1991) proposed "functional diversity" to describe "the variety of different responses to environmental change, especially the diverse space and time scales with which organisms react to each other and to the environment." Diverse biological, ecological and physical interactions occur within the coastal and ocean land- and seascape to produce highly dynamic and variable mosaics of ecosystems. Thus, we recognize estuaries, mudflats, oyster reefs, coral reefs, sea grass beds, algal communities, large pelagic areas of importance to commercial fisheries, etc. These ecosystems are organized hierarchically and can be characterized by their time/space properties, their productivity, amenities to people, criticalness to dependent species, integrity over time, and a wide variety of other parameters. In order to comprehend this diversity, many questions must be addressed, for example: How do patterns of ecosystems compare functionally among different regions (i.e., the Coastal Virginian Province versus the Carolinian Province)? How does regional diversity relate to global diversity? To what extent is species diversity related to ecosystem function? Has human disturbance been responsible for the present alterations of ecosystem function that can be observed for many coastal-marine regions?

Answers to such questions require a comparative information base, and a research and monitoring program that can assess the functional aspects of biodiversity. Essential to the emphasis on function is, first, the recognition of the coastal zone as the global ecotone between land and sea. This zone extends from the continental plains to the continental slope (Ketchum 1972, Hayden et al. 1984). So important is this zone, that the International Geosphere-Biosphere Programme (IGBP) is presently developing a subprogram entitled "Land-Sea Interactions in the Coastal Zone" (Holligan 1990, 1991). The rational for this subprogram is that the coastal zone is critical to understanding how terrestrial, marine, and atmospheric processes interact. A sense of urgency is gained when one recognizes that the major portion of humanity also occupies this zone, with the probable consequence that it is among the most threatened major realms of Earth—at least on the same level of threat as forests, but on a much greater scale.

Second, we must recognize that a major portion of coastal and marine interactions concerns the living component, that is, the hierarchical biodiversity of ecosystem organization. Species and species' communities interact with physical and biotic variables at a number of spatial and temporal scales. The response of species communities to physical variables (e.g., ocean currents) is particularly important at large scales, whereas interactions among the biota (e.g., competition and predation) are most obvious at smaller scales. As a terrestrial example, Chown (1992) found that interspecific competition determined weevil assemblage structure at the local level, but that geologic and climatic disturbances were necessary to explain this structure at the regional level.

So little is known about species and community biodiversity of coastal-marine environments (Grassle 1991) that a land- and seascape, i.e., systems level, approach will prove more useful for conservation and management. We propose that the relationships among mosaics of ecosystems and between diversity and ecosystem function can be made more clear through the creation of a *functional environmental systematics*, analogous to the systematics of species and species groups that has proven vital for comprehension of evolutionary processes. At first, emphasis should be on the large-scale, regional level, but later should include the diversity of life forms and their natural histories, as data become available.

Requirements for an Environmental Systematics

Classification of terrestrial environments is far more advanced than for coastal-marine environments. Terrestrial classifications most often describe biogeographic-climatic regimes or biotic realms and provinces and thus can be interpreted functionally to achieve the level of "systematics" (*see* Holdridge 1967, Udvardy 1975, Bailey 1989). Nevertheless, there is no shortage of useful coastal-marine classifications. Watershed boundaries have been identified and regionally classified (U.S. Water Resources Council 1978). Thom (1984) summarized the coastal classifications for Australia and Roy (1984) has classified New South Wales estuaries. Cowardin et al. (1979) present a classification of wetlands and deepwater habitats of the U.S., which also could serve other regions. Functional classifications of coastal-marine environments also include those of Inman and Nordstrom (1971), which concentrate on multi-scaled geologic processes, and Hayden et al. (1984), which is mainly concerned with biogeography.

There are three major requirements for a useful systematics of coastal-marine biodiversity. The first is that it be functional. This approach is very different from indices of species richness or other measures of biodiversity, that can interpret ecosystem function only indirectly. For example, sea grasses occur in many nearshore systems, but does the temperate sea grass, *Zostera*, serve the same role as the tropical *Thalassia*? Is the function of the mangrove, *Avicennia*, the same in cool, temperate, Victoria, Australia, as it is in warm, tropical northern Queensland, Australia? Answers to such questions are needed to clarify functional attributes.

A second requirement is that the systematics aim at the ecosystem level of organization to reveal how superficially-similar systems may require very different management as a result of geographic location, regional setting, or human-use patterns. The Chesapeake and San Francisco bays are among the largest extended estuarine systems in the continental U.S. and, as for most estuaries, are of critical importance to human economies. Their drainage sizes are comparable and they both share many similar characteristics. They also share distinct attributes and environmental problems. The Chesapeake Bay consists of a complex network of coastal plain river valleys in the relatively flat and wet eastern seaboard of the U.S. The San Francisco Bay is not situated in a flat and extensive coastal plain. Rather, its drainage pattern and human uses are affected by coastal mountain formations (Wright and Phillips 1988) and a much drier climatic regime. Furthermore, California has a narrow continental shelf, a factor that influences estuarine mixing in very different ways than for Chesapeake Bay, which faces a very wide shelf. Water quality problems are common to both systems, but Cheasapeake Bay is more affected by over-enrichment and oxygen depletion, whereas San Francisco Bay is more affected by the accumulation and biotoxicity of trace metal contamination. Both bays have experienced decreases in the anadromous striped bass (*Morone saxatilis*) but for the Chesapeake Bay, where this species is native, declines are attributed mainly to overfishing, nutrient enrichment, and deterioration of nearshore habitat. The decline of striped bass in San Francisco Bay, where it has been introduced, is attributed to the interactive effects of reduced freshwater outflow, increased freshwater diversion, decreased bay flushing and increased pollutant burdens (Setzler-Hamilton et al. 1988).

A third requirement for the proposed systematics is that it be comparative. It would be useful to differentiate and compare small, discontinuous systems of relatively low species richness from large, patchy systems of variable richness and from relatively even systems of differing time/space properties (di Castri and Younes 1990). The purpose of an environmental systematics is to highlight these functional differences in terms of characteristic patterns and processes, and relate what is learned about one system to solving problems for others.

Hypothesis Development

The requirement for a functional, process-oriented and comparative biodiversity systematics demands that ecological concepts be made explicit, preferably in the form of testable hypotheses. Biodiversity has become the primary goal of present-day conservation and many aspects of management. Unfortunately, as Angel (1991) has observed: "Like so many buzz-words, biodiversity has many shades of meaning and is often used to express vague and ill-thought-out concepts." This lack of clarity is partly because of the complexity and breadth of the subject. As Solbrig (1991) has stated: "Diversity is a fundamental property of every living system. Because biological systems are hierarchical, diversity manifests itself at every level of the biological hierarchy, from molecules to ecosystems." The development of hypotheses on which to build either a research program or a basis for conservation and management is made especially challenging by this all-inclusive nature of biological diversity.

Although all environments consist of hierarchical and functionally dynamic mosaics, coastal-marine environments are distinguished by especially complex temporal and spatial scales of dynamic interactions. Generally, coastal-marine environments function at much larger scales than terrestrial systems, but with shorter response times. In addition, terrestrial primary producers (plants) provide the bulk of biomass, are relatively long-lived, and can be very large. For most coastal-marine environments, consumers provide the greatest biomass, and the plants are characterized by their small size and high rate of turnover. The nearer to shore, the more we observe a mix of these terrestrial and marine characteristics.

Steele (1991), in addressing the functional aspects of marine diversity, posed the following questions: How do these various ecological systems change through time? How diverse are their rates of change? How rapidly or slowly do these differing communities respond to their physical and chemical environments? Grassle et al. (1991) and Solbrig (1991) proposed many hypotheses related to such questions, samples of which are given in Table 1. Hypothesis 4, for example, considers the effects of fragmentation of habitat. The prediction, made on the basis of island biogeographical theory, is that fragmentation and alteration of patch size will dramatically alter species richness. Yet, there is virtually no proof of this for marine communities, despite the fact that it is intuitively attractive and perhaps correct. Similarly, hypotheses 5 and 6 relate functional groups and species richness to spatial configuration. This is important because conservation and management fundamentally concern human alterations of habitat pattern and ecological process.

Table 1. Hypotheses on biodiversity and ecosystem function (from: Grassle et al. 1991, Solbrig 1991).

1. The spectrum of environmental variation is fundamentally different in marine and terrestrial ecosystems.
2. Biogeographic patterns of biodiversity and ecosystem function are determined by a combination of environmental patterns, i.e., single-factor theories are not viable.
3. Offshore primary production and nutrient cycling are dominated by pelagic processes that determine biogeographic differences in biodiversity.
4. Habitat fragmentation has no effect on extinction probability.
5. Spatial heterogeneity of the regional land and seascape has no effect on the number of functional types of coexisting species in a local community.
6. Removals and/or additions of functional groups that produce changes in spatial configuration of land- and seascape elements will have no significant effect on ecosystem functional properties over a range of time and space scales.

Provided that it is hypothesis-based, an environmental systematics can facilitate distinctions and relationships among types of ecosystems by identifying their different controlling mechanisms. One major purpose of an environmental systematics is to provide a basis for comparing characteristic attributes that are in common or unique among different regions of the world. Also, the systematics should allow us better to identify and measure the diversity of habitats and ecosystems that occur within and among regions. It should allow us to understand better the functioning of ecosystems at various scales of resolution and to understand better the differences or similarites among species that occur in different regions. In short, a functionally oriented and comparative environmental systematics would contribute towards the precise and factual information needed for conservation of biodiversity and also would provide for better management responses to human disturbances.

Patterns of coastal-marine ecosystems can be recognized at various scales and for different purposes by examination of different biologic responses to complex physical changes in the environment. The responses, for example, of diatoms in the California current to climatic fluctuations are so varied and complex that special tools, such as principal components analysis, are needed to reveal changes in the composition of this primary producer community (Tont 1987). Another example concerns the spatial distribution of species in estuaries. The Chesapeake and Delaware bays are both moderately stratified estuaries, defined by circulation patterns produced by the interaction of marine and fresh waters, seasonal flow, and tidal action, of the East Coast coastal plain (Pritchard 1967). Differences between them can be made clear when characteristic range patterns of fish are identified. The spatial distributions of fishes and invertebrates in estuaries are controlled by physiological and physical interactions. Bulger et al. (1989) reported complex fish and invertebrate distributions for the Chesapeake Bay, for which five species assemblages were shown to be related to salinity regimes. Does Delaware exhibit the same patterns of biotic/physical interactions? An environmental systematics could emphasize differences or similarities.

Large-scale biogeographic patterns are consistent over time, as are certain processes such as productivity. Differences among systems in these respects may be revealed by species range patterns or assemblages of species that can be recognized over regionally definable geographical settings. Although individual species may vary annually, the variance of the total is less than the sum of the variance of the individual species, as exemplified for fisheries catch (Sissenwine 1986). Of course, sustainment of the patterns observed depends greatly on the dispersal ability of organisms (Buzas and Culver 1991), on historical factors (Ricklefs 1987), physical and biological thresholds, and on break points in ecosystems (May 1977).

Natural productivity and physical disturbance regimes also can be useful in characterizing patterns of ecosystems. These two processes are hypothesized to be among the major causative factors of species and community biodiversity (Huston in press). Emphasis, in these cases, is placed on rates of change and how environmental gradients may result to produce ecotones (Ray and Hayden 1992), e.g., differences among rapidly changing systems (barrier beaches and islands) and relatively slowly changing systems (slope benthos, mature forests).

Finally, the alteration of patterns at all scales may result from human uses. In the coastal zone, this is most obvious as habitat disturbance, particularly in estuaries and lagoons and along beaches. The effect of human impact is to alter the time/space properties of ecosystems, and thus their individual and aggregated functions.

For example, some coastal environments are highly perturbed by man (deep water ports of mid-Atlantic estuaries), whereas other Atlantic estuaries have been less influenced by humans, e.g., some well protected coastal wetlands of the Carolinian-Atlantic region and the rugged coasts of Maine. The major differences among such systems are best revealed by changes in their scale-dependent properties.

A complete description of the methods for coastal-marine environmental classification is beyond the scope of this paper. Nevertheless, it is clear that regions and their subregions can be described by many attributes, which can also introduce great and probably undesired complexity. Hence, in development of an environmental systematics, the salient points include, first, that a variety of scientific tools and functional attributes are needed. Second, it is dubious that any of the patterns revealed can be explained by single factors alone. Third, the stability or predictability of some systems may only be a function of the scale of observation (Jackson 1991). Increasingly needed are evolving scientific tools, such as modelling tools and geographic-information-system technology, to help us understand the inherent complexity of ecological organization, and so that we can better understand and manage ecosystems for sustainment of biodiversity.

Examples of Functional Units

We will now describe some examples that together have the potential for developing a coastal-marine environmental systematics.

The large marine ecosystem concept. Regional seas have lately become known as "large marine ecosystems" or LMEs, ". . . characterized by unique hydrographic regimes, submarine topography, and trophically-dependent populations" (Sherman 1986). Even though the LME concept described by this author is principally oriented towards resource management, it is based soundly on the known distributions of major populations of marine organisms and on such functions as primary productivity. LMEs are dependent to varying degrees on coastal-zone interactions. Most LMEs lie over continental shelves. Others occur in upwelling areas that may be oceanic and offshore—that is, not over continental shelves, in which case, the land/sea coupling is weaker. As for nearshore processes and functional interactions, estuaries and lagoons may play a significant role in the productivity of these systems.

Hayden et al. (1984) approached the task of a global-scale environmental systematics for coastal and marine environments by describing oceanic realms on a traditional physical basis, and coastal realms and provinces both physically and biologically. For coastal areas, the physical and biotic provinces proved to be reasonably well matched. The advantages of this scheme are: (1) that it is comparative in that similar provinces with similar properties could be associated, and (2) that it is hierarchical, accounting for certain global and regional features. The major flaws are: (1) that it is at too large a scale to be useful for identifying sites representative of coastal-marine biodiversity at the subregional level and (2) that it is not three-dimensional and therefore, does not reflect the true nature of marine systems.

Ray and Hayden (1992) scaled down to the subregional level in describing how hydrological regimes could be used for coastal classification. Again, their scheme was both comparative and hierarchical, but associations between physical processes and the biota were not attempted. The question now becomes: how may a comparative coastal-marine, environmental classification be developed that can serve the specific purposes of describing and conserving coastal-marine biodiversity? It is important that this be done so that what is learned at one site can be translated functionally to other sites.

Distributions of species in regional seas. Robins (1991) observed that the regional diversity of Caribbean fishes "varies greatly from place to place even in a restricted geographic area. Reasons for such differences are many and are rooted in differences in ecology, climate, geological history, and geography and in their interplay." The Caribbean is rich in fishes, containing about 10 percent of the world's marine species. Some species are ubiquitous and some are not. Three distinct faunal sectors may be identified: northern continental, southern continental, and insular. These sectors are not distinct, as some large island areas (e.g., Cuba, Hispaniola) have a mixed fish fauna that approach continental conditions due to these islands' extensive coastal habitats. Robins (1991) also pointed out the difficulties in sampling. For any one location, only about 60 percent of the species occur in all collections. The other 40 percent are inconsistent from collection to collection, making estimates of species richness at any one time difficult to achieve.

A multivariate statistical approach may be used to address the problem of delineating regional species assemblages. Ray and Hufford (1989) applied principal components analysis to seasonal range data of nine species of Beringian (Bering, Chukchi, and Beaufort seas) marine mammals. Six species assemblages resulted, and correlations with sea ice type were indicated for some of these. A more extensive study for the same region was conducted by Ray and Hayden (in press) for 86 species representative of invertebrates, fishes, birds, and marine mammals. Seven species assemblages, similar in many respects to those shown for mammals, were revealed (Figure 1): (A) southeast Bering Sea; (B) Beringian shelf; (C) Beringian inner shelf; (D) Bering Sea slope; (E) North Pacific (F_1) Chuckchi-Beaufort seas shelf; and (F_2) Bering Sea shelf. These two studies back up Robins' observations for Caribbean fishes and are illustrative of the fact that species assemblages are complex and overlapping within any region. Further, a variety of physical and biotic factors control these complex patterns.

Distributions of species across the coastal zone. As has been stated above, the coastal zone includes the entirety of the continental plains and continental shelves. Because of its unique position at the interface of terrestrial, atmospheric, and marine processes, it is extraordinarily rich, complex and dynamic. This is illustrated by the fact that about 50 percent of all fish species occur exclusively within this zone (Nelson 1984), despite the fact that the coastal zone includes less than 10 percent of total ocean area (Holligan 1990).

Hay (1992) described sea bird species diversity and abundances by statistical analysis and found distinct differences in the marine zones (nearshore, the continental shelf, shelf irregularities, continental slope, continental rise, and ocean basin). Ray (1991) made a similar study on patterns of distributions for 553 fish species that occur from Cape Code to Cape Hatteras, i.e., within the Virginian and Carolinian biotic provinces. The results are presented in Table 2. There is a clear north-south gradient in fish species diversity. Of the 1,052 species given in Robins and Ray (1986) for the entire East Coast, only about half (553) are known from Cape Canaveral

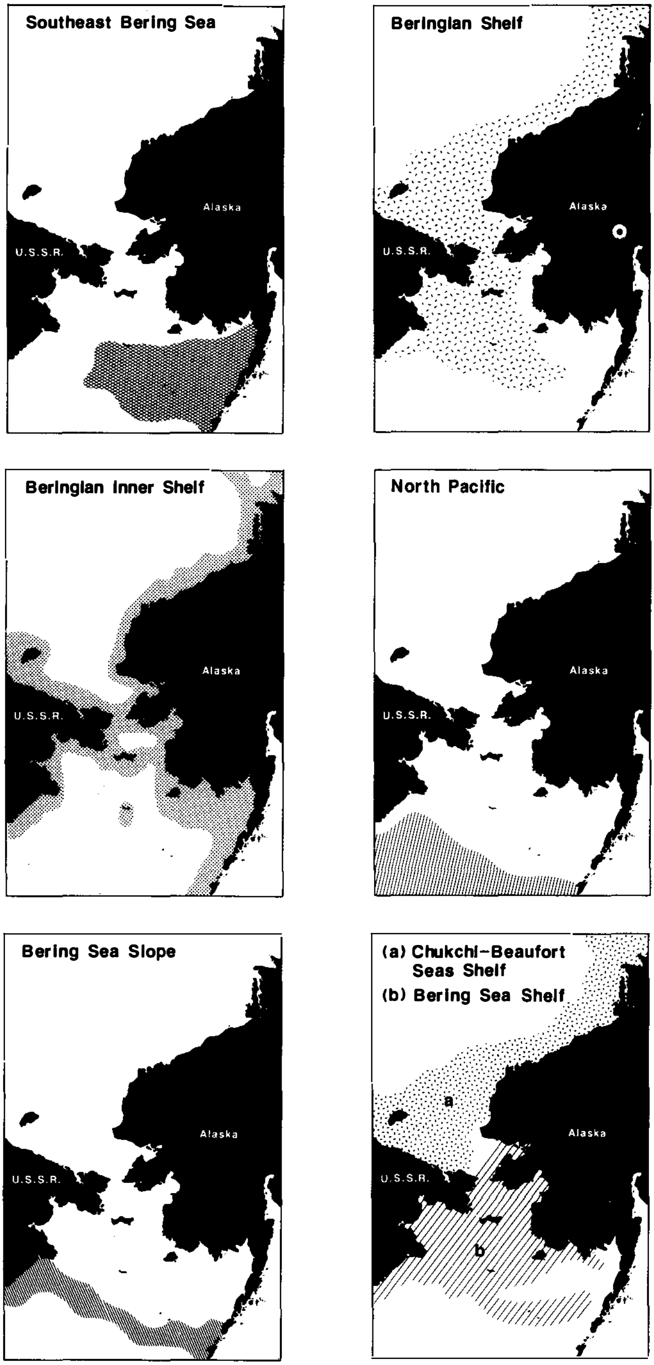

Figure 1. Biogeographic assemblages of Beringia.

Table 2. Distributions of Virginian and Carolinian fishes (from Ray 1991).

Distribution	Species number	Percentage
Province		
Virginian	375	67.8
Carolinian	500	90.4
Total	553[a]	100.0
Habitat		
Nearshore	148	26.8
Continental shelf	83	15.0
Slope/oceanic	84	15.2
Nearshore-shelf	113	20.4
Shelf-slope/oceanic	95	17.2
Ubiquitous	27	4.9

[a]322 species occur in both provinces; 53 occur from the Virginian northward; 178 occur from the Carolinian southward.

northward, and the more northern Virginian Province is poorer in fish species than is the Carolinian. Of the three major cross-shelf provinces (nearshore, shelf, and slope/oceanic), the richest zones are the nearshore, but overlapping patterns occur with none clearly dominant. A very small proportion of the species is ubiquitous (4.9 percent).

Habitat diversity. We may examine species distributions at yet a smaller scale. We will take the example of the three major nearshore habitats of tropical seas: coral reefs, sea grasses, and mangroves. Each of these habitats may be examined independently. Each has its own characteristic species, food webs and energetics. However, such an approach will not yield sufficient insight into biodiversity patterns. Figure 2 illustrates how these three habitats may be visualized as seven quite different functional associations. Once again, fishes illustrate the complexity of patterns and relationships. Species representative of these seven associations are:

1. Coral reefs. The neon goby (*Gobiosoma oceanops*) is a "cleaner" species that inhabits coral reefs in shallow waters. Many clinid blennies (Family Clinidae) also are exclusive to coral reefs.
2. Sea grasses. The emerald clingfish (*Acyrtops beryllinus*) occurs only on blades of turtle grass (*Thalassia*) and is entirely pale, emerald green to match.
3. Mangroves. The mangrove blenny (*Lupinoblennius dispar*) is found in mangroves and enters low-salinity lagoons and estuaries. The Florida blenny (*Chasmodes saburrae*) is common on clumps of oysters, mangrove roots and sea walls.
4. Coral reef/Sea grass. Many of the grunts (Family Haemulidae) lead split lives, on coral reefs by day and on sea grass beds by night. Notable examples are the bluestriped grunt (*Haemulon sciurus*) and the French grunt (*Haemulon flavolineatus*).
5. Sea grass/mangrove. Several pipefishes and seahorses (Family Sygnathidae) follow this pattern. Other examples are the clown goby (*Microgobius gulosus*), which occurs in muddy waters near the water's edge, and the code goby (*Gobiosoma robustum*), which occurs in clearer, shallow, protected waters.

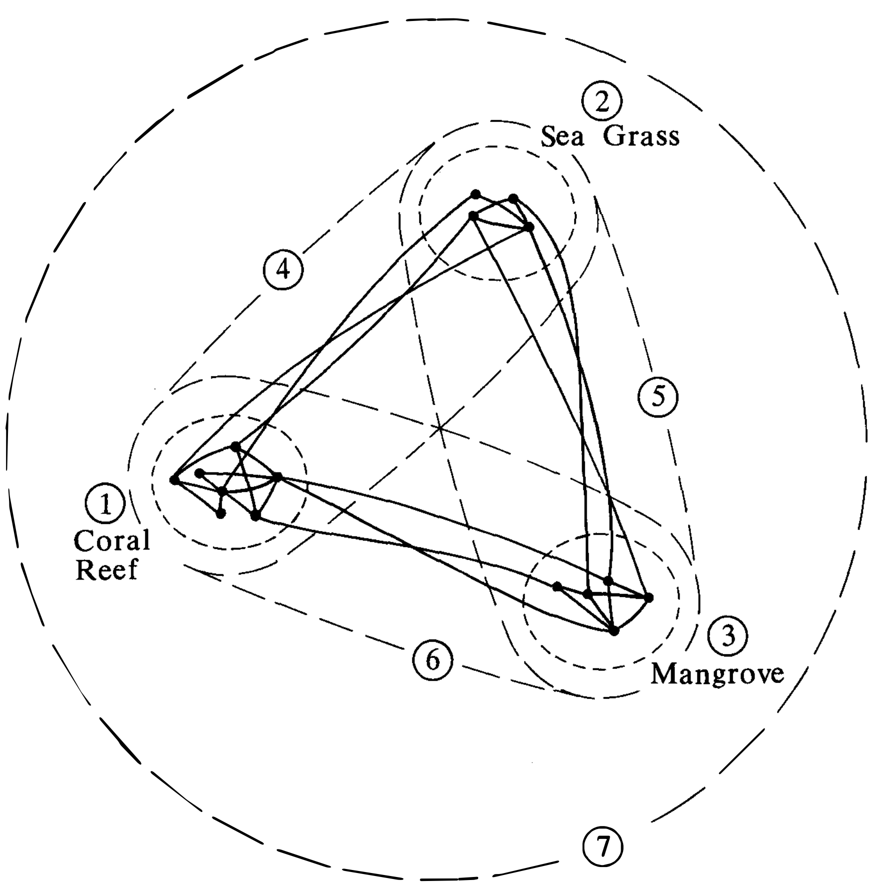

Figure 2. Associations among inshore, tropical ecosystems.

6. Coral reef/mangrove. Only a few species apparently follow this pattern. One is the gray snapper, also called the "mangrove snapper" (*Lutjanus griseus*). This species also occurs over sea grasses, but probably only as a transient.
7. Ubiquitous. A large number of species, most of them mid- to large size, occur throughout these three habitats. Examples are the barracudas (Family Sphyraenidae) and the needlefishes (Family Belonidae).

The conclusion from all of the examples given in this section is that assemblages of species across the shelf, within estuaries or among habitats show similarities, in that patterns are complex and overlapping. The major difference among these examples is one of scale. According to hierarchy theory (O'Neill et al. 1986, Urban et al. 1987), larger scale properties in either time or space act as controls on smaller scales. This means that larger scale patterns will be more predictable. As Jackson (1991) concluded: "There is a pressing need for more large-scale, descriptive, and experimental studies of . . . distributions and ecological processes within single habitats and across environmental gradients. . . .'' Insights into biodiversity patterns will not easily be attained unless scale becomes a major factor in our analyses.

Managing for Biodiversity

Two decades ago, Ray and Norris (1972) noted before the North American Wildlife Conference that ''we know only grossly the problems we face'' in managing marine ecosystems. This is still true, as we still have very poor knowledge about species- and community-level biodiversity. But two major factors have since intervened; first, we now know much more about how these systems operate and, second, powerful new tools for analysis are available. This makes a global, comparative coastal-marine systematics now possible.

Humankind has introduced unnatural disruptions into ecosystem functions at varying spatial and temporal scales. This has resulted in a rescaling of the spatial and temporal patterns to which species and their communities have adapted. One of the most widespread, and perhaps most deleterious, human interference is fishing. Another is pollution. However, there are some who feel that no matter how great the disturbances, ecosystem function will be retained. This leads to other testable hypotheses. It is obvious that the study of biodiversity is as complex as it is urgent.

Three important questions for management of biodiversity are: (1) are species or the systems themselves at risk; (2) is species diversity related to ecosystem function, and (3) to what extent has human disturbance been responsible for the present situation? The scientific challenge inherent in such questions has been recognized by the International Union of Biological Sciences (IUBS), which has proposed that a major goal of biodiversity research should be ''to understand biological diversity in the context of the structure and function of ecosystems'' (Simpson 1989). Di Castri and Younes (1990) pointed out that many of the arguments for conserving biodiversity are subject to question, including whether fragmentation and loss of habitat decreases biodiversity, and at what rate. It also was determined that few data exist on the relationship between species diversity and ecosystem function—i.e., ''sustainability of ecosystems may be maintained in spite of species deletions up to a point, at which time there will be system degradation.'' An *Ecosystem Function of Biodiversity Programme* is now underway, organized jointly by IUBS with the Scientific Committee on Problems of the Environment (SCOPE) and the United Nations Educational, Scientific, and Cultural Organization (UNESCO). Marine and coastal systems are a significant component (Grassle et al. 1990).

A principal means for biodiversity research and conservation is the establishment of protected areas. Due to the nature of coastal and marine systems, it is clear that protected areas must be integrated over a hierarchy of scales. And, due to the nature of marine systems and the natural histories of their life forms, ''conservation in the sea must be geographically scaled to mosaics of ecosystems, defined by ocean processes and distributions of biological diversity'' (Ogden in press). This is to say, small ''islands'' or patches of biodiversity may appear of disappear, depending on the hierarchical level that is observed (Jackson 1991). Or, more simply, small protected areas will always be at risk.

The conclusion is that conservation of coastal-marine biodiversity must be placed in a regional—even a global—context. Thus, the level of biodiversity that coastal-marine conservation should address concerns the interaction among nested hierarchies of systems, from local habitats within estuaries to whole estuaries, to shelf or upwelling areas, to the LMEs themselves, and to their global context.

The attainment of a mosaic pattern of protected areas or development of other means that can conserve biodiversity will not be simple. No nation currently has a comprehensive, representative system of marine protected areas in place. Australia, however, is probably in the lead with its extensive system of MEPAs (Marine and Estuarine Protected Areas), shared by the states and the Commonwealth, and proposes a major development of this system (cf. Ray and McCormick-Ray 1992). The most well-known Australian MEPA is the Great Barrier Reef Marine Park. However, that park is actually a regional planning and zoning scheme. It has not yet achieved an ecologically sustainable pattern of protection, largely due to the paucity of hard scientific information in which to examine natural and anthropogenic changes over such a complex ecosystem.

Protected areas are but one means for achieving conservation of coastal-marine biodiversity. Identification of their location, scale, number, and what purpose they serve remain to be determined if they are truely to protect coastal marine environments and conserve their biological diversity. However, no matter what the methods for conservation are, they will depend on an information base, of which a functional systematics is an essential element.

References

Angel, M. V. 1991. Biodiversity in the oceans. Ocean Challenge 2:23–26.

Bailey, R. G. 1989. Ecoregions: A new aid to monitoring global change. Explanatory supplement to ecoregions map of the continents. Envir. Conserv. 16(4):307–309.

Bulger, A. J., B. P. Hayden, M. G. McCormick-Ray, M. E. Monaco, and D. M. Nelson. 1989. A proposed estuarine classification: Analysis of species salinity ranges. ELMER rept no. 5, Strategic Assessment Branch, NOS/NOAA, Rockville, MD.

Buzas, M. A. and S. J. Culver, 1991. Species diversity and dispersal and benthic foraminifera. BioScience 41(7):483–489.

Chown, S. L. 1992. A preliminary analysis of weevil assemblages in the sub-Antarctic: Local and regional patterns. J. Biogr. 19:87–98.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS–79/31, Washington, D.C., December.

di Castri, F. and T. Younes. 1990. Ecosystem function of biological diversity. Biol. Inter. Special Issue no. 22. Inter. Union Bio. Sci., Paris.

Dexter, D. M. 1992. Sandy beach community structure: The role of exposure and latitude. J. Biog. 19:59–66.

Grassle, J. F. 1991. Deep-sea benthic biodiversity. BioScience 41(7):464–469.

Grassle, J. F., P. Lasserre, A. D. McIntyre, and G. C. Ray. 1990. Marine biodiversity and ecosystem function. Biol. Inter., Special Issue No. 23. Inter. Union of Biol. Sci., Paris.

Hay, R. B. 1992. The oceanic habitats of seabirds: Their zonal distribution off Vancouver island, British Columbia, Canada. J. Biog. 19:76–85.

Hayden, B. P., G. C. Ray, and R. D. Dolan. 1984. Classification of coastal and marine environments. Envir. Conserv. 11(3):199–207.

Holdridge, L. R. 1967. Life zone ecology. San Jose, Costa Rica Tropical Science Center.

Holligan, P., ed. 1990. Coastal ocean fluxes and resources. Global Change Report No. 14. The Inter. Geosphere-Biosphere Programme: A study of Global Change (IGBP) of the International Council of Scientific Unions (ICSU), Stockholm.

———. 1991. Land Ocean Interactions in the Coastal zone (LOICZ). Global Change Newsletter No. 8:5–6.

Huston, M. A. In press. The ecological regulation of biodiversity. Cambridge, U.K.: Cambridge Univ. Press.

Inman, D. L. and C. E. Nordstrom. 1971. On the tectonic and morphologic classification of coasts. J. Geo. 79, 1–21.
IUCN, UNEP, WWP. 1991. Caring for the Earth. A strategy for sustainable living. Gland, Switzerland.
Jackson, J. B. C. 1991. Adaptation and diversity of reef corals. BioScience 41(7):475–482.
Ketchum, B. H., ed. 1972. The water's edge. MIT Press, Cambridge, MA.
May, R. M. 1977. Threshold and breakpoints in ecosystems with a multiplicity of stable states. Nature 269:471–477.
———. 1988. How many species are there on Earth? Science 241:1,441–1,449.
McNeely, J. A., K. M. Miller, W. V. Reid, R. A. Mittermeier, T. B. Werner, eds. 1990. Conserving the worlds biological diversity. IUCN, Gland, Switz; WRI, CI WWF-US and World Bank, Washington, D.C.
Nelson, J. S. 1984. Fishes of the world. John Wiley and Sons, New York, NY.
Ogden, J. In press. Setting priorities in marine conservation. National Forum on Ocean Conservation. Smithsonian Inst. Washington, D.C.
O'Neill, R. V., D. L. DeAngelis, J. B. Waide, and T. F. H. Allen. 1986. A hierarchical concept of ecosystems. Princeton Univ. Press, Princeton, NJ.
Office of Technical Assessment (OTA). 1987. Technologies to maintain biological diversity. OTA–F–330. U.S. govt. Print. Off., Washington, D.C.
Pritchard, D. W. 1967. Observations of circulation in Coastal Plain estuaries. Pages 37–44, *in* George H., ed., Estuaries. AAAS, Washington, D.C.
Ray, G. C. 1985. Man and the sea—The ecological challenge. Am. Zool. 25:451–468.
———. 1991. Coastal-zone biodiversity patterns. BioScience 41(7):490–498.
Ray, G. C. and J. F. Grassle. 1991. Marine biological diversity. BioScience 41(7):542–557.
Ray, G. C. and B. P. Hayden. 1992. Coastal zone ecotones. *In* Andrew J. Hansen and Francisco di Castri, eds., Landscape boundaries. Springer-Verlag, New York.
Ray, G. C. and B. P. Hayden. In press. Marine biogeographic provinces of the Bering, Chukchi, and Beaufort seas. *In* K. Sherman, ed., The large marine ecosystem (LME) concept and its application to regional resource management. AAAS Selected Symposium Series.
Ray, G. C. and G. L. Hufford. 1989. Relationships among Beringian marine mammals and sea ice. Rapp. P.-V. Reun. Cons. Int. Explor. Mer. 188:225–242.
Ray, G. C. and M. G. McCormick-Ray. 1992. Marine and estuarine protected areas: A strategy for a national representative system within Australian coastal and marine environments. Report of a consultancy for Australian National Parks and Wildlife Service, Canberra, Australia.
Ray, G. C. and K. S. Norris. 1972. Managing marine environments. Trans. 37th N. Am. Wildl. and Nat. Resour. Conf. Washington, D.C.
Ricklefs, R. E. 1987. Community diversity: Relative roles of local and regional processes. Science 235:167–171.
Robins, C. R. 1991. Regional diversity among Caribbean fish species. BioScience 41(7):458–459.
Robins, C. R. and G. C. Ray. 1986. A field guide to Atlantic coast fishes of North America. Houghton Mifflin, Boston.
Roy, P. S. 1985. New South Wales estuaries: Their origin and evolution. Pages 99–122 *in* B. G. Thom, ed., Coastal geomorphology in Australia. Academic Press, Sydney.
Setzler-Hamilton, E. M., J. A. Whipple, and R. B. Macfarlane. 1988. Striped bass populations in Chesapeake and San Francisco bays: Two environmentally impacted estuaries. Mar. Pol. Bull. 19(9):466–477.
Sherman, K. 1986. Introduction to parts one and two: Large marine ecosystems as tractable entities for measurement and management. Pages 3–7 *in* Kenneth Sherman and Lewis M. Alexander, eds., Variability and management of large marine ecosystems. AAAS Selected Symposium. Westview Press, Boulder, CO.
Simpson, B. B. 1989. Biological diversity in the context of ecosystem structure and function. Bio. Inter. 17:15–17.
Sissenwine, M. P. 1986. Perturbation of a predator-controlled continental shelf ecosystem. Pages 55–85 *in* Kenneth Sherman and Lewis M. Alexander, eds., Variability and management of large marine ecosystems. AAAS Selected Symposium. Westview Press, Boulder, CO.
Solbrig, O. T., ed. 1991. From genes to ecosystems. A research agenda for biodiversity. Intern. Union of Biol. Sci., Cambridge, MA.
Steele, J. H. 1991. Marine functional diversity. BioScience 41(7):470–474.

Thom, B. G. 1984. Geomorphic research on the coast of Australia: A preview. Pages 1–21 *in* B. G. Thom, ed., Coastal geomorphology in Australia. Academic Press, Sydney.
Tont, S. A. 1987. Variability of diatom species populations: From days to years. J. Mar. Res. 45:985–1,006.
Udvardy, M. D. F. 1975. A classification of the biogeographical provinces of the world. IUCN Occas. paper no. 18, IUCN, Morges.
Urban, D. L., R. V. O'Neill, and H. H. Shugart, Jr. 1987. Landscape ecology. BioScience 37(2):119–127.
U.S. Water Resources Council. 1978. The nation's water resources, 1975–2000. U.S. Govt. Print. Off., Washington, D.C.
Wright, D. A. and D. J. H. Phillips. 1988. Chesapeake and San Francisco bays. Mar. Poll. Bull. 19(9):405–412.
Wilson, E. O. and F. M. Peter. 1988. Biodiversity. National Academy Press, Washington, D.C.
World Resources Institute (WRI), The World Conservation Union (IUCN) and United Nations Environment Programme (UNEP). 1992. Global biodiversity strategy. Guidelines for action to save, study, and use Earth's biotic wealth sustainably and equitably. World Resources Institute, Washington, D.C.

Maintaining Marine Biodiversity: The Missing Link in Global Ecosystem Management

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Introduction

As the world's resources, including fish and wildlife, continue to be exponentially or near-exponentially depleted, the term "biological diversity" (hereafter, "biodiversity") has become a popular and often used buzz word. The concept of biodiversity, however, is generally misunderstood, misused and misinterpreted by most of the public, legislators and the business community. When it is discussed, biodiversity is almost exclusively applied to terrestrial ecosystems, especially tropical rain forests, with, perhaps, an occasional reference to coral reefs. Although rain forest ecosystems are unquestionably diverse with an incredible array of plants and animals—perhaps millions of species yet to be discovered, let alone classified—rainforests occupy only 7 percent of our planet's terrestrial habitats and are rapidly diminishing.

Virtually excluded from the biodiversity discussion, however, are our vast global marine and estuarine ecosystems comprising over 70 percent of the earth's surface. In addition, when depth is included in the equation, these waterine ecosystems contain an order of magnitude of 100 times more space inhabited than those of the continents (Thorne-Miller and Catena 1991). Yet for all their vastness, marine ecosystems have been little studied and even less understood—at least until very recently (Grassle 1991, Grassle and Maciolek 1992). For example, even with a growing interest in the marine environment, access to this realm has been severely limited. Our deepest ocean bottom, the 7 mile (11.3 km) deep Mariana Trench, has only once been explored. That exploration was accomplished in a bathyscaph nearly 31 years ago and lasted only 20 minutes. With all our global technology, only 10 percent, at most, of the oceans have been sampled, and even less superficially mapped (Thorne-Miller and Catena 1991). Until lately, our inability and/or unwillingness to study deep ocean ecosystems has resulted in a recalcitrance in addressing what is out there or the problems that humankind has inflicted on our waterine planet. Most marine research, in fact, has been concentrated on near-shore and shallow-water ecosystems. This paper, then, addresses this discrepancy, showing why we must deal with marine biodiversity if humans as a species are to succeed in effective global ecosystem management. It also addresses a number of overriding problems we have created, presents some results of research from the North Pacific Ocean, makes several calls for action, and recommends a number of specific solutions.

Methods

I and several assistants conducted various studies in the Aleutian Islands to assess the status of certain marine mammals and seabirds, and to determine kinds, amounts, sources and observable impacts of plastic debris on wildlife there. From 1988–1991, we examined 113 beaches on 31 Aleutian Islands, carried out 4 surveys of beaches on the Alaska Peninsula and conducted 14 open-water surveys (July 12–20, 1988, July 12–18, 1989, June 20–29, 1990 and August 21 to September 5, 1991). The U.S. Fish and Wildlife Service's (FWS) research vessel M/V *Tiglax* served as a home base. We assessed beaches in the western Aleutian chain in 1988 and 1990, and examined those in the eastern chain in 1989 and 1991. Survey methods are further described by Wilber (1987) and Manville (1988, 1991).

With help from FWS personnel, we conducted bull, cow and pup counts of Steller's sea lions (*Eumetopias jubata*) during the summer study periods, as well as at various other times. We performed counts of adult and juvenile northern fur seals (*Callorhinus ursinus*) at sea during the summer study periods and attempted to count all northern fur seals on Bogoslof Island on August 21, 1991. Where possible, we photographed and videotaped all seals entangled in plastic. We conducted harbor seal (*Phoca vitulina*) counts at most beaches assessed for plastic debris, as well as counts for sea otters (*Enhydra lutris*). We also photographed carcasses of all animals entangled in plastic netting or debris and carcasses of rarely sighted animals not entangled, such as the Stejneger's beaked whale (*Mesoplodon stejnegeri*).

Results and Discussion

Defining Marine Biodiversity and Evaluating Its Importance

To understand marine biodiversity, we must first define *diversity*, which deals with the physical or biological complexity of a system, that in many cases leads to ecosystem stability (Miller 1979). *Marine biodiversity*, in simple terms, refers to the vast rich variety of plant and animal species in coastal and ocean regions, including a tremendous array of biological communities, from estuaries to coastal wetlands, to beaches and tidal flats, to reefs and deep water environments (Hertel 1991). To the purist, *biodiversity* refers only to the number and identification of different species present in a particular ecosystem, including species richness and distribution. This approach, however, is too simplistic. To truly appreciate the complexity and importance of biodiversity, one must include more than just the numerical identification of species (Thorne-Miller and Catena 1991). To the U.S. Congressional Office of Technology Assessment (OTA), biodiversity includes three principal components: (1) *species diversity*, the variety of species in an ecosystem; (2) *ecological diversity*, relating to the variety of types of biological communities found on earth; and (3) *genetic diversity*, referring to genetic variation occurring among members of the same species (OTA 1987). To this list, Thorne-Miller and Catena (1991) added a fourth category, (4) *functional diversity*, referring to the variety of biological or functional processes characteristic of a particular ecosystem. This latter element is particularly useful in assessing biodiversity within the oceans because it avoids the predicament of itemizing all ocean species, most of which have not yet been identified. Maintaining functional diversity may be considerably more useful to decision makers than are the other components of biodiversity since endangering an ecosystem's function may be viewed by many as more important—at least politically—than jeopardizing a single species for which no one has any particular apparent use.

Two often-asked questions regarding biodiversity issues are: what good is a species, and why is it important to save an ecosystem? Until recently, most humans believed that the oceans were limitless in their resources and invulnerable to human insults.

We now know better. To answer our two questions, we need to first discuss principles basic to biodiversity theory. A key concept to biodiversity maintenance is diversification; simply put, a biologically plentiful/diverse ecosystem is a healthy ecosystem—both on land and in the water. By failing to maintain marine biodiversity, a system begins to break down and may reach a point where it is irreparable, at least in the short term. As a system loses its genetic diversity, the population's ability to adapt is weakened. Loss of species diversity can cripple a community's ability to acclimate. As functional diversity is lost, the ecosystem's ability to adjust is debilitated, and if an ecosystem is eroded, planet Earth may also not adapt (Norse 1991, Thorne-Miller and Catena 1991). The whole system could conceivably collapse as a result. Whether a single species is known or perceived by us to be of any importance or concern is inconsequential. Each time we lose an individual species, we chip away at species, genetic, ecological and functional diversity.

Documented, Calculated and Speculated Loss of Biodiversity

Data on existing marine species, their composition and distribution are generally far less complete—or in the majority of cases simply nonexistent—than those from terrestrial systems because, until very recently, so little inventorying has been done in the marine environment. For all we have done taxonomically, only about 1.4 million species have been described and classified by scientists worldwide, the majority consisting of terrestrial insects. Scientists estimate that the earth may still contain from 5–80 million living species (Cottingham 1991). While so much yet remains to be identified, current estimates of species loss are frightening. Estimates today by scientists of terrestrial species extinctions range from a low of one to three species per day to a high of one every four minutes (Cottingham 1991). Estimates by conservation organizations such as The Nature Conservancy are placing global species loss as high as one per minute by the end of this decade (The Nature Conservancy personal communication: 1991). Will similar losses occur in the marine environment? The answer, of course, depends directly on what we do.

Because of the lack of study, little is known about, or even predicted for, species extinction in marine ecosystems. Only a scant four marine species have been documented to have become extinct in recent years. Overharvest resulted in the demise of the Steller's sea cow (*Hydrodamalis stelleri*) in the 1800s, the Caribbean monk seal (*Monachus tropicalis*) was driven to extinction by the mid-1960s, a diminutive marine snail called the eelgrass limpet (*Lottia alveus*) disappeared from the Atlantic Ocean sometime during the 1930s without anyone noticing its absence until 1991 (Norse 1991, Carlton et al. 1991), and the probable extinction of a reef-building hydrocoral (*Millepora* sp. nov.) reportedly was caused by reef bleaching in the eastern tropical Pacific following the 1982–83 El Niño warming event (Glynn and de Weerdt 1991). While popular attention to marine wildlife has been focused on great whales, sea turtles and seabirds, recent evidence shows that many marine species—including many in the aforementioned categories—are in dire straits.

For years we have been treating our world's oceans as giant garbage dumps, sewage sludge repositories and toxic wasteyards. It is not surprising that Mother Nature is now rebelling. Signs are everywhere that our world's oceans are threatened. Articles appear weekly or more often in leading newspapers and magazines around the world documenting the problems and plights of marine flora and fauna.

In the February 12th edition of this year's *New York Times*, for example, scientists reported the latest flare-up of a morbillus virus that in 1991 killed at least 1,000 dolphins, mostly striped dolphins (*Stenella coeruleoalba*) off of France, Italy and Spain. The same virus was blamed for the deaths of some 18,000 seals in the North Sea in 1988. Considerable concern was raised over the impact of this suspected pollution-caused virus on the critically endangered Mediterranean monk seal (*Monachus monachus*), which may number less than 300 worldwide. Recently, five were found dead and one was reported sick. Off the coast of Greece, observers found six dead goose-beaked whales (*Ziphius cavirostris*), an increasingly rare species. Scientists also noted other warnings including diminishing coastal beds of sea grass, critical nurseries for a host of marine species; increased intensity of algae plagues such as red tides; large-scale deaths of sea sponges; and loss of the spikes on sea urchins. Taken together, all are signs indicating that the marine environment is in trouble (Simons 1992).

While scientists cannot yet agree on the global impacts of ozone depletion, warning signs are becoming more prevalent worldwide, including in the oceans. Within the last few years, several million dead starfish were recorded washing ashore in the White Sea, and in the opposite hemisphere in Patagonia, fishermen are catching blind salmon, likely the result of increased harmful short-wave (ultraviolet [UV]) radiation due to the depletion of our stratospheric ozone layer (Gore 1992). While the infamous ''hole'' in the ozone layer has been essentially restricted to the Antarctic and Australia, new evidence indicates that sizeable portions of New England and eastern Canada have levels of ozone-depleting chlorine even greater than those over the Antarctic, or anywhere else in the world for that matter. Their impacts to the marine ecosystem can be anything but good, especially since plants, including phytoplankton, which normally remove enormous quantities of global-warming CO_2 gasses, are vulnerable to large increases in UV radiation. In the Antarctic, new evidence indicates that the expanding hole in the ozone layer is significantly reducing the growth of phytoplankton—critically important in the removal of enormous quantities of global-warming CO_2 gasses and in the production of oxygen. Rates of phytoplankton growth were reportedly decreased by 6–12 percent during periods when the hole in the ozone layer was over them. Decreased amounts of phytoplankton could lead to decreases in fish populations, further imbalances in CO_2 and O_2 levels, and other problems (National Public Radio 1992). It is thus imminently clear that humans as a species are doing far more than just chipping away at marine biodiversity.

Results of Studies of Marine Biodiversity in the Aleutian Islands

Plastic debris surveys. During July 12–20, 1988, July 12–18, 1989, June 20–29, 1990 and August 21 to September 5, 1991, I and several assistants examined 113 beaches, averaging approximately 106 yards (97 m) in length on 31 Aleutian Islands and four Alaska Peninsula sites to assess the kinds, amounts, sources, estimated weights and observable impacts of plastic debris on wildlife there. In addition to those areas assessed and described by Manville (1991), we also evaluated beaches from Anangula Island east to the Semidi Islands in August and September 1991, enabling survey coverage of the vast portion of the Aleutian chain between 1988–1991. We also conducted 14 open-water surveys during the same period.

The quantity and diversity of plastic debris found on Aleutian Island beaches were truly astounding, especially given the distant and isolated nature of these islands, and the minimal opportunity for direct human deposition of plastic debris on them. The observed incidence of wildlife entanglement was low (Manville 1991). Given the magnitude of the debris problem, we were surprised that we did not find more entangled animals. On the 6.8 miles (10.9 km) of beach observed during the 113 surveys and 14 open-water inspections conducted, we tallied 12,692 individual plastic items (12,665 on land, 27 in the water) representing 137 different plastic types. The 31 types of plastic whose weights were estimated between 1989–1991, weighed in at a cumulative total of 35,491 pounds (16,113 kg). As expected, fishing-related debris was most prevalent, with trawl nets and net fragments by far the most widespread.

On the average, we found 112 different items per beach surveyed. One 50–yard (45.7 m) survey at Sand Point Harbor, Popof Island, yielded a high of 612 plastic items. All beaches examined, including the most protected, contained plastic; even the cleanest was littered with at least seven items. While concern was raised by Manville (1991) about the serious potential problem for entanglement and plastic ingestion by wildlife there, the continued existence—and the recent apparent dumping of plastics—raises serious questions about the ability to maintain marine biodiversity in the Aleutians. On August 29, 1991, for example, I photographed the fishing vessel *Crystal Dawn*, out of Sand Point, dumping plastics overboard while departing the harbor, in direct violation of the Marine Plastic Pollution Research and Control Act of 1987. While entanglement is probably a greater threat to marine fish and wildlife than is plastic ingestion, some scientists are arguing that ingestion of plastic and heavy metal pollutants is weakening the natural defense mechanisms of marine mammals (Simons 1992).

Wildlife assessments. On August 21, 1991, we counted 5,252 northern fur seals (4,839 adults and juveniles, and 413 pups of the year) on Bogoslof Island, a fur seal rookery. At least 10 (0.2 percent) were entangled in plastic debris, mostly in trawl net fragments. Attempts to disentangle a female fur seal were unsuccessful. She died during the process, likely as the result of being severely weakened by massive wounds around her neck and an apparent infection.

On Sedanka Island, we located the skeleton of a Stejneger's beaked whale—the second find of this uncommon species during the past four summers. No evidence of plastic entanglement was noted. Evidence continues to show, however, that the Alaska population of Steller's sea lions is further plummeting in the Aleutians (Manville 1988, 1991, *The Sacramento Bee* 1992). This pinniped is currently listed as threatened under the U.S. Endangered Species Act. Environmentalists continue to express concern that the fishing industry's overharvest of pollock (especially *Theragra chalcogramma*) in the Bering Sea and elsewhere is resulting in a 75-percent decline in pollock stocks and that this decline is playing a major part in the percipitous decline of the Steller's sea lion. On some rookeries in Alaska, sea lion numbers have dropped by over 82 percent. Similar downturns have also been noted for harbor and fur seals, and some species of seabirds (*The Sacramento Bee* 1992). In the 1950s and 1960s, overfishing destroyed the herring (*Clupea passasii*) population, a fish previously important to the sea lion. Some scientists theorize that, because of the loss of this valuable food resource, sea lions resorted to feeding on pollock, which are too large and too fast for young sea lions to capture, resulting in the sea lion's decline. Further loss of the pollock will only exacerbate this situation.

Decline and loss of species diversity in the Aleutians are indicative of problems elsewhere in other marine systems worldwide. These include threats from marine debris, numerous insults from local oil spills (likely including some oil from the *Exxon Valdez* spill), overfishing, dumping and other problems yet undiscovered or poorly documented. Restoration of this fractured ecosystem will require years of work, further study, major changes in fishing practices and other steps. My limited research in the Aleutians shows this system is under serious duress.

Related scientific efforts. Not all of the news about the Aleutian marine ecosystem is bad, however. As a member of the U.S. Scientific Delegation for the Regional Review of Large-scale Pelagic Driftnetting in the North Pacific (U.S. Department of State 1991), and as a lobbyist at the United Nations during the fall 1991, I am pleased to announce that on December 20, 1991 the U.N. General Assembly passed by consensus Resolution 46/215, calling for an end to all large-scale, high-seas driftnetting by December 31, 1992, including a 50 percent reduction in fishing effort by June 30, 1992 (United Nations General Assembly [UNGA] 1992). To help implement earlier marine-protective U.N. resolutions, the U.S. Congress passed and the President signed into law Title IX of the Magnuson Fisheries Conservation and Management Act of 1990 (the so-called "Dolphin Consumer Protection Information Act"), which bans the import into the United States of any fish caught in high-seas driftnets. Additional federal legislation is also pending. While the incidence of derelict driftnet on Aleutian Island beaches has been small (Manville 1991), these actions will at least take some pressure off the marine mammals documented to have been negatively impacted primarily by high-seas driftnetting in the North Pacific. These include the northern right whale dolphin (*Lissodelphis borealis*) and the Pacific white-sided dolphin (*Lagenorhynchus obliquidens*). They also may help critically endangered species such as the northern right whale (*Eubaleana glacialis*), the endangered humpback whale (*Megaptera novaengliae*) and others (UNGA 1992), which environmentalists believe are also harmed in high-seas driftnets.

Recent Breakthroughs in Estimating Marine Biodiversity

While the world's oceans are home to all but one of the phyla of animals on earth, and nearly half of these phyla occur only in the marine environment, scientists, until recently, thought of these deep sea systems as "wastelands" suitable only for ocean dumping (Norse 1991). Until the 1960s, the deep seas were thought to have relatively few species and graphs showed reductions in the numbers of species with increasing depth (Vinogradova 1979, Abele 1982). This belief, however, changed in the mid-1960s when Hessler and Sanders (1967) discovered unexpectedly high numbers of species in the deep sea, far richer than in shallower environments. More recent research, most notably by Grassle and Maciolek (1992, *see also* Grassle 1991), has shown that the ocean bottoms support communities that may be as diverse as those of any habitat on earth, suggesting that the number of species occupying the sea bottoms has been greatly underestimated. For example, Grassle and Maciolek (1992) discovered 798 faunal species representing 171 families and 14 phyla from a total surface area of 226 square feet (21 m^2). Of these organisms, fully 58 percent ($N = 460$) were unknown to science.

Grassle and Maciolek (1992), in fact, suggested that Thorson's (1971) estimate of 160,000 marine species is much too low. As more of the deep sea is sampled, they estimate that the number of species will certainly be greater than 1 million, even perhaps exceeding 10 million. Development of new technologies, such as a fiber optic video camera system, may aid further studies in scanning the ocean bottoms. The equipment may be able to reach up to 95 percent of the sea floor (Cottingham 1991).

Major Threats to Maintenance of Marine Biodiversity

While we probably are not facing the extinction crisis in marine ecosystems at the same rate that we are in the terrestrial environments (Reid 1991), evidence clearly shows that marine biodiversity is being eroded. The threats to maintenance of marine biodiversity are varied. Ironically, we (*Homo sapiens*), as a terrestrial species, are probably the greatest threat to life in the oceans. Threats caused or exacerbated by human activities include: (1) *habitat destruction* from blast fishing on coral reefs to deep seabed mining and seabed burial of wastes; (2) *water pollution* from diverse causes such as toxic disposal, nonpoint source pollution, eutrophication, sedimentation, the overgrowth of corals by algae and sewage discharge; (3) *marine debris* from actions such as dumping of plastic debris, loss and discard of fishing gear, and trash and garbage disposal; (4) *overharvest* of species including, for example, 14 marine species of finfish in U.S. waters in a state of serious decline, and fully one-third of all stocks for which information is available in a state of decline; (5) *introduction of alien species* from the 1986 accidental introduction of the zebra mussel (*Dreissena polymorpha*) into the Great Lakes to the 1991 appearance of an Atlantic salmon (*Salmo salar*) in the North Pacific; and (6) *global climate change* including rises in ocean temperature and increases in UV radiation harmful to plankton in the ocean's upper layers, bleaching and resultant death of coral reefs, sea level rises affecting salt marshes, mangrove stands, and seagrass beds, and the effects of El Nino (Norse 1991, Prosser 1991, Reid 1991, Thorne-Miller and Catena 1991, Baker 1992).

While the vastness and remoteness of the deep-sea floor makes it appear safe for waste deposition, serious concern has recently been raised about the potential effect of toxic compounds that have been found to accumulate in deep-sea sediments (Knap et al. 1986, Grassle 1991). Almost nothing is known about the tolerances of deep-sea organisms to the gradual accumulation of anthropogenic chemicals. Out-of-sight must no longer mean out-of-mind.

Why We Must Maintain Marine Biodiversity: A Pragmatic Approach

While the threats to maintaining marine biodiversity may seem insurmountable, our continued unwillingness to seriously deal with the aforementioned problems may, ultimately, result in our demise. The oceans are too important and the products we derive from them are too extensive, for us not to act responsibly now. Properly protected and managed, the world's oceans can continue to provide humans with a cornucopia of materials on a sustained yield basis. In addition to the ecological importance of maintaining marine biodiversity, the oceans can meet many of our most pragmatic needs.

The tremendous variety of known and yet undiscovered species provide potential new sources of food; genetic material for agriculture, aquaculture and sylviculture breeding; genetic stock for biotechnology application; a rapidly growing source of important drugs and medicines; new cosmetics; and sources of materials used in food processing as well as other industrial applications (Robertson 1991, Thorne-Miller and Catena 1991). The fact that many marine organisms produce toxins has already made them invaluable for many pharmaceutical applications including antibiotics, antivirals, cancer treatments, coagulants, anticoagulants and treatments for cardiovascular ailments. Other economically important derivatives include food additives, shampoos, detergents, and seaweed extracts for the development of fibers, plastics, waxes, lubricants and paper. Continued destruction of marine biodiversity will almost certainly hurt our chances of further developing these opportunities (Robertson 1991).

Solving Our Marine Biodiversity Crisis

To solve the aforementioned problems, scientists, legislators, the business community and the public must first accept conclusions reached by a panel of scientists recently convened to discuss marine biodiversity (Norse 1991). (1) Efforts must be focused at *all* marine ecosystems, not just at those that are species-rich (e.g., coral reefs) at the expense of those that are less species-rich (e.g., seagrass beds) or species-poor but highly productive (e.g., Arctic waters). (2) Efforts to study the seas have been woefully inadequate, particularly in the areas of taxonomy and the monitoring of the health of the seas. (3) Excessive exploitation of the seas has been largely ignored by government agencies and conservation organizations, except where marine mammals are concerned. (4) While species extinctions are a real concern, preventing extinctions is simply not sufficient. It is ultimately in our best interest to maintain marine biodiversity, and, thus, the integrity of the seas, because the oceans are sources of products and services critical for humankind now and in the future. (5) The burden of proof must be shifted from those who would conserve to those who would use or abuse the marine ecosystems.

If we accept these conclusions, then the next step is to take action with the intent of tangible, positive results. At the very least, these actions should include the following. (1) Establish a new National Institutes for the Environment, whose research function would be analogous to that which is done for human health by the National Institutes of Health. (2) See that existing legislation that applies to the protection and maintenance of marine biodiversity is implemented and enforced. Most notable are, as amended, the National Environmental Policy Act (NEPA) of 1969; the Endangered Species Act of 1973; the Marine Protection, Research and Sanctuaries Act of 1972 (Title III); the Coastal Zone Management Act (Section 315); the Marine Mammal Protection Act of 1972; the Magnuson Fisheries Conservation and Management Act of 1976; the Marine Plastic Pollution Research and Control Act of 1987; and others. (3) Avoid redundancy by implementing existing federal orders that have yet to be undertaken rather than passing new federal legislation (e.g., the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 was passed while a 15–year executive order [1977 E.O. 11987] directing federal agencies to do many of the same activities remains today unexecuted). (4) Congress needs to ignore pressures from special interest groups opposing the maintenance and protection of healthy marine environments, and pass strong, comprehensive marine biodiversity legislation. Two bills presently in the 102nd Congress which begin to seriously address these needs are found in H.R. 585 and H.R. 2082. When such legislation is passed, it must be effectively implemented and sufficiently enforced. (5) The scope of biodiversity conservation must be applied worldwide. One way to do that at home is to pass amendments to NEPA that ensure that all U.S. federal actions—including in our coastal and marine ecosystems—with a potential for major environmental impact, either domestically or abroad, are accompanied by an environmental impact statement and subjected to public review and comment. (6) Other solutions, only covered in part by the above recommendations, also are critical. They include the control of marine pollution, development of an integrated resource management program, creation of economic incentives, protection of critical areas, regulation of living marine resources and establishment of living gene banks (Norse 1991, Reid 1991, Thorne-Miller and Catena 1991). As the evolving Biodiversity Convention continues to take more substantive shape, maintenance of marine biodiversity also must be factored into the convention as an integral part of the equation protecting global biodiversity.

Summary

Until now, humankind has viewed each new environmental crisis like the alcoholic who has a string of drunk-driving accidents and blames each one on a separate set of circumstances (Gore 1992). We can no longer afford this short-sighted and foolish approach. We must recognize that the planet is in serious trouble. While there is, indeed, much growing bad news, there also is much good news. If we act responsibly, globally and expeditiously, we can save our marine environment and ourselves. For those of us living in the developed world, it will require some belt-tightening. It, however, will not require major changes in our life styles, at least not if we act immediately. For the developing world to follow suit will be more challenging. We must help educate, share our expertise and train our third world neighbors. Our actions must not be patronizing but rather conducted in a spirit of true cooperation, working to overcome crises and challenges that affect us all. To succeed globally, we all must work together. Planet Earth and her marine environments can be saved if we work quickly and cooperatively; any other option is untenable.

References

Abele, L. G. 1982. Biogeography, the Biology of Crustacea, vol. 1. Academic Press, NY.

Baker, B. 1992. Aliens! The Amicus J. 14(1):8–11.

Carlton, J. T., G. J. Vermeij, D. R. Lindberg, D. A. Carlton, and E. C. Dudley. 1991. The first historical extinction of a marine invertebrate in an ocean basin: The demise of the eelgrass limpet (*Lottia alveus*). Biol. Bull. 180(1):72–80.

Cottingham, D. 1991. Testimony of David Cottingham, Office of the Chief Scientist, NOAA, before the Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf and the Subcommittee on Fisheries and Wildlife Conservation and the Environment, U.S. House of Representatives, July 23. Review of Current Scientific Knowledge of Biodiversity as it Relates to the Marine Environment, Serial 102–32:38–47.

Glynn, P. W. and W. H. de Weerdt. 1991. Elimination of two reef-building hydrocorals following the 1982–83 El Niño warming event. Science 253(5015):69–71.

Gore, A. 1992. The ozone catastrophe: Warning from the skies. 2 February International Sect., *The New York Times*.

Grassle, J. F. 1991. Deep-sea benthic biodiversity. BioScience 41(7):464–469.

Grassle, J. F. and N. J. Maciolek. 1992. Deep-sea species richness: Regional and local diversity estimates from quantitative bottom samples. Am. Nat. 139:in press.

Hertel, D. H. 1991. Opening statement, Chairman Hertel, before the Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf and the Subcommittee on Fisheries and Wildlife Conservation and the Environment, U.S. House of Representatives, July 23. Review of Current Scientific Knowledge of Biodiversity as it Relates to the Marine Environment, Serial 102–32. 98 pp.

Hessler, R. R. and H. L. Sanders. 1967. Faunal diversity in the deep sea. Deep-Sea Research 14:65–78.

Knap, A. H., K. S. Brinkley, and W. G. Deuser. 1986. Synthetic organic chemicals in the deep Sargasso Sea. Nature 319:572–574.

Manville, A. M. II. 1988. New technologies dealing with marine plastic pollution and efforts at mitigation. Trans. N. Am. Wildl. and Nat. Resour. Conf. 53:191–203.

———. 1991. Aleutian Islands plastics, pelagic drift and trawl net problems, and their solutions. Trans. N. Am. Wildl. and Nat. Resour. Conf. 56:205–214.

Miller, G. T. 1979. Living in the environment. Wadsworth Publ. Co., Belmont, CA. 470 pp.

Norse, E. A. 1991. Testimony of Dr. Elliott Norse, Chief Scientist, Center for Marine Conservation, before the Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf and the Subcommittee on Fisheries and Wildlife Conservation and the Environment, U.S. House of Representatives, July 23. Review of Current Scientific Knowledge of Biodiversity as it Relates to the Marine Environment, Serial 102–32:55–70.

Office of Technology Assessment. 1987. Technologies to maintain biological diversity. U.S. Congress, OTA–F–330. U.S. Govt. Print. Off., Washington, D.C.

Prosser, N. S. 1991. Testimony of Norville S. Prosser, Vice President, Sport Fishing Institute, before the Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf and the Subcommittee on Fisheries and Wildlife Conservation and the Environment, U.S. House of Representatives, July 23. Review of Current Scientific Knowledge of Biodiversity as it Relates to the Marine Environment, Serial 102–32:81–88.

Reid, W. V. 1991. Testimony of Walter V. Reid, Associate, Program in Forests and Biodiversity, World Resources Institute, before the Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf and the Subcommittee on Fisheries and Wildlife Conservation and the Environment, U.S. House of Representatives, July 23. Review of Current Scientific Knowledge of Biodiversity as it Relates to the Marine Environment, Serial 102–32:71–75.

Robertson, M. L. 1991. Testimony of Mark L. Robertson, Director, Florida Keys Protection Project, The Nature Conservancy, before the Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf and the Subcommittee on Fisheries and Wildlife Conservation and the Environment, U.S. House of Representatives, July 23. Review of Current Scientific Knowledge of Biodiversity as it Relates to the Marine Environment, Serial 102–32:89–92.

Simons, M. 1992. Dead Mediterranean dolphins give nations pause. 2 February International Sect., *The New York Times*.

The Sacramento Bee. 1992. Killing the golden pollack. 14 January Opinion, *The Sacramento Bee*, p. B4.

Thorne-Miller, B. L. and J. G. Catena. 1991. The living ocean: Understanding and protecting marine biodiversity. Island Press, Washington, D.C. 180 pp.

Thorson, G. 1971. Life in the sea. McGraw-Hill, NY.

U.N. General Assembly. 1992. Large-scale pelagic drift-net fishing and its impact on the living marine resources of the world's oceans and seas. Resolution 46/215, adopted 20 December 1991, 92–06149. 3 pp.

U.S. Department of State. 1991. Scientific review of North Pacific high seas driftnet fisheries, Sidney B.C., June 11–14, 1991. Report for Presentation to the United Nations Pursuant to Resolutions 44/225 and 45/197. 86 pp.

Vinogradova, N. G. 1979. Vertical zonation in the distribution of deep-sea benthic fauna in the ocean. Deep-Sea Res. 8:245–250.

Wilber, R. J. 1987. Plastic in the North Atlantic. Oceanus 30(3):61–68.

An Ecosystem Approach to the Conservation and Management of Freshwater Habitat for Anadromous Salmonids in the Pacific Northwest

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Introduction

Many stocks of wild anadromous salmonids (*Oncorhynchus* spp.) are presently in precarious condition. (A stock is a locally adapted population of fish that are reproductively isolated to a large degree from other stocks [Ricker 1972]). Nehlsen et al. (1991) identified 214 stocks in Idaho, Washington, Oregon and California that are in immediate need of special management considerations because of low or declining numbers. In addition, 106 major stocks were believed to be already extinct. Factors responsible for the demise of these fish include: (1) habitat degradation and loss from urbanization, agriculture, livestock grazing, mining, timber harvest and dams; (2) over exploitation in sport and commercial fisheries; (3) migratory impediments, such as dams; and (4) loss of genetic integrity due to influence of hatchery practices and introduction of non-local stocks. These factors do not operate in isolation from each other; the cumulative effects of two or more of these factors acting on a stock may exacerbate or magnify effects of individual factors (*see* Cederholm et al. 1981, Salo and Cederholm 1981).

The state of anadromous salmonid stocks in the Pacific Northwest is reflective of the general condition of fish throughout North America. Concern about biodiversity has focused on the tropics, but the loss of temperate species is equal to the loss in tropical areas. This is particularly true for fish in western North America (Allendorf 1988). Williams et al. (1989) listed 364 species and subspecies of fish in North America that are in need of special management considerations because of low numbers. This is an increase of 139 taxa since 1979. Moyle and Williams (1990) found that 57 percent of the freshwater native fishes of California were extinct or in need of immediate attention. The demise of these fish is attributable to factors similar to those responsible for the condition of anadromous salmonid stocks (Williams et al. 1989, Moyle and Williams 1990).

Habitat loss is the most frequent factor responsible for the decline of anadromous salmonid stocks (Nehlsen et al. 1991). This includes decreases in the quantity and quality of available habitat and the fragmentation of habitat into isolated patches. In the Pacific Northwest, effects from forest management activities have degraded the freshwater habitat of many anadromous salmonid stocks (*see* Hicks et al. 1991). However, quantitative relationships between long-term trends in fish abundance and effects of forest management practices have been difficult to establish (Bisson et al. 1992).

Hicks et al. (1991) and Bisson et al. (1992) concluded that, despite the lack of strong quantitative relationships between forest management activities (and other land-management activities as well), a primary consequence of these activities has been the simplification of fish habitat. Simplification includes a decrease in the range and variety of hydraulic conditions (Kaufmann 1987), reductions in amount of large wood and other structural elements (Bisson et al. 1987, Bilby and Ward 1991), and a decrease in the frequency and diversity of habitat units and substrate types (Sullivan et al. 1987). Salo and Cundy (1987) and Meehan (1991) contain several additional references detailing the link between effects of land-management activities and the condition of fish habitat.

The purpose of this paper is to describe a plan for managing habitat on federal lands in parts of the Pacific Northwest (northern California and western Oregon and Washington) for anadromous salmonids. This plan was initially developed as part of an effort that was requested by the Agriculture Committee and the Merchant Marine and Fisheries Committee of the United States House of Representatives to develop alternatives for managing old-growth ecosystems (Johnson et al. 1991). Here we describe the components of the report that dealt with the management of fish habitat, referred to as the Watershed/Fish Emphasis (WFE) in Johnson et al. (1991). These were designed as part of an integrated package for managing late-successional and old-growth ecosystems, and were not meant to stand on their own.

Components of the Watershed/Fish Element

The WFE is designed to address one factor, habitat degradation, that is responsible for the demise of anadromous salmonids. By itself, the WFE will not lead to the recovery of stocks that are in trouble. As mentioned previously, a suite of factors is responsible for the current status of these fish. The WFE represents actions we believe are necessary to prevent further deterioration and loss of freshwater habitat on federal lands, and to initiate the recovery of degraded habitats. It also is designed to maintain and restore ecological function and processes that influence fish and fish habitat.

Elements of the WFE are designed to protect habitat that is currently in good condition, minimizing probability of disturbance from future land-management activities in all areas, and initiating actions that restore ecological functions and processes influencing fish and fish habitat. The primary elements are: (1) key watersheds located throughout the area covered by Johnson et al. (1991); (2) expansion of riparian management areas throughout the area covered by Johnson et al. (1991); and (3) initiation of watershed restoration programs. Additional elements are listed in Johnson et al. (1991). Each element addresses a critical aspect for maintaining and restoring fish habitat and ecological functions in streams. They were developed as a package and were not designed to be implemented alone or in some limited combination.

Watersheds

Conservation efforts designed to aid threatened fish should be focused at the watershed scale (Sheldon 1988, Williams et al. 1989). We identified 137 watersheds as the nuclei of a broad-scale habitat protection and restoration program. Criteria for selection of these watersheds were: (1) they were greater than six square miles (15 km^2) and had relatively high quality water and fish habitat, or had the potential of providing high quality habitat with the implementation of restoration efforts; and (2) contained habitat for potentially threatened stock of anadromous salmonids or other potentially threatened fish species. Figure 1 shows watersheds in Oregon and

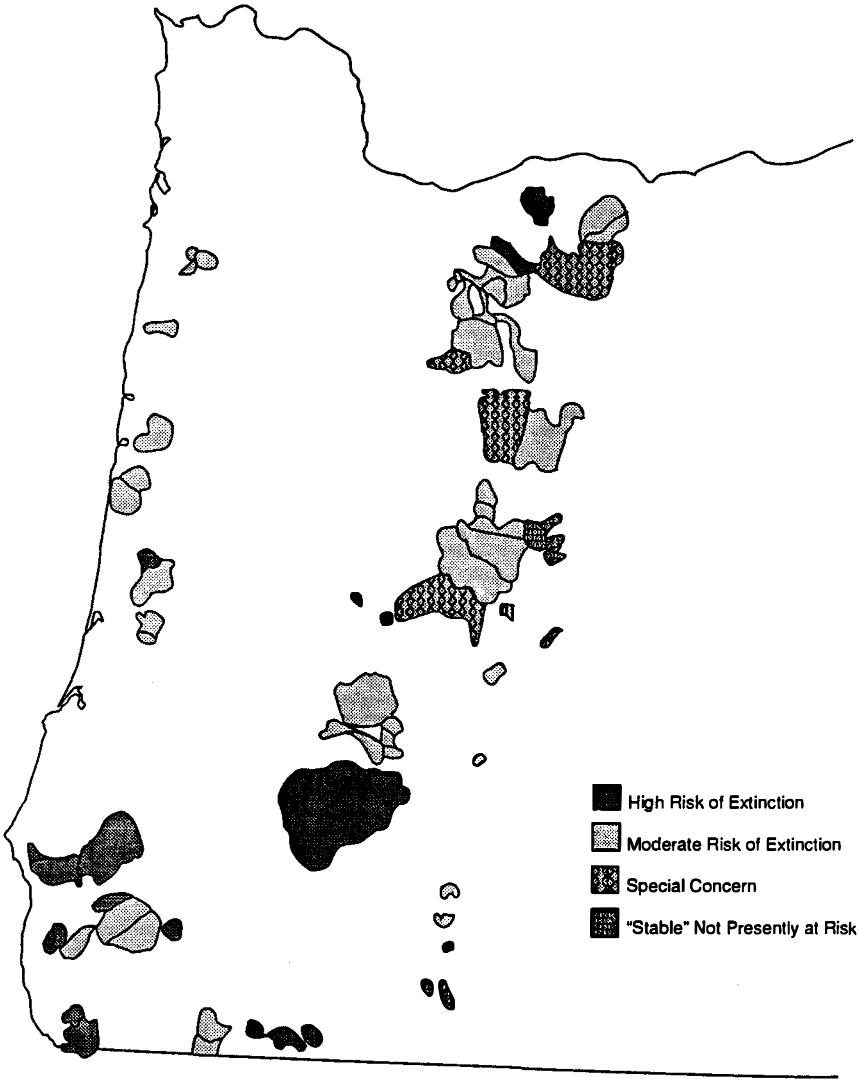

Figure 1. Location of key watersheds in Oregon and status of anadromous salmonid stocks (as determined by Nehlsen et al. 1991) within them.

the status of the stocks within the (*see* Johnson et al. 1991) for a complete list and maps of all watersheds). These watersheds will function as freshwater refugia for species or stocks that are currently at low population levels and also will be source areas of individuals to recolonize streams that may develop more favorable conditions.

Land-management activities within these watersheds will be restricted. Reserve areas for the northern spotted owl (*Strix occidentalis caurina*) and late-successional/old-growth ecosystems within these watersheds will be managed under guidelines established by Johnson et al. (1991). Timber harvest and other land-management activities would be curtailed in owl and old-growth reserves, at least in the short term (i.e., 3–4 years). All of the watershed outside of these reserves and other Congressionally established reserves (e.g., wilderness areas, national parks, etc.) would be managed for timber harvest on a 180-year rotation. One to two entries for silvicultural objectives will be allowed over a rotation. A primary benefit to fish and fish habitat from the reserves and long rotations is decreased probability of disturbance from land-management activities, both in frequency and magnitude. In addition, there will be increased time for recovery from anthropogenic, as well as natural, disturbance.

Ninety stocks of anadromous salmonids listed by Nehlsen et al. (1991) are found in the watersheds identified by this proposal (Table 1). An additional 85 stocks were found in watersheds within the area covered by Johnson et al. (1991). However, fish habitat in such watersheds was primarily affected by activities not occuring on federal lands, such as water withdrawal, agricultural practices and private forest management. Such activities were outside the scope of Johnson et al. (1991) and these watersheds were excluded from our proposal. In addition, four species of potentially threatened fish, bull trout (*Salvelinus confluentus*), redband trout (*O. mykiss gibbsi*), Oregon chub (*Oregonichthys crameri*) and the Olympic mudminnow (*Novumbra hubbsi*) (Williams et al. 1989) were found in these watersheds.

Riparian Management Zones

Fish habitat and ecological functions in streams are influenced by riparian zone characteristics (Gregory et al. 1991). The width of the riparian zone and the strength of its influence on the stream are related to stream size and local topography (Gregory

Table 1. Stocks of anadromous salmonids covered under the Watershed/Fish Emphasis (WFE) and those listed by Nehlsen et al. (1991).

Species	Number in WFE	Number in Nehlsen et al. (1991)
Cutthroat trout (*O. clarkii clarkii*)	4	13
Steelhead trout (*O. mykiss*)	32	75
Chinook salmon (*O. tshawystcha*)	28	64
Coho salmon (*O. kisutch*)	17	35
Sockeye salmon (*O. nerka*)	2	6
Chum salmon (*O. keta*)	6	17
Pink salmon (*O. gorbuscha*)	1	4
Total	90	214

et al. 1991). Riparian areas provide sources of large wood, food resources and nutrients, and influence water temperature. An ecologically functional riparian zone is an essential component of a productive aquatic ecosystem.

Under the WFE, we recommended expansion of riparian management areas on all federal lands covered by Johnson et al. (1991). The focus was on streams in watersheds smaller than 30 square miles (47,400 ha). In fish bearing streams in these watersheds, riparian management areas would extend 300 feet (91 m) on each side of the stream. In nonfish-bearing but perennially flowing streams, the riparian management area is 150 feet (45.5 m) on each side of the stream. The riparian management area in intermittent streams in moderate to highly unstable areas would have riparian management areas of 50 feet (15.2 m) on each side. In larger streams draining watersheds greater than 30 square miles (47,400 ha), the riparian management zone would be ⅛ mile (200 m) on each side of the stream or the 100-year flood zone, whichever is larger. To maintain the greatest potential for recruitment of large trees to these streams, no scheduled timber harvest would be allowed in any riparian zone. Silvicultural management may be required, in some areas, to facilitate the recovery of desired vegetation and conditions, however.

Expanded riparian management zones along all stream classes and elimination of scheduled timber harvest within them is necessary to create conditions more favorable to fish and other aquatic and terrestrial organisms associated with riparian zones. Streams within basins that have been managed for timber harvest generally have reduced levels of large wood compared to streams in basins with little or no timber harvest (Bisson et al. 1987, Bilby and Ward 1991). In fish-bearing streams, the increased riparian management areas will insure that all trees capable of falling into the stream will have the potential of being recruited to the stream. It also will protect trees in the riparian zone against blowdown. Third, it will protect cold water seeps and springs that deliver cold subsurface water to streams. In nonfish-bearing streams, wood creates areas for the storage and processing energy sources that are used in larger streams, stores sediments, and collects smaller material that filter and trap suspended sediments (Gregory et al. 1991). Many amphibians are found in these streams and are strongly associated with wood-formed habitat (Bury et al. 1991).

Expansion of riparian management zones will confer benefits to aquatic organisms other than fish and to terrestrial organisms associated with riparian zones. It will increase habitat for organisms that are dependent on the transition zone between upslope and riparian areas. Improved travel and dispersal corridors for numerous terrestrial animals and plants, and a greater connectivity of the watershed also will result from expansion of riparian management zone boundaries (Gregory et al. 1991).

Riparian zones that provide the full spectrum of structures and functions are necessary for maintaining and restoring productive aquatic ecosystems. Stipulated boundaries of riparian management areas and the accompanying restrictions on commodity production in the WFE will maintain currently functioning riparian zones in all parts of the watershed. Also, riparian zones that presently do not function optimally should improve as a consequence of these actions.

Watershed Restoration

Streams throughout the area covered by this proposal are in poor condition and will require active programs to restore their fish-producing potential. A major focus of such efforts will be on an examination of existing roads and drainage networks on federal lands.

Forest roads may have strong negative impacts on streams and fish habitat (*see* Furniss et al. 1991, Hicks et al. 1991). They are major sources of excess sediment and water. Many roads also disconnect streams from adjacent riparian areas. A comprehensive review of road networks and implementation of an improvement program is necessary to reduce the impacts of forest roads. Removal, relocation and realignment of roads will be required to restore fish habitat and steam ecosystems on a watershed scale.

Reduction of the miles of forest roads is an important component of watershed restoration. In Region 6 (Oregon and Washington) of the USDA Forest Service, road mileage has risen from 22,000–24,000 miles (33,850–36,900 km) in 1962 to over 90,000 miles (138,460 km) in 1990. This is important because there is a legacy of roads built without adequate consideration of requirements for drainage or placement necessary to maintain fisheries and other aquatic values. Higher road densities may result in increased frequency of debris avalanches, which can cause massive sediment entry into fish bearing streams. Many miles of road must be "put to bed," by pulling culverts, resloping road beds, pulling fill and replanting. Roads should be relocated out of floodplains where feasible. Road mileage for new harvest units should be minimized; roadless areas should remain roadless and should be harvested by other means where possible.

Improving the road drainage network also will be required as part of the watershed restoration effort. Removing unnecessary culverts can reduce impacts associated with culvert blockage and failure (Furniss et al. 1991). Increasing the size of other culverts is necessary to reduce risks to streams from floods. Replacement of culverts with hardened stream fords also can reduce risks to streams during storm events.

Other components of the watershed restoration effort include stabilization of hill-slopes, which may be sources of sediment to channels, and placement of instream structures that create fish habitat. Together, these activities will facilitate the recovery of fish habitat and stream ecosystems.

Conclusions

We reiterate that the WFE will not, by itself, prevent the demise of potential threatened fish stocks. Decline of freshwater habitat and disruption of ecological processes and functions are only one of the factors responsible for the decline of fish stocks. This program, in conjunction with that proposed by Johnson et al. (1991) for the northern spotted owl and late-successional and old-growth ecosystems, represents a set of actions that we believe are necessary to ensure a moderate probability of maintaining freshwater habitat on federal lands into the foreseeable future.

Some of the Pacific Northwest's most valuable aquatic resources are in serious jeopardy and decisive action is needed to prevent their demise. Past and present approaches to management have been based more on mitigating losses than on protecting or restoring natural processes that have created and maintained diverse and productive stream habitat. Mitigation, while well intentioned, has not been effective as witnessed by the current situation. The WFE protects and restores the processes necessary for productive stream ecosystems. Some benefits will accrue immediately, such as preservation of high quality areas. Restoration and recovery of degraded habitats may require an extended period, but it is, nonetheless, important for the future. We believe that the WFE, in combination with other aspects of Johnson et al. (1991), will accommodate the naturally dynamic nature of stream systems in the Pacific Northwest, facilitate the recovery of degraded systems to more productive states, maintain options for future management, and sustain fish habitat and ecologically necessary functions until additional knowledge allows us to implement new management measures.

References

Allendorf, F. W. 1988. Conservation biology of fishes. Conserv. Biol. 2:145–148.

Bilby, R. E. and J. W. Ward. 1991. Large woody debris characteristics in streams draining old-growth, clear-cut, and second-growth forest in southwestern Washington. Canadian J. Fisheries and Aquatic Sciences 48:2,499–2,508.

Bisson, P. A., R. E. Bilby, M. D. Bryant, C. A. Dolloff, G. B. Grette, R. A. House, M. L. Murphy, K. V. Koski, and J. R. Sedell. 1987. Large woody debris in forested streams in the Pacific Northwest: Past, present, and future. Pages 143–190 *in* E. O. Salo and T. W. Cundy, eds., Streamside management: Forestry and fishery interactions. Contribution No. 57, Inst. Forest Resour., Univ. Washington, Seattle.

Bisson, P. A., T. P. Quinn, G. H Reeves, and S. V. Gregory. 1992. Best management practices cumulative effects, and long-term trends in fish abundance in Pacific Northwest river systems. Pages 189–232 *in* R. J. Naiman, ed., Watershed management: Balancing sustainability with environmental change. Springer-Verlag. NY.

Bury, R. B., P. S. Corn, K. B. Aubry, F. F. Gilbert, and L. L. C. Jones. 1991. Aquatic amphibian communities in Oregon and Washington. Pages 353–362 *in* L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, tech. coor., Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rept. PNW–GTR–285. USDA For. Serv., Pacific Northwest Res. Sta., Portland, OR.

Cederholm, C. J., L. M. Reid, and E. O. Salo. 1981. Cumulative effects of logging road sediment on salmon populations of the Clearwater River, Washington: Project summary. Pages 373–398 *in* Proceeding of a Conference "Salmon spawning gravel: A renewable resource in the Pacific Northwest?" Report 39, St. of Washington Water Resource Center, Washington St. Univ., Pullman.

Furniss, M. J., T. D. Roelofs, and C. S. Yee, 1991. Road construction and maintenance. Am. Fish. Soc., Spec. Publ. 19:297–324.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41:540–551.

Hicks, B. J., J. D. Hall, P. A. Bisson, and J. R. Sedell. 1991. Responses of salmonids to habitat change. Am. Fish. Soc., Spec. Publ. 19:483–518.

Johnson, K. N., J. F. Franklin, J. W. Thomas, and J. Gordon. 1991. Alternatives for management of late-successional forests of the Pacific Northwest. A report to the Agriculture Committee and the Merchant Marine and Fisheries Committee of the U.S. House of Representatives. 59 pp.

Kaufmann, P. R. 1987. Channel morphology and hydraulic characteristics of torrent-impacted streams in the Oregon Coast Range, U.S.A. Ph. D. diss., Oregon St. Univ., Corvallis. 235 pp.

Meehan, W. R., ed. 1991. Influences of forest and rangeland management on salmonid fishes and their habitat. Am. Fish. Soc., Spec. Publ. 19.

Moyle, P. B. and J. E. Williams. 1990. Biodiversity loss in the temperate zone: Decline of the native fish fauna of California. Conserv. Biol. 4:275–284.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4–21.

Ricker, W. E. 1972. Herediatary and environmental factors affecting certain salmonid populations. Pages 19–160 *in* R. C. Simon and P. A. Larkin, eds., The stock concept in Pacific salmon. Univ. British Columbia. Vancouver.

Salo, E. O. and C. J. Cederholm. 1981. Cumulative effects of forest management on watersheds: Some aquatic considerations. Pages 67–78 *in* The Edgebrook Conference: Cumulative effects

of forest management on California watersheds. Division of Agricultural Sciences, Univ. California, Berkely.
Salo, E. O. and T. W. Cundy, eds. 1987. Streamside management: Forestry and fishery interactions. Contribution No. 57, Institute of Forest Resources, Univ. Washington, Seattle.
Sheldon, A. I. 1988. Conservation of stream fishes: Patterns of diversity, rarity, and risk. Conserv. Biol. 2:149–156.
Sullivan, K., T. E. Lisle, C. A. Dolloff, G. E. Grant, and L. M. Reid. 1987. Stream channels: The link between forests and fish. Pages 39–97 *in* E. O. Salo and T. W. Cundy, eds., Streamside management: Forestry and fishery interactions. Contribution No. 57, Institute of Forest Resources, Univ. Washington, Seattle.
Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Conreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Bacon. 1989. Fishes of North America endangered, threatened, or special concern. Fisheries 14(6):2–20.

Bring Back the Natives: A New Strategy for Restoring Aquatic Biodiversity on Public Lands

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> *During the past two decades it has become evident that knowledge no longer limits our ability to protect native fishes. Most endangered species can be recovered, if we choose* (J. E. Deacon and W. L. Minckley 1991).

Introduction

The above quote—taken from the "Epilogue" of Minckley and Deacon's book, *Battle Against Extinction: Native Fish Management in the American West*—provides a clear call for action. This call is especially poignant when placed in its context, wherein the authors note that the number of rare fishes in North America has risen 45 percent during the past decade, and that none of the 251 fish taxa listed by Deacon et al. (1979) as endangered, threatened or of special concern could be removed from the list one decade later on the basis of recovery actions (Williams et al. 1989). Furthermore, the rate of extinctions of freshwater fishes has increased dramatically since 1960 (Miller et al. 1989).

The greatest number of endangered and threatened rare fishes occur in the West. This is surprising on at least two fronts. First, the fish fauna in the West is far less diverse than in any other region of the country. And second, much of the western lands are public lands managed by federal agencies, such as the USDA Forest Service (FS), Bureau of Land Management (BLM) and National Park Service.

The Forest Service manages approximately 191 million acres (77 million ha) of public lands throughout the country. Public lands administered by the Bureau of Land Management are almost exclusively in the West, and total more than 270 million acres (109 million ha). Together, both agencies are responsible for management of about 70 percent of all federal lands in the U.S. These lands provide habitat for 68 percent of the federally listed threatened or endangered fishes in the nation, and 61 percent of the candidate fish species (Table 1). At least 46 percent of the federally listed aquatic invertebrate species occur on National Forest System lands. The BLM lands largely remain unsurveyed for aquatic invertebrates.

The vast acreages of public lands, especially in the West, and the large number of threatened and endangered aquatic species occurring on these lands, clarifies the urgent need and opportunity for positive action to protect the nation's aquatic biological diversity. The opportunities for cooperative efforts by the BLM and Forest

Table 1. Numbers of rare fish and aquatic invertebrate species on public lands as compared with the national totals.

	National Forest System	BLM	NFS or BLM lands	National totals
Threatened or endangered fishes	40	40	59	87
Candidate fishes	48	40	69	113
Threatened or endangered aquatic invertebrates	26	3[a]	27	56

[a]Most BLM lands have not been surveyed for aquatic invertebrates.

Service are especially evident in the West, where both agencies often manage lands along the same stream or river.

Recent observers have suggested that federal agencies possess sufficient authority to maintain biological diversity on their lands, if they choose to apply it (Williams and Deacon 1991). The purpose of this paper is to describe a new strategy for applying existing authority to restoring aquatic biodiversity on public lands—"Bring Back the Natives"—and to examine the theory and practice of the early stages of this promising effort.

Restoration Principles

The effort to control the health of land has not been very successful. It is now generally understood that when soil looses fertility, or washes away faster than it forms, and when water systems exhibit abnormal floods and shortages, the land is sick (Aldo Leopold [1941] *in* Flader and Callicott [1991]).

The health of many aquatic habitats has continued to decline since Aldo Leopold's observations of more than five decades ago. Benke (1990) reported that federal surveys of 3,229,200 miles (5 million km) of streams in the contiguous 48 states found that only 1.8 percent still retain sufficient high quality features to be worthy of federal designation as wild or scenic. Lists of endangered and threatened aquatic species, which are indicators of the health of these aquatic habitats, continue to grow. Although a few fish species have been reclassified from endangered to the less critical category of threatened, no aquatic species have recovered sufficiently to warrant their removal from the federal list of endangered or threatened wildlife. In addition to the easily foreseeable reasons for the lack of success in recovering threatened or endangered aquatic species, such as lack of adequate funds and staff, there is growing evidence that the traditional approaches to species conservation and preserve design are not adequate to conserve biological diversity, especially in aquatic systems (Moyle and Sato 1991, Williams 1991).

Historically, conservation and recovery efforts have focused on the needs of individual species. Reintroduction of rare fishes within their historic ranges is a common form of recovery effort. Unfortunately, such efforts usually fall short of expectations, especially if habitats have been altered or if non-native species are present. Nearly 12 million young of the endangered razorback sucker (*Xyrauchen texanus*), for example, have been stocked into Arizona rivers, yet only 118 have been recaptured during seven years of intensive monitoring, and most of those were taken soon after release (Minckley et al. 1991). Some riverine systems, such as the Illinois (Karr et al. 1985) and the Colorado (Miller 1961, Williams et al. 1985), now have the majority of their native fishes listed as endangered or threatened, or deserving of such status. The lack of success in recovering listed species, and the presence of endangered communities and ecosystems have fueled desires for new approaches to conservation.

A new focus on habitat health rather than species numbers would facilitate greater success in recovery of listed species. The restoration and maintenance of habitat health, i.e., biological integrity, is essential for conservation of aquatic faunas (Karr 1990). Biological integrity is defined as the habitat's capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition and functional organization comparable to that of natural habitat of the region (Karr and Dudley 1981). Maintenance of biological integrity requires a focus on ecosystem processes and communities, rather than species. Several procedures that compare fish or macroinvertebrate community structure and diversity are available for measuring biological integrity in aquatic habitats (Karr et al. 1986, Plafkin et al. 1989).

Many existing parks and refuges have been unsuccessful in protecting biological diversity of riverine communities because they were established and managed on the basis of terrestrial landscapes and political boundaries, rather than watersheds (Williams 1991). Even large preserves, such as Canyonlands National Park, may not be effective in conserving native fish faunas. Only 7 of 23 fish species collected from Cataract Canyon in Canyonlands National Park were native to the Colorado River system (Valdez and Williams 1987). In terms of numbers, native fishes comprised only 18 percent of all individuals collected.

For riverine communities, where aquatic species diversity is greatest, ecosystem management should be planned and conducted on a watershed basis. Unfortunately, agency boundaries and jurisdictions often have little correspondence to natural watershed boundaries. Successful ecosystem management clearly requires cooperative management, especially among federal agencies (Grumbine 1990). The Forest Service and BLM share management in many watersheds, especially in the West, where headwaters of streams often are on national forests and downstream reaches are on public lands managed by the BLM.

Poor land-use practices in the past have resulted in reduced stream health and increased rarity of native fishes throughout much of the nation. On public lands, poor timber harvest practices and overgrazing by livestock are the primary causes of the declines. Reversing these trends requires an understanding that upland areas, riparian areas, groundwaters and surface waters are connected within each watershed. It usually is futile to treat the symptoms of poor land management through stream rehabilitation projects if upland disturbances are not corrected (Gregory and Ashkenas 1990). Erosion control projects, such as bank stabilization and stream drop structures, can be very effective if used with improved upland and riparian management. Such rehabilitation projects, however, are no substitute for effective land-use management.

Because riparian zones are the interface between riverine and upland processes, they provide an appropriate focus of restoration management. Riparian habitats probably are the most dynamic feature of many landscapes because they are shaped by fluvial events, such as floods, as well as processes in upland areas, such as fire or overgrazing (Gregory et al. 1991). Although occupying only a small fraction of the land, riparian zones are highly diverse and play a critical role in determining the health of riverine systems.

It is clear that successful conservation of aquatic biological diversity on public lands requires a new approach. First, the primary goal of land-use planning must be the restoration of biological integrity, rather than production of certain commodities or production of certain numbers of individual species. Secondly, it must provide a basinwide or watershed approach that emphasizes cooperative efforts among land managers. Finally, it must rectify land-use problems throughout the watershed, rather than focus solely on the symptoms of poor management in the streams. As noted above, riparian areas are a logical focal point for restoration and monitoring efforts. Once systems are restored, native aquatic species can be reintroduced and reestablished.

Bring Back the Natives

"Bring Back the Natives" is a new, national approach by the Forest Service, BLM, and National Fish and Wildlife Foundation to restore the health of entire riverine systems and their native species on public lands. This is not a separate program of either federal agency, but rather, is the application of a new strategy that utilizes a watershed approach to restoring stream health. Although restoration of the entire native aquatic community is a common goal, many Bring Back the Natives projects originated by the desire to reintroduce one or more rare species. In many projects, these "target" species are native trouts, such as the Lahontan cutthroat (*Oncorhynchus clarki henshawi*) or Colorado cutthroat (*O. c. pleuriticus*), that have been severely reduced in range because of habitat degradation and the introduction of hatchery rainbow trout (*O. mykiss*).

A key element to Bring Back the Natives is a coordinated effort by the Forest Service and BLM within those watersheds, where both agencies manage a large portion of individual stream systems. Although the participation of all landowners in each watershed is the ideal approach, cooperation by the Forest Service and BLM can approximate this for many streams in the West. Most Bring Back the Natives projects have streams with headwaters on Forest Service land and downstream reaches on BLM land. In the East, because of less public lands in general, and virtually no BLM lands, fewer projects are the result of joint efforts.

Partners play a key role in the success of Bring Back the Natives. The National Fish and Wildlife Foundation provided a $500,000 challenge grant to the Forest Service and BLM in 1991, to stimulate work on the first series of Bring Back the Natives projects. Trout Unlimited, at the national level and through numerous local chapters, is a cooperator on many of the projects. The participation of state fish and wildlife agencies also is critical because many projects call for reintroduction of native aquatic species, which has traditionally been a function of state agencies. Many projects also feature cooperative management plans with private landowners, livestock permittees or timber operators.

Another key feature of Bring Back the Natives projects is the desire of agencies and private parties to modify past practices, particularly those associated with improper livestock management or poor timber harvest, that originally caused declines in stream health. For this reason, most projects begin by developing livestock management plans or timber harvest plans that contain expanded objectives for fisheries and riparian habitats.

The initial list of Bring Back the Natives activities includes 20 projects, mostly in the West (Table 2). These projects range from relatively small efforts of two years for 6 miles (10 km) of streams to proposals requiring more than 10 years, and treating more than 62 miles (100 km) of stream and associated watershed. Some of the projects continue to be revised to meet the principles outlined in this section and several are being expanded to broader watershed areas.

Because many of the Bring Back the Natives projects feature rare trout species, they are of interest to a number of sportfishing and conservation constituent groups. The projects also serve to implement existing strategies and programs within both agencies. *Fish and Wildlife 2000* and the *Riparian-Wetland Initiative for the 1990s* are BLM initiatives aimed at improvements to overall fish and wildlife management, and restoration of riparian habitats. The BLM has established a goal of restoring proper functioning condition to 75 percent or more of the riparian habitat on public lands within its jurisdiction by 1997. Within the Forest Service, Bring Back the Natives projects help achieve goals in *Rise to the Future*, a fisheries program initiative, *Get Wild!*, a wildlife program initiative, and *Every Species Counts*, an initiative to conserve threatened and endangered species, as well as the agency's riparian

Table 2. Bring Back the Natives projects for 1991 (prepared by the U.S. Bureau of Land Management and the USDA Forest Service).

State	Drainage	Public lands
Arkansas	Saline River	Ouachita NF
California	Dutch Flat Creek	Modoc NF/Susanville District BLM
Colorado	Cunningham Creek	San Juan NF/Grand Junction District BLM
Idaho	Fish Haven Creek	Cache NF/Idaho Falls District BLM
Idaho	Hardtrigger Creek	Boise District BLM
Idaho	North Fork Owyhee River	Boise District BLM
Idaho	Squaw Creek	Boise District BLM
Idaho	Wet Creek	Challis NF/Idaho Falls District BLM
Montana	Big Hole River	Beaverhead NF/Butte District BLM
Nevada	Eightmile Creek	Humboldt NF/Winnemucca District BLM
Nevada	Marys River	Humboldt NF/Elko District BLM
New Mexico	Aguacaliente Creek	Carson NF/Albuquerque District BLM
Oregon	Wickiup Creek	Ochoco NF/Burns District BLM
Utah	Bunker Creek	Dixie NF
Utah	Boulder Creek	Dixie NF
Utah/Wyoming	West Fork Smith River	Wasatch-Cache NF
Wyoming	Currant Creek	Rock Springs District BLM
Wyoming	Huff Creek	Rock Springs District BLM
Wyoming	La Barge Watershed	Bridger-Teton NF/Rock Springs District BLM
Wyoming	Littlefield Creek	Medicine Bow NF/Rawlins District BLM

habitat goals. The projects also serve as excellent examples of implementing the 1990 joint *Forest Service/BLM Recreational Fisheries Policy.*

A variety of benefits are achieved through Bring Back the Natives. Recovery plans of threatened or endangered species, such as the Modoc sucker (*Catostomus microps*) and Lahontan cutthroat trout, will be implemented. The status of candidate species, such as the redband trout (*Oncorhynchus mykiss* ssp.) or Malheur mottled sculpin (*Cottus bairdi* ssp.), may be improved to the point that future listing as endangered or threatened will not be needed. Recreational anglers should benefit by larger populations and more diversity of trout species. In addition, numerous other benefits, such as improved water quality, more consistent flows during summer and increased flood protection, will accrue to users of public lands and all who live downstream.

Marys River Case Study

Marys River is one of the first and largest Bring Back the Natives projects in the nation. Headwaters of the Marys River are in the Jarbridge Mountains on the Humboldt National Forest of Elko County, Nevada. The river flows south and finally reaches the Humboldt River, which was the longest and most important tributary of the pluvial Lake Lahontan drainage. Within the Humboldt River system, the decline in stream health and fish populations is epitomized by the current status of the threatened Lahontan cutthroat trout. Historically, Lahontan cutthroat trout occurred in 2,210 miles (3,556 km) of the Humboldt River drainage (Coffin 1981). As recently as the 1960s, the Marys River was considered to be a trophy-class fishery for cutthroat trout. Now the Lahontan cutthroat trout exist in only 313 miles (504 km) of the Humboldt drainage (BLM Elko District files). The decline in range and abundance has been caused by poor livestock management, stream diversions for agriculture, and the introduction of brook (*Salvelinus fontinalis*) and rainbow trout (Gerstung 1988). The Humboldt drainage is extremely important to recovery of the Lahontan cutthroat because it supports most of the remaining fluvial populations and contains much of the unoccupied historic range.

Although the FS and BLM had been working on projects to restore the Marys River for many years, a major breakthrough in land management possibilities occurred on May 29, 1991 when the BLM acquired much of the private lands in the basin by acquisition and land exchange. Stream length within the Marys River drainage managed by the BLM increased by 273 percent as a result of the acquisition. The Marys River Bring Back the Natives project area extends from the headwaters on the Humboldt National Forest almost to the Humboldt River, including many of the principal tributaries, such as Wildcat, Cutt, Chimney, "T," Conners and Hanks creeks. Of 176 miles (283 km) of streams within the project area, 30 miles (48 km) are managed by the Forest Service, 86 miles (138 km) are managed by BLM and 60 miles (97 km) are in private ownership.

At the time of the exchange, habitat condition within the watershed was variable. Some good conditions existed on headwater streams on the Humboldt National Forest. The overall riparian condition on streams throughout the watershed was described by BLM as "poor to fair" (BLM Elko District files). The lower Marys River was described as being in poor condition because of a lack of bank cover, downcutting of the stream and subsequent lowering of the water table, and mechanical straightening of the channel. Despite these conditions, the rehabilitation potential of the system is good.

The primary goal of the Marys River project is to restore stream habitat health so that the range and abundance of Lahontan cutthroat trout within the system may approximate natural conditions. Total costs to implement the Marys River project are estimated at $34,300 in 1991, $491,895 in 1992, $229,150 in 1993, $143,425 in 1994 and $662,020 in 1995, for a five-year total of $1,560,790.

Both BLM and Forest Service plans for the watershed emphasize more intensive management of livestock. Some riparian areas will be fenced to exclude livestock. Prescribed burns are planned to restore upland areas. Riparian areas will be restored naturally through decreased pressure from livestock, and from plantings of aspen, cottonwood, chokecherry and alder. Other planned actions include placing boulders in streams to increase habitat complexity, constructing stockwater wells away from riparian areas, and providing increased public access and interpretive facilities to explain the project and goals. An intensive, long-term habitat monitoring program, consisting of vegetation transects, macroinvertebrate samples, water quality samples, installation of stream gauging stations and low-level aerial photography, will help determine progress in meeting project goals and the need for management changes. Another monitoring program is planned with the Nevada Department of Wildlife for the Lahontan cutthroat trout.

Conclusion

In the 1870s, streams in the Humboldt drainage were described as clear, trout-filled and surrounded by uplands ''clothed with luxuriant grasses . . . a delightful region, represented as the paradise of Nevada'' (Coffin 1981). The conditions in 1992 are markedly deteriorated from those of more than 100 years earlier, but Bring Back the Natives is providing a means to bring the Marys River, other streams, and their aquatic life back to a healthy condition. Aldo Leopold realized the need for federal agencies to restore biological integrity to our forests and streams as early as 1939 (*in* Flader and Callicott 1991): ''Government is slowly but surely pushing the cutovers back into forest; the peat and sand districts back into marsh and scrub. This, I think, is as it should be.''

References

Benke, A. C. 1990. A perspective on America's vanishing streams. J. N. Am. Benthol. Soc. 9:77–88.

Coffin, P. D. 1981. Distribution and life history of the Lahontan/Humboldt cutthroat trout Humboldt River drainage basin. Nevada Dept. Wildl., Reno. 69 pp.

Deacon J. E. and W. L. Minckley. 1991. Western fishes and the real world: The enigma of ''Endangered Species'' revisited. Pages 405–413 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: Native fish management in the American West. Univ. Arizona Press, Tucson. 517 pp.

Deacon, J. E., G. Kobetich, J. D. Williams, S. Contreras-Balderas, and others. 1979. Fishes of North America endangered, threatened, or of special concern: 1979. Fisheries. 4(2):29–44.

Flader, S. L. and J. B. Callicott, eds. 1991. The River of the Mother of God and other essays by Aldo Leopold. Univ. Wisconsin Press, Madison. 384 pp.

Gerstung, E. R. 1988. Status, life history, and management of the Lahontan cutthroat trout. Am. Fish. Soc. Symp. 4:93–106.

Gregory, S. V. and L. Ashkenas. 1990. Riparian management guide: Willamette National Forest. U.S.D.A. Forest Service, Pacific Northwest Region. 120 pp.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience. 41:540–551.

Grumbine, R. E. 1990. Viable populations, reserve size, and Federal lands management: A critique. J. Conserv. Biol. 4:127–134.

Karr, J. R. 1990. Biological integrity and the goal of environmental legislation: Lessons for conservation biology. J. Conserv. Biol. 4:244–250.

Karr, J. R. and D. R. Dudley. 1981. Ecological perspective on water quality goals. Environ. Manage. 5:55–68.

Karr, J. R., L. A. Toth, and D. R. Dudley. 1985. Fish communities of midwestern rivers: A history of degradation. BioScience. 35:90–95.

Karr, J. R., K. D. Fausch, P. L. Angermeier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: A method and its rationale. Illinois Nat. Hist. Surv. Spec. Publ. 5. 28 pp.

Miller, R. R. 1961. Man and the changing fish fauna of the American Southwest. Papers Michigan Acad. Sci., Arts, Letters. 46:365–404.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries. 14(6):22–38.

Minckley, W. L., P. C. Marsh, J. E. Brooks, J. E. Johnson, and B. L. Jensen. 1991. Management toward recovery of the razorback sucker. Pages 303–357 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: Native fish management in the American West. Univ. Arizona Press, Tucson. 517 pp.

Moyle, P. B. and G. M. Sato. 1991. On the design of preserves to protect native fishes. Pages 155–169 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: Native fish management in the American West. Univ. Arizona Press, Tucson. 517 pp.

Plafkin, J. L., M. T. Barbour, K. D. Porter, S. K. Gross, and R. M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish. EPA/440/4–89/001, U.S. Environ. Protection Agency, Washington, D.C.

Valdez, R. A. and R. D. Williams. 1987. Endangered fishes of Cataract Canyon. Proc. Desert Fishes Coun. 18(1986):212–220.

Williams, C. D. and J. E. Deacon. 1991. Ethics, Federal legislation, and litigation in the battle against extinction. Pages 109–121 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: Native fish management in the American West. Univ. Arizona Press, Tucson. 517 pp.

Williams, J. E. 1991. Preserves and refuges for native western fishes: History and management. Pages 171–189 *in* W. L. Minckley and J. E. Deacon, eds., Battle against extinction: Native fish management in the American West. Univ. Arizona Press, Tucson. 517 pp.

Williams, J. E., J. E. Johnson, D. A. Hendrickson, S. Contreras-Balderas, J. D. Williams, M. Navarro-Mendoza, D. E. McAllister, and J. E. Deacon. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14(6):2–20.

Williams, J. E., D. B. Bowman, J. E. Brooks, A. A. Echelle, R. J. Edwards, D. A. Hendrickson, and J. J. Landye. 1985. Endangered aquatic ecosystems in North American deserts with a list of vanishing fishes of the region. J. Arizona-Nevada Acad. Sci. 20:1–62.

Protecting the Biodiversity of Riverine and Riparian Ecosystems: The National River Public Land Policy Development Project

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Introduction

The objective of the National River Public Land Development Project is to draft a proposal for the U.S. Congress outlining the measures necessary to protect the health of the nation's public riverine (stream channel, riparian and floodplain) ecosystems. The policies that will be drafted will be based on the recommendations from 16 task force members from around the country (Table 1). The task force is primarily built around a core group of stream ecologists. The role of the Oregon Rivers Council is to facilitate the process of merging state-of-the-art stream ecology with public policy and closing what may be a ten-year science and policy gap. The Council believes that the health of the nation's riverine ecosystems is the foundation for protection of biodiversity (the full range of the resident biota). The question that we posed to the task force was: What steps are necessary to protect the health of the nation's riverine ecosystems?

The Problem

The scope of the problem is national. Of the 3.2 million miles (5.2 million km) of rivers in the contiguous 48 states at this time only about 2 percent are healthy enough to be considered high quality and worthy of protection (Benke 1990). Of middle-sized rivers (greater than 124 miles [200 km long]), only 42 have not been dammed. However, dams are far from the only source of demise for the nation's rivers: logging, acidification and sedimentation from mining, water diversions, atmospheric deposition, introduction of exotic species, development and grazing in riparian zones and floodplains, stream cleaning, poor upland management, as well as point and non-point source pollution also have led to extensive degradation.

These activities have led to habitat loss which has been found to be a major cause of the decline of North American fish fauna. Habitat alteration has significantly contributed to the extinction of 73 percent of the 40 native North American fish species known to have gone extinct since 1900 (Miller et al. 1989). Nehlsen et al. (1991) also have recently identified habitat damage as the single most widespread contributor to the decline of almost 200 anadromous fish stocks on the west coast.

Even though much of the aquatic habitat on public land nationwide is seriously degraded, just as it is on private land, the remaining pockets of high integrity aquatic habitat are almost exclusively on public lands, especially in the west. These public lands provide perhaps the only opportunity to maintain the existing, though degraded, state of riverine ecosystem health by protecting the headwaters which sustain down-

Table 1. National rivers policy task force members.

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stream reaches, and provide the only opportunity to establish aquatic refuges, and on which to anchor a watershed recovery plan.

Current policies are inadequate to address the problems, and the degradation continues, despite regulatory efforts made under various federal laws (Karr 1991). For example, while the Clean Water Act was responsible for dramatic biological changes in some reaches of rivers, largely the result of diminishing point source biological oxygen demand, it has not been an effective policy for maintaining the biology of systems. While the Clean Water Act, the Federal Land Policy and Management Act of 1976, the National Forest Management Act, the National Environmental Policy Act of 1969 and other acts provide some of the authorizing language and direction needed to sustain the health of public land river and riparian ecosystems, the combined directives fail because:

1. There is no explicit national goal to maintain the natural ecological health of whole riverine landscapes. Alternatively it can be argued that the authorizing language of the Clean Water Act is available or can be strengthened to provide an adequate statement of the goal, and national regulations to accomplish that goal are lacking.
2. Few public land management agencies have adopted state-of-the-art aquatic ecosystem management policies, standards and guidelines.
3. No process or framework has been mandated to show the trends in health of public aquatic ecosystems. It can be argued that some state regulations have been developed which do work, and these could be established nationally.

4. No policies mandate coordination between agencies that have management responsibilities within the same basin.
5. Management decisions are not based on the long-term, whole-basin perspective.

A New National Goal

A new national goal must be established, and new federal mandates are needed to protect and restore the ecological integrity of riverine ecosystems. Maintaining the existing levels of aquatic ecosystem health is vital, but not enough. The United States must commit itself to a program of restoring aquatic ecosystem health on public lands. All new mandates must be based on a stream ecosystem perspective emphasizing that streams are intimately linked with their drainage basins.

The new national goal that the task force proposed was: *To protect and restore the natural ecological integrity of riverine landscapes.*

The riverine landscape is the network of streams and riparian systems within a given catchment basin. The definition of "natural ecological integrity" shall include species composition, diversity, and functional organization comparable to that of the natural habitat of the region under conditions of aboriginal influence. The definition shall also be based on the principals of connectedness, natural variability and on the capacity of the ecosystems to self-repair.

These basic ecological principles underlie the new national goal.

In a seminal lecture, Hynes (1975) described how rivers are manifestations of the biogeochemical nature of the valleys they drain, and he proposed that understanding the connectedness between the terrestrial and the aquatic biotopes would yield important predictions about factors that control the structure and function of riverine ecosystems. In the last two decades, riverine ecosystem connectedness has been elucidated in four dimensions: longitudinal (upstream-downstream); lateral (stream channel-floodplains and riparian zones); vertical (stream channel-hyporheic zones); and temporal (past-present-future) (Stanford and Ward 1991).

The river continuum concept (Vannote et al. 1980) provides a template for examining how biotic attributes of rivers change along the longitudinal dimension of connectedness from the headwaters to the ocean. It also provides the framework for understanding how the lateral dimension of connectedness changes along the longitudinal dimension.

Streams also are dynamic systems, which are intrinsically variable over time (e.g., flood and drought regimes). Any successful management scheme for riverine ecosystems must include the four dimensionality of connectedness as well as physical, chemical and biological processes that create and shape riverine landscapes, over long time scales (greater than 100 years). Therefore, single-species or single-issue management is inadequate to protect and maintain healthy riverine ecosystems.

The Fundamentals of the New Policy

At least three new federal policy directions must be established to meet the new national goal. These policies must serve as the foundation for efforts to optimize the protection and restoration of public aquatic ecosystems and riverine landscapes.

1. *A mandate to protect and restore the headwater streams, riparian areas and floodplains, and to reconnect streams with floodplains where possible.* The health of riparian areas is dependent on all components and all age-size classes of vegetation, this includes grasses, sedges, shrubs and trees. The primary management goal is the protection and restoration of these riverine areas; management activities such as grazing, mining, campgrounds, road building and timber harvest, should be allowed only when they do not compromise the primary goal. New management directives need to be placed on timber harvest and salvage logging near floodplains and riparian areas to provide enough large wood for both the stream channels and the floodplains. This wood is critical for maintaining habitat complexity, and to serve as a supply of large woody debris as new stream channels are carved in the floodplains. Restoration of degraded areas is critical, and reconnecting streams with their floodplains is a critical component of *any* restoration policy. In such a mandate, critical concepts (e.g., riparian areas) must be defined ecologically.

The headwater reaches provide critical linkages with the terrestrial portions of each basin, and they control many functional processes of the entire downstream system. Appropriate upland management is a necessary corollary to floodplain management to ensure that soil and hillslope water storage capacity is not reduced, and that management activities return the frequency and magnitude of sediment transport into the stream systems back toward more natural rates. Major sources of sediment include mining, roads, surface runoff and mass erosion from the uplands. Water diversions must also be minimized and prior diversions progressively retired. We propose protection and restoration of riparian areas of all permanent and intermittent headwater streams.

2. *The establishment of a national system of watershed or aquatic refuges.* There are few areas with high natural integrity remaining on public (or private) lands nationwide. These must be set aside to protect the few remaining healthy aquatic ecosystems and to protect remnant pockets of rare biological communities from extinction (Sedell et al. 1990). The watersheds that are the healthiest and possess the greatest diversity of species would serve not only as species banks but as ''benchmarks'' or controls for the entire basin. The watershed refuges would be primarily public land areas where the sole management goal is the maintenance of the integrity of aquatic habitat for the preservation of the entire assemblage of aquatic and riparian associated processes and species. Management activities in those areas would be limited to those practices that are known to result in increased habitat integrity. Roads should be removed within the refuge and/or a program established to improve road drainage.

The watershed refuges should be spaced to ensure the maximum recolonization, with each refuge large enough to function as a biological unit. They should be managed specifically to maintain aquatic biodiversity, genetic islands and recolonization sources. These refuges will also serve as anchors for a long-term watershed habitat restoration strategy. The refuges must include the stream channels and their associated uplands, floodplains, wetlands and hyporheic zones. This network of refuges will facilitate recovery of listed species and reduce the need to list additional candidates. Also, these refuges are critical monitoring sites to detect long-term chronic problems such as acid precipitation and global climate change.

In addition, aquatic species or biological communities that are facing imminent danger of extinction need to be immediately identified and given the same refuge status and protection as above. Immediate action should be taken to protect and restore them. The need for these refuges can be identified by "gap analysis" or some similar means, and habitat recovery should be initiated immediately.

3. *Watershed assessments and historical reconstruction.* Because most public aquatic ecosystems have been significantly degraded, policies that mandate an understanding of the complete system and the conceptual reconstructions of the natural river ecosystems are necessary. Without these reference points, maintenance and restoration lack the biologically meaningful context in which to frame restoration policy. These models will function as "benchmarks" or standards for health and biological integrity of river systems.

An assessment of the watershed should begin at the landscape level first, and then move to the tributary and stream reach level. This involves documentation, both spatially and temporally, of the ecological processes, status and trends, identification of the critical components, control points and other areas of high priority (such as areas of greatest connectivity and "pristine" sites) of the riverine landscape. In addition, these conceptual models must be based on historical reconstructions. Information from early natural history writings, surveys of aquatic organisms, historical journals, diaries, cadastral surveys, well-drilling records, snagging records, beaver trapping, etc. must be integrated with research on current stream ecosystem community structure and functional processes, and synthesized into the conceptual frameworks.

As the conceptual reconstructions proceed, comparisons can be made with the current state of the aquatic systems, providing the context for developing basin protection and restoration policy. With greater understanding of the changes that have occurred in basins, we can more effectively prioritize the management needs. For instance, if gaps in the protection of critical organisms or biological communities can be identified, we can determine areas that need to be added to the refuge system.

The Oregon Rivers Council believes these new long-term policy directions represent the fundamental approach for restoring the nation's public aquatic ecosystems. These actions provide a standardized general perspective applicable to all rivers, yet provide the necessary flexibility to deal with the unique character and individual problems of each river basin.

Proposed Public Land Riverine Landscape Management Standards

Riparian Area Management

Careful attention to riparian area is a foundational component of any successful riverine landscape protection and restoration plan. The following definition and policy recommendations follow generally from Gregory et al. (1991), Gregory and Ashkenas (1990). Gregory and Ashkenas (1990) is currently used by the Willamette National Forest, Oregon. Adoption of similar riparian standards would greatly improve the management practices on public lands.

Definition: The riparian zone is a functional region of transition between the stream channel and the hillslope, or between the aquatic and the terrestrial portion of the drainage basin. In general, the landform boundaries of the riparian zone extend from the stream channel to the toe of the hillslope, and include the floodplains, terraces and connecting swamps and wetlands. The objective in delimiting this zone is to capture the longitudinal, lateral and vertical dimensions of connectedness. In most riverine landscapes, the stream channel and riparian zone will delimit the surface of alluvial formations; the major exception would be areas of Pleistocene glaciation. In these areas, the upper boundary would be established at the 100-year flood level. However, the riparian zone would extend to the boundary of the alluvial formation when considering the subsurface hydrology or hyporheic zones. Also, especially in small headwater streams, the riparian zone will extend upslope to include the zone of vegetative inputs of leaves, needles and wood to the riparian area, as well as the zone of shade influence.

The following proposed standards are necessary for maintaining the ecological integrity of riparian areas:

1. *Timber harvest* should be prohibited, except where it can be demonstrated not to degrade the ecological integrity of the riparian area. This restriction would be placed on permanently flowing or intermittent (normally flowing at least six months of the year) stream channels and their associated riparian areas. Logging practices adjacent to streams must be designed to minimize the impacts on the stream systems and the riparian zones. Also, timber harvest should be prohibited on sites that have locally unstable soils.
2. *Salvage logging* will not be permitted from riparian areas, including blow-down salvage, except where necessary for human health and safety reasons.
3. *Large woody debris management* plays an important role in the maintenance of the integrity of riverine ecosystems. No removal of down large woody debris will be allowed in any riparian areas or stream channels.
4. *Road and bridge design and location* should be designed to minimize the impacts on the riverine ecosystem. Road construction on floodplains should be prohibited or minimized to prevent fragmentation of the riverine landscape. Also, a policy of progressive road removal should be instituted for existing roads within riparian areas. In particular, look for opportunities to reconnect the stream with the floodplain through new culverts, etc. All roads should be constructed and maintained (including culvert cleaning and placement, etc.) to minimize modifications of water routing (surface and subsurface), and to minimize additions of sediments (direct and indirect) to streams. The timing of road and bridge construction should also be determined primarily to minimize possible disturbance.
5. *Grazing* shall be prohibited in most riparian zones, especially in watersheds of high integrity or refuges. Where not eliminated, grazing should be restricted to specific seasons and certain levels to insure that adequate grass, herb, tree and shrub vegetation is constantly maintained, since vegetation is a major determinant of bank stability, soil conditions, nutrient loading and water balance.

Upland Management

While upland management must be basin and biome-specific, a new upland management policy must be developed to protect against major changes in basin hydrology. The policy needs to insure that the frequency and magnitude of erosion processes is not substantially altered. The standard for what would constitute "substantially altered" needs to be determined ecologically.

Dams

There are currently 68,000 (according to the Environmental Protection Agency) to 75,000 (according to the National Park Service) dams on the nation's river systems. During the last 20 years, research has demonstrated that dams have a profound negative impact on river ecosystems (e.g., Stanford and Ward 1979).

Few sites for new large hydropower plants remain in the U.S., so the current emphasis on new dams is on small tributary streams, which are the *critical* areas that need protection to maintain existing levels of ecosystem health and on which to anchor recovery strategies. A large number of small hydroprojects would contribute little to the nations total generating capacity. An increase of 55 percent in new projects on small tributaries will add less than 1 percent to the nation's energy capacity, yet have enormous ecological impacts (Benke 1990). The Council proposes that the use of rivers for hydroelectric dams should no longer be considered as a renewable resource. it is time for a new national policy direction.

New public land policies for dam approval, operations, and removal should be instituted. The following policies are viewed as necessary, given the new national goal of protecting and restoring the natural ecological integrity of riverine ecosystems:

(1) A national priority list of dams should be established that cause the greatest ecological impact, or are incompatible with basin protection or restoration policy goals, or are generally unneeded within a basin.
(2) Dams on the list which result in the greatest impacts should be given the highest priority for removal.
(3) A national *moratorium* on new dam construction should be implemented.
(4) Power-generating equipment on existing dams not scheduled for removal should be repaired, rewound or retrofitted where ecologically appropriate. Existing dams should upgrade their operations to protect stream integrity whether through the relicensing process or otherwise. Stream diversions should be minimized, and existing diversions progressively retired. The energy gain would be greater than if many new dams were built.

Mining

The Mining Law of 1872 allows individuals to buy ''all valuable mineral deposits in lands belonging to the United States.'' It does not apply to organic fuel minerals like oil and coal. The statute gives the finder a right to extract and sell the minerals. The finder can also get government patent and title. At present, Congress considers mining rights more important than most other land use concerns. As long as mining has this priority over other uses, the significant ecological consequences of mining within riverine landscapes will be difficult to address. The Council proposes that Congress remove the priority status given to mining within or near riparian areas, floodplains and toeslopes, and within any area hydrologically connected to streams.

Riverine Landscape Restoration Policies

With very few exceptions, the nation's riverine landscapes are seriously degraded. While it is critical to protect the existing levels of ecosystem health, a new national policy of *Riverine Landscape Restoration* must be established. The policies should be based on the following principles:

(1) Restoration should be based on a long term, whole basin perspective, rather than single-species or other single-issue concerns.

(2) Restoration of stream function is the goal (e.g., reconnecting the stream with the floodplain and allowing the stream to repair itself, where possible).
(3) Restoration plans should be designed to minimize the need for future human maintenance.
(4) Restoration management plans should focus on the source of the degradation, not the symptoms.

Restoration Policy Components

Key areas within a basin should be identified to preserve natural ''capital'' for future use. These areas can be established and protected as aquatic refugia. They help allow for error of future risk within the basin.

The use of exotic species should be prohibited (only use species native to the basin). The cost of exotic species removal should be calculated and carried out in those cases where feasible. Native materials should be used for restoration.

A new national ''after-the-flood policy'' should be established that prohibits reconstruction within riparian areas or floodplains on public lands after floods. Any development must be consistent with these policies; therefore, there should be no use of federal flood damage or insurance funds for rebuilding. Restoration management plans and goals should be established around the flood scale (e.g., 10y, 100y).

A new national ''after-the-drought policy'' should also be established. No modification of water resource management practices should ensue for drought or flood. Extremes are no excuse for poor resource management. Water policy and land-use development should coordinate with water availability within a basin, and conservation of water and use or reuse of ''graywater'' should be promoted. Also, in-stream water rights for native species should be a high national priority, based on natural flows that reconnect the surface water with the riparian area. Regulation of in-stream flows must reflect needs of native species, and stream functions and processes (e.g., channel morphology).

On-going Evaluation Policies

The on-going evaluation of protection and restoration programs must be a fundamental component of any successful new national policy. Effective evaluation requires historical and current baseline and inventory information, and must be continually monitored over longer time frames to evaluate the scientific and tactical assumptions of protection and restoration programs. This information should be collected and analyzed through a common currency of communication (data bases must be able to communicate and be accessible). Biological criteria are the most sensitive and important. Chemistry, temperature, physical and hydrological criteria also should be included.

Implementation Policies

Having identified the biological strategies necessary to protect the biodiversity and health of the nation's riverine ecosystems, the next task will be to identify the appropriate legal mechanisms for implementing these strategies.

An examination of existing resource protection and federal land management statutes reveals that current statutory schemes and their implementing regulations fail to provide adequate protection for riverine ecosystems based on the biological criteria developed by the task force. Of the many overlapping statutory schemes that govern the management of federal lands, none give clear priority to the maintenance and restoration of riparian ecosystems.

In order to accomplish the goal of protecting and restoring the biological integrity of riverine ecosystems, new federal legislation is needed. However, from a purely political perspective, it may be wise to pursue the amendment of existing statutes in order to build a constituency for more comprehensive legislation. As of this writing, the National Rivers Policy Project is still developing its legislative strategies.

References

Benke, A. C. 1990. A perspective on America's vanishing streams. J. N. Am. Benthological Soc. 9(1):77–88.

Gregory, S. and L. Ashkenas. 1990. Riparian management guide: Willamette National Forest. U.S. For. Serv.

Gregory, S., F. J. Swanson, and W. A. McKee. 1991. An ecological perspective of riparian zones. BioSci. In press.

Hynes, N. B. N. 1975. The stream and its valley. Verhandlungen Internationale Vereinigung fur Theoreticshe und Angewandte Limnologie. 19:1–15.

Karr, J. R. 1991. Biological integrity: A long neglected aspect of water resources management. Ecological Applications 1(1):66–84.

Miller, R. R., J. D. Williams, and J. E. Williams. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22–38.

Nehlsen, W., J. E. Williams, and J. A. Lichatowich. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries 16(2):4–20.

Sedell, J. R., G. H. Reeves, F. R. Hauer, J. A. Stanford, C. P. Hawkins. 1990. Role of refugia in recovery from disturbance: Modern fragmented and disconnected river systems. Environ. Manage. 14(5):711–724.

Stanford, J. A. and J. V. Ward. 1979. Stream regulation in North America. Pages 215–236 *in* J. V. Ward and J. A. Stanford, eds., The ecology of regulated streams. Plenum Press, New York, NY.

Stanford, J. A. and J. V. Ward. 1992. Management of aquatic resources in large catchments: Recognizing interactions between ecosystem connectivity and environmental disturbance. *In* R. J. Naiman, ed., Watershed management: Balancing sustainability with environmental change. Springer-Verlag, New York, NY. In press.

Ward, J. V. 1989. The four-dimensional nature of lotic ecosystems. J. N. Am. Benthological Soc. 8:2–8.

Special Session 7. *The Potential and Promise of Wildlife Disease Study and Control*

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Wildlife Health: When to Intervene

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During the past 30 years, there has been an explosion of interest in wildlife and the environment. Some might identify Rachel Carson's *Silent Spring* as the initial springboard which launched a movement that has captured the imagination of millions of people. For many individuals, to include both laymen and professionals, what once consisted of only a moderate interest in wildlife is now an overriding passion. Today, the desire to intervene on behalf of wildlife and wildlife health has taken on a degree of interest and momentum unimagined by the pioneer wildlife professionals of the first half of this century.

Some of the interest reflects the fact that major segments of our population have become urbanized. For many, routine exposure to the traditional wildlife habitats of field and forest, farm and ranch, has diminished or is nonexistent. Wildlife programs on television and articles in glossy magazines provide some exposure to species and life histories which previously might have been experienced "in the flesh." For others, interest and concern relates to the degradation of the environment with its potential impact on the health and welfare of both wildlife and man. Perhaps of greatest significance, individually perceived ethical and moral values are driving the interests and actions of significant portions of the populace who describe themselves as being concerned about wildlife.

For the uninitiated, it might seem that wildlife health should fall exclusively under the domain of veterinary professionals. That, of course, is not the case. Wildlife management professionals have been intervening on behalf of the health and welfare of wildlife for decades, although that fact is seldom recognized and little understood by either the general public or most veterinarians.

National and international concern for the "health" of wildlife, both individually and at the population level, has historically been manifest by the promulgation of various legislative initiatives. The National Environmental Policy Act (NEPA) and the Rare, Threatened and Endangered Species Act have been among the most visible to emerge within the past several decades. These have, in fact, had a significant impact on certain aspects of wildlife health. Concern for the health and welfare of our wildlife populations, however, is far from being a recent phenomenon. In response to diminishing populations of wildlife during the first half of the century, many individuals and organizations expended great energy in the pursuit of laws which would impact positively on our wildlife resources.

Firm foundations were built with legislation such as the Lacey Act (1900), Weeks-McLean Act (1913), Migratory Bird Treaty Act (1918) and the Migratory Bird Conservation Act (1929), which authorized the National Wildlife Refuge System. These initiatives were followed by the Duck Stamp and Fish and Wildlife Coordination Acts in 1934, establishment of the Cooperative Wildlife Research Unit Program in 1935, and the landmark Federal Aid in Wildlife Restoration Program (Pittman-Robertson Act) in 1937 (Williamson 1987). These and other critical pieces of legislation have proved their considerable value over time.

Concern for wildlife saw the emergence of citizen conservation organizations such as the National Audubon Society, National Wildlife Federation and Ducks Unlimited. The Wildlife Management Institute, The Wildlife Society, International Association of Fish and Wildlife Agencies, and other professional organizations have contributed, and will continue to contribute, to ensuring the perpetuation of healthy wildlife populations.

In today's society, wildlife professionals are continually confronted with questions regarding intervention on behalf of wildlife. The magnitude and scope of potential interventions are beyond the ability of most of us to comprehend. The appropriateness or prudence of interventing is essentially in the eye of the beholder.

From a management perspective, the perpetuation of quality habitats and the maintenance of diversity are among the primary cornerstones necessary for the existence of healthy populations. In today's socio-political environment, however, there are significant concerns being expressed regarding the health of individual wild animals, as well as populations. Many of the most vocal individuals and organizations injecting themselves into decision-making processes have little or no training in population dynamics, disease processes or the application of management techniques.

While some would advocate a laissez faire attitude, i.e., standing back and letting "nature take its course," others feel a compelling need to rehabilitate each sick, injured or dying wild bird or animal encountered. Reason and practicality probably lie somewhere between these two extremes.

Examples of questions germane to wildlife management and disease specialists include:

"Is intervention appropriate and if so, to what degree? Who is guiding, directing, or demanding the intervention? Is there a sound basis for the proposed intervention? Are wildlife managers, biologists and disease specialists involved in the decision making process? What are the cost/benefit ratios associated with intervention versus nonintervention? What are the political risks, rewards or benefits? Are there public health implications? Is there potential for domestic livestock or poultry involvement? Will intervention affect only individual animals or will it impact at the herd, flock or population level? Is the involved species ubiquitous or is it threatened with extinction? Is more than one species of wildlife involved? Where does the animal rights community fit in?'' The questions are infinite, and the answers not readily forthcoming.

Wildlife health, as a high visibility area of interest, is a relatively recent phenomenon. However, if one looks back in history fifty or sixty years, it is evident that early wildlife professionals readily recognized the importance of wildlife diseases and the relationship of healthy habitats to healthy wildlife.

Herbert Stoddard, in his classic text *The Bobwhite Quail*, theorized that parasitic and infectious diseases might serve as significant morbidity and mortality factors for quail. Recognizing the lack of research data, he also suggested that fire might aid in the control of certain quail diseases and parasites (Stoddard 1931).

The father of wildlife management, Aldo Leopold (1933), devoted an entire chapter in his text, *Game Management*, to ''Control of Disease.'' He articulated the belief that ''the role of disease in wild-life conservation has probably been radically underestimated.'' Many of his observations are as applicable today as they were decades ago. For example, he stated, ''Contact with domestic animals is of obvious importance in all diseases shared with or carried by them'' and ''. . . dispersion of game food and cover is probably of great importance in all diseases where ease of transmission from one individual to another affects either the virulence of the disease or its distribution.'' Significantly, Leopold also expressed concern regarding the potential negative implications of the ''planting of game-stock bearing diseases acquired in game farms, or in other regions, or in transit. . . .'' Even in his perspectives regarding wildlife diseases, Leopold was progressive.

He was not, however, totally clairvoyant. In the same text, Leopold stated that ''It is obvious even to the layman that control of disease by medication of wild game is impossible.'' We now know that such is not always the case. Conversely, he correctly recognized the potential for habitat and population manipulations to impact positively on the course of disease. He described the relationship of manipulating freshwater impoundments with subsequent effects on outbreaks of avian botulism. He also cited the beneficial impact of radical reductions of whitetailed deer upon the course of the foot-and-mouth disease outbreak in the Stanislaus National Forest, California, in the early 1920s. Intervention directed toward the prevention or control of disease outbreaks is most certainly not a new phenomenon.

Examples of interventions on behalf of free-ranging wildlife health are numerous. Some approaches have been employed for years, while others are currently under development and will benefit from emerging technologies. A few examples include: the use of anthelminthic laced apple mash to treat bighorn sheep infected with lungworms; dusting flea infested prairie dog burrows with insecticides during epizootics of plague; use of chemicals to control ticks associated with rodents in Lyme disease endemic area; and field testing of oral recombinant rabies vaccines directed toward particular species of wildlife (Hable et al. 1992). Regulatory interventions, such as the restrictions placed upon the use of lead shot by waterfowlers, have also impacted upon wildlife health. Some interventions impact at the individual and population level, whereas others, such as the elimination of the use of DDT or other pesticides, impact at the community and ecosystem level.

Increasingly, the public is demanding interventions which focus heavily on individual wild animals. The highly publicized rescue of two whales trapped beneath arctic ice, an effort which took nearly three weeks and involved scores of people, resulted in expenditures approaching $1 million. The Exxon Valdez oil spill brought national attention to rescue and rehabilitation efforts directed toward various species of birds and mammals, particularly sea otters. It has been estimated that the cost incurred, per sea otter returned to the wild, exceeded $80,000. Survival data gleaned from radio-implanted otters indicates that probably fewer than 50 percent of those released were alive a year later. If true, the cost *per survivor*, after a year, may have approached or exceeded $175,000 (Estes 1991). Questions regarding the appropriateness of such interventions, and the resulting expenditures, generate a mountain of moral, ethical and economic concerns.

In this year of increased focus on the Endangered Species Act, there has been considerable discussion regarding the large dollar amounts being spent on "charismatic megafauna," while the vast majority of other "listed" species receive relatively minor attention (Nash 1992). Decisions involving the management of endangered species may impact not only on their state of health, but ultimately upon whether they survive as a species or become extinct.

Individual and organizational pursuit of scientific knowledge is critical if resulting intervention strategies are to be meaningful and successful. There are, in fact, a number of organizations which have had a positive impact upon wildlife health. Examples of some of those which have embraced the pursuit and application of scientific knowledge on behalf of wildlife health include: The Wildlife Disease Association (WDA), American Association of Wildlife Veterinarians (AAWV), American Veterinary Medical Association (AVMA), U.S. Animal Health Association (USAHA) through its Wildlife Diseases Committee, and the International Association of Fish and Wildlife Agencies (IAFWA) through its Fish and Wildlife Health Committee.

Organizations such as the Southeastern Cooperative Wildlife Disease Study, located at the University of Georgia, in Athens and the National Wildlife Health Laboratory, headquartered in Madison, Wisconsin, serve as foci for wildlife disease diagnostic and research activities. They also play a significant role in recommending appropriate interventions, during both routine and emergency situations. Additionally, for decades state wildlife and natural resource agencies, universities, and private institutions have provided expertise in similar areas and continue to impact upon decision-making processes involving wildlife health. Many veterinary schools and university wildlife curricula now offer some type of formalized course or courses which address the subject of wildlife disease or wildlife health.

It should be of particular note to wildlife management professionals that there is rapidly increasing interest being expressed within the veterinary profession regarding the fate of our wildlife resources. The Pew National Veterinary Education Program report (Pritchard 1989), which explored "Future Dimensions for Veterinary Medicine," predicted increasing involvement by the veterinary profession in wildlife related activities. Some veterinarians have called for the formation of a national wildlife contingency plan in the event of environmental disasters (Williams 1991).

A two-day, veterinary-oriented, Wildlife Health Workshop was conducted in August 1991, at Fort Collins, Colorado, under the sponsorship of the Pew Foundation. The workshop explored such topics as "Issues Affecting the Involvement of Veterinarians in Wildlife Health," "Future Needs and Roles for Veterinarians in Wildlife

Health and Conservation Biology,'' ''Training Future Wildlife Veterinarians,'' and the development of ''Strategies and Action Plans'' (Boyce et al. 1992).

In September 1991, the AVMA sponsored a Public and Corporate Veterinary Practice Symposium to explore current and future roles for the veterinary profession other than those involving traditional private practice (Freeman 1992). Considerable attention was given to development of new and expanded veterinary involvement in wildlife related issues. In the same AVMA Journal issue which reviewed the Symposium, an article was published describing the exceptional career of Albert W. Franzmann, a well-known wildlife veterinarian.

In November 1991, the AVMA's Second Annual Animal Welfare Forum, held in Chicago, focused on ''The Veterinarian's Role in the Welfare of Wildlife.'' The symposium brought together speakers whose professional expertise included environmental ethics, wildlife legislation, endangered species, rehabilitation, capture techniques, health management of free-ranging species of wildlife, zoological medicine, etc. (Spencer 1992).

The significance of these veterinary organizational initiatives, directed toward a role with wildlife, cannot be understated. It is important that the veterinary profession not develop a perspective of ''we are the ones who are best qualified to intervene when wildlife health issues emerge.'' Professional biologists, who have long been involved in wildlife health issues, must be an integral part of the team effort when it comes to issues involving free-ranging wildlife populations. They also have a responsibility to provide the public with accurate information and reasoned biological perspectives regarding such issues as wildlife rehabilitation. A recent essay published in Audubon (Steinhart 1990), entitled ''Humanity Without Biology,'' provided inciteful analysis regarding the increasing number of licensed and unlicensed individuals engaged in wildlife rehabilitation. Wildlife health issues are fraught with controversy. For example, the mere mention of steelshot, leghold traps, brucellosis in bison and elk, or tuberculosis among game-farm cervids, evokes strong emotional responses from a variety of constituencies. Such controversy will undoubtedly continue to emerge for decades to come.

Ultimately, rational decisions need to be made regarding who is going to diagnose problems, make ''treatment'' recommendations and write the ''prescriptions.'' Knowledgeable professionals must monitor the effects of such ''treatments'' and interpret the results. It is imperative that professional wildlife biologists, disease experts and other specialists assume strong leadership roles in decision-making processes. Only through skillful use of public relations personnel, an informed media and the application of sound biological principles can we ensure that wildlife, their habitats, and man will be responsibly served.

References

Boyce, W., N. Elliot, and J. Mazet. 1992. Unpublished proceedings of the Wildlife Health Workshop, sponsored by the Pew National Veterinary Education Program, August 1991, Fort Collins, CO.

Estes, J. A. 1991. Catastrophes and conservation: Lessons from sea otters and the Exxon Valdez. Science 254 (5038):1596.

Freeman, J. I. 1992. AVMA public and corporate veterinary practice symposium. J. Am. Vet. Med. Assoc. 200(3) 295–336.

Hable, C. P., A. N. Hamin, D. E. Snyder, R. Joyner, J. French, V. Nettles, C. Harlon, and C. E. Rupprecht. 1992. Prerequisites for oral immunization of free-ranging raccoons (*Procyon lotor*) with a recombinant rabies virus vaccine: Study site ecology and bait system development. J. Wildl. Dis. 28(1):64–79.

Leopold, A. 1933. Game Management. Charles Scribner's Sons, NY. 481 pp.

Nash, J. M. 1992. The $25 million bird. Pages 56–57 *in* Time magazine, January 27. TIME Inc., NY.

Pritchard, W. R., ed. 1988. Future directions for veterinary medicine. Pew National Veterinary Education program, Institute for Policy Sciences and Public Affairs, Duke Univ., Durham, NC. 189 pp.

Spencer, L. 1992. Animal welfare forum explores scientific management of wildlife. J. Am. Vet. Med. Assoc. 200(3):12–19.

Steinhart, P. 1990. Humanity without biology. Pages 24–27 *in* May issue, Audubon, Nat. Audubon Soc., NY.

Stoddard, H. 1931. The bobwhite quail, its habits, preservation and increase. Charles Scribner's Sons, NY. 559 pp.

Williams, T. D. 1991. Need for a national wildlife contingency plan in the event of environmental disasters. J. Am. Vet. Med. Assoc. 199(6):674.

Williamson, L. L. 1987. Evolution of a landmark law. Pages 1–17 *in* H. Kallman et al., eds., Restoring America's wildlife, U.S. Govt. Print. Off., Washington, D.C. 394 pp.

Oral Wildlife Rabies Vaccination: Development of a Recombinant Virus Vaccine

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Rabies is an ancient, acute, highly fatal, infectious viral disease of warm-blooded animals with a global distribution. Because free-ranging canids and other mammalian carnivores serve as the principal wild terrestrial reservoirs, ultimate disease control has been historically difficult to achieve. The initial concept of vaccination of wildlife en masse, as an extension of induced herd immunity to potentially control the disease, was developed more than three decades ago by the father of Oral Rabies Vaccination, Dr. George Baer, at the Centers For Disease Control, Atlanta, Georgia. This approach appears both novel and more appealing than the more traditional one of animal population reduction; yet, the actual successful application of this strategy beyond the laboratory to the field, by the inclusion of a potent liquid rabies vaccine contained within an edible bait, was only accomplished some 20 years later, but not in the United States, due to a variety of complex biological and socio-political factors.

In contrast, oral vaccination of the red fox (*Vulpes vulpes*) via baiting is now an important aspect of rabies control in Europe and Canada (Johnston et al. 1988, Schneider et al. 1988, Wandeler et al. 1988). Only recently has the intensity of a raccoon (*Procyon lotor*) rabies epizootic in the mid-Atlantic region of North America provided the renewed impetus for more comprehensive rabies control programs in the United States, including oral wildlife immunization, in addition to proven public health measures, such as vaccination of companion animals. Evolution of auto-vaccination methodology from a fox model to the raccoon involved extensive field and laboratory research upon relevant biological variables. For example, preliminary aerial and hand baiting trials at a single fixed density of approximately 100 baits/km^2 resulted in the demonstration that up to 70 percent of free-ranging raccoons in rural areas of Pennsylvania (Table 1) would accept placebo baits designed ultimately to deliver rabies vaccine (Rupprecht et al. 1987). Unfortunately, although existing attenuated rabies vaccines result in successful oral immunization of foxes, they are largely ineffective by this route in raccoons or the striped skunk (*Mephitis mephitis*) (Baer 1985, Rupprecht et al. 1986, Rupprecht et al. 1989). Moreover, safety concerns exist over the possibility of vaccine-induced disease in wildlife exposed to attenuated rabies viruses (Debbie and Bogel 1988, Rupprecht et al. 1990). Thus, currently available modified-live rabies virus vaccines do not completely satisfy the need for safe and efficacious oral vaccines suitable for the most important North American wildlife rabies vectors.

Table 1. Raccoon placebo baiting trials—Pennsylvania.

Season	Study area	Bait/attractant	Tetracycline positive samples (percentage)
Autumn 1985	176	Paraffin/BNA[a]	13/17 (76.5)
Autumn 1985	252	Paraffin/TKY	5/15 (35.7)
Autumn 1985	Butler Hill	Paraffin/SFO	6/9 (66.7)
Spring 1986	188	Paraffin/TKY	9/14 (64.3)
Spring 1986	242	Paraffin/FC	4/15 (26.2)
Spring 1986	254	Paraffin/BNA	3/7 (42.9)
Autumn 1986	43	Polybait/BNA-MM	5/15 (33.3)
Autumn 1986	Ridley Creek	Polybait/MM	14/28 (50)
Autumn 1986	145	Polybait/MM	8/16 (50)

[a]Abbreviations: BNA: banana homogenate; FC: feta cheese homogenate; MM: whipped marshmallow; SFO: shellfish oil; TKY: turkey gravy slurry.

To solve this dilemma, a vaccinia-rabies glycoprotein (V-RG) recombinant virus vaccine was developed that has proven to be an effective oral immunogen in raccoons (Wiktor et al. 1985, Rupprecht et al. 1986) and a variety of other species (Rupprecht and Kieny 1988, Brochier et al. 1990), providing long-term protection against rabies (Rupprecht et al. 1988, Blancou et al. 1989). The advantages of this recombinant orthopox rabies vaccine include greater thermostability than attenuated rabies vaccines, maximum duration and efficacy of a live virus vaccine system, and the inability to cause rabies, since only the cDNA of the surface glycoprotein of the Evelyn-Rokitnicki-Abelseth (ERA) strain of rabies virus is included in the recombinant virus (Kieny et al. 1984).

In the United States, bait development and placebo baiting trials have been conducted in an attempt to tailor vaccine packaging and distribution methods to be specifically attractive to raccoons and less attractive to other species (Rupprecht et al. 1987). Nevertheless, when vaccine is offered free choice in baits under natural conditions, contact by non-target wildlife species cannot be totally excluded by bait design and distribution alone. Subsequent to extensive vaccine safety and efficacy testing in raccoons, a rational, methodological approach was needed to evaluate potential V-RG vaccine safety in the array of non-target species potentially at risk for vaccine contact (Table 2). Relevant major taxonomic groups were defined as those most likely to contact vaccine-laden baits under natural conditions. Biomarkers, innocuous substances that could be incorporated to mechanically or physiologically identify animals in contact with baits, were used to determine these taxonomic groups in placebo trials in the United States (Hanlon et al. 1989, Hable et al. 1992) and actual oral rabies vaccination campaigns in Europe and Canada (Brochier et al. 1988, Pastoret et al. 1988, Schneider et al. 1988; Wandeler et al. 1988). Relevant groups included ecological competitors of raccoons and foxes, such as the opossum, mustelids, other members of the Canidae family and rodents. Additionally, other species were included because of their association with humans as companion animals (e.g., dogs and cats), domestic livestock (e.g., cattle, sheep) or commonly harvested game species (e.g., white-tailed deer). The rationale for including avian species was based partially upon observations by Canadian researchers (Bachmann et al. 1990) indi-

Table 2. Summary of vaccinia-rabies glycoprotein recombinant virus vaccine safety trials in non-target species.[a]

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
MAMMALIA						
Order marsupiala						
Family didelphidae						
Opossum (*Didelphis virginianus*)	6	10^{7}	Oral	0.9–56.8	30	Rupprecht and Kieny 1988
Order insectivora						
Family sorcidae						
Short-tailed shrew (*Blarina brevicauda*)	1	$10^{7.0}$	Oral	ND	70	Rupprecht unpublished
Order primates						
Family cebidae						
Squirrel monkey (*Saimiri sciureus*)	12	$10^{8.0}$	ID	>0.5 (7/8)	60	Rupprecht et al. 1992
Family pongidae						
Chimpanzee	8	$10^{7.2}$	Oral	<0.5 (8/8)	60	Rupprecht et al. 1992
(*Pan troglodytes*)	8[e]	$10^{9.0}$	Oral	>0.5 (6/8)	60	
	3	$10^{9.0}$	Oral	>0.5 (2/3)	60	
Order lagomorpha						
Family leporidae						
European rabbit (*Oroctolagus* sp.)	4	$10^{8.3}$	ID	>444.4	14	Wiktor et al. 1984
	2	$10^{7.8}$	ID	126.0	21	Wiktor et al. 1984
	2	$10^{7.8}$	IM	711.1	21	
	2	$10^{7.8}$	SC	1037.0	21	
	2	$10^{7.8}$	Oral	1037.0	21	
	3[e]	$10^{7.6}$	ID	0.1–177.8		Wiktor et al. 1985
		$10^{7.6}$	ID	355.5–1037.0	180	

Table 2. Continued.

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
Order rodentia						
Family muridae						
House mouse	12	$10^{8.3}$	ID	>444.4	14	Wiktor et al. 1985
(*Mus musculus*)	12	$10^{7.7}$	FP	>444.4	14	
	6	$10^{6.9}$	Oral	18.5–444.4	14	Rupprecht et al. 1988
	6	$10^{6.9}$	Oral +	>444.4	14	
Family erethizonidae						
Porcupine (*Erethizon dorsatum*)	3	$10^{9.0}$	Oral	162.0–1458.0	30	Rupprecht unpublished
Family sciuridae						
Groundhog (*Marmota monax*)	10	$10^{7.9}$	Oral	11.0–89.0	90	Artois et al. 1990
Grey squirrel (*Sciurus carolinensis*)	11	$10^{7.9}$	Oral	0.4–22.0	90	Artois et al. 1990
Flying squirrel (*Glaucomys volans*)	2	$10^{8.0}$	Oral	0.2–0.4	90	Rupprecht unpublished
Family cricetidae						
Cotton rat	1	10^{8}	Oral	ND	1	Rupprecht unpublished
(*Sigmodon hispidus*)	1	10^{8}	Oral	ND	2	
	1	10^{8}	Oral	ND	3	
	1	10^{8}	Oral	ND	4	
	4	10^{8}	Oral	0.3–486.0	30	
Marsh rice rat (*Oryzomys palustris*)	7	10^{8}	Oral	0.2–18.0	60	Rupprecht unpublished
Syrian hamster (*Mesocricetus auratus*)	12	10^{7}	IM	>0.5 (12/12)	30	Wiktor et al. 1985
Field vole (*Microtus agrestis*)	1	$10^{6.5}$	Oral	>0.5 (1/1)	35	Brochier et al. 1989

Table 2. Continued.

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
Meadow vole	12	$10^{7.9}$	Oral	0.1–22.3	30	Artois et al. 1990
(*M. pennsylvanicus*)	14	10^{9}	Oral	0.7–44.0	90	
Common vole (*M. arvalis*)	2	$10^{6.5}$	Oral	>0.5 (2/2)	35	Brochier et al. 1989
Bank vole (*Clethrionomys glareolus*)	13	$10^{6.3}$	Oral	>0.5 (8/13)	35	Brochier et al. 1989
Red-backed vole (*C. gapperi*)	3	$10^{7.0}$	Oral	0.2–3.4	60–90	Rupprecht unpublished
Water vole (*Arvicola terrestris*)	5	$10^{6.5}$	Oral	>0.5 (4/5)	35	Brochier et al. 1989
Deer mouse (*Peromyscus maniculatus*)	10	$10^{9.0}$	Oral	0.7–18.0	90	Rupprecht unpublished
European field mouse (*Apodemus sp.*)	4	$10^{6.3}$	Oral	>0.5 (3/4)	41	Brochier et al. 1989
Yellow-necked mouse (*A. flavicollis*)	7	$10^{6.5}$	Oral	>0.5 (5/7)	41	Brochier et al. 1989
Wood mouse (*A. sylvaticus*)	27	$10^{6.3-6.5}$	Oral	>0.5 (16/27)	28–43	Brochier et al. 1989
Family zapodidae						
Woodland jumping mouse (*Napeozapus insignis*)	1	$10^{7.0}$	Oral	0.2	90	Rupprecht unpublished
Order carnivora						
Family canidae						
Red fox	2	10^{8}	Oral	ND	0.5	Thomas et al. 1990
(*Vulpes vulpes*)	2	10^{8}	Oral	ND	1	
	2	10^{8}	Oral	ND	2	
	1	10^{8}	Oral	ND	4	

Table 2. Continued.

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
	10	10^{6}	Oral	0.1–2.3	28	Blancou et al. 1986
	10	10^{7}	Oral	0.1–24.6	28	
	10	10^{8}	Oral	0.1–6.7	28	
	8	$10^{8.5}$	Bait	11.1–44.5	90	Tolson et al. 1988
	6	$10^{8.5}$	GI	1.4–5.6	90	
	2	$10^{8.5}$	ID	22.3	90	
	4	10^{8}	Oral	0.1–24.6	365	Blancou et al. 1989
	4	10^{4}	Oral	0.1–1.3	28	Blancou et al. 1986
	4	10^{6}	Oral	0.1–0.8	28	
	4	10^{8}	Oral	2.3–2.7	28	
	5	10^{8}	Bait	1.1–2.6	28	
	2	$10^{7.6}$	Ocular	>0.5 (2/2)	30	Brochier et al. 1990
	2	$10^{7.6}$	Intranasal	>0.5 (2/2)	30	
	2	10^{8}	ID	2.6–3.0	28	Blancou et al. 1986
	2	10^{8}	SC	0.1–3.0	28	
	4	10^{8}	Oral +	1.9–2.7	28	
Fox cubs (*V. vulpes*)	13	$10^{7.2}$	Oral	0.1–28.9	33–365	Brochier et al. 1988b
Domestic dog (*Canis familiaris*)	3	$10^{4.6}$	SC	0.1–5.1	28	Blancou et al. 1989
	3	$10^{6.6}$	SC	2.1–9.6	28	
	3	$10^{8.6}$	SC	1.9–14.0	28	
	4	$10^{8.6}$	Oral	0.1–3.6	28	Blancou et al. 1989
	4	$10^{9.6}$	Oral	1.6–13.7	28	
Coyote (*C. latrans*)	10	$10^{7.9}$	Bait	0.17–5.6	90	Artois et al. 1990

Table 2. Continued.

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
Grey fox *(Urocyon cinereoargenteus)*	3	10^{9}	Oral	486.0–1458.0	30	Rupprecht unpublished
Arctic fox *(Alopex lagopus)*	9	$10^{7.2-9.2}$	Oral	0.5–29.4	60	Chappuis and Kovalev 1991
Raccoon dog *(Nyctereutes procyonoides)*	9	$10^{7.2-9.2}$	Oral	0.9–46.7	60	Chappuis and Kovalev 1991
Family felidae						
Bobcat *(Lynx rufus)*	3	10^{9}	Oral	0.3–486.0	30	Rupprecht unpublished
Domestic cat *(Felix domesticus)*	4	10^{8}	Oral	0.1–39.0	115	Blancou et al. 1989
	3	10^{4}	SC	0.1	52	Blancou et al. 1989
	3	10^{6}	SC	2.5–17.4	52	
	3	10^{8}	SC	2.4–27.0	52	
Family mustelidae						
Skunk	8	10^{9}	Bait	0.1–4.61	90	Tolson et al. 1987
(Mephitis mephitis)	8	10^{9}	GI	0.1–14.4	90	
	6	$10^{8.3}$	ID	44.5–159.0	90	
	3	$10^{8.3}$	IM	19.6–37.4	90	
Ferret	2	10^{8}	Oral	1.3–15.3	28	Brochier et al. 1988a
(Mustela putorius)	2	10^{9}	Oral	3.2–15.3	28	
Mink *(M. vision)*	7	$10^{7.7}$	Oral and ID	6.0–162.0	180	Rupprecht unpublished
River otter *(Lutra canadensis)*	3	10^{9}	Oral	6.0–18.0	30	Rupprecht unpublished
European badger *(Meles meles)*	6	$10^{8.3}$	Oral	6.1–68.8	45	Brochier et al. 1989

Table 2. Continued.

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
Family ursidae						
Black bear	3	$10^{8\ 8}$	Oral	≤0.2	30	Rupprecht unpublished
(*Ursus americanus*)						
Order artiodactyla						
Family bovidae						
Cattle	10	10^8	SC	4.9–40.0	120	Koprowski 1988
(*Bos taurus*)	10	10^8	ID	4.6–40.0	120	
	2	10^8	ID	12.8–20.3	35	Brochier et al. 1988a
	1	10^8	SC	17.6	35	
	1	10^8	IM	1.1	35	
Sheep (*Ovis ovis*)	4	10^7	Oral	>0.5 (4/4)	30	Baltazar et al. 1987
Family suidae						
Wild boar	4	$10^{8\ 3}$	Oral	0.5–5.5	88	Brochier et al. 1989
(*Sus scrofa*)						
Family cervidae						
White-tailed deer	4	10^9	Oral	54.0–1458.0	30	Rupprecht unpublished
(*Odocoileus virginianus*)						
AVES						
Order falconiformes						
Family accipitridae						
Red-tailed hawk	6	10^8	Oral	0.3–14.0	30	Artois et al. 1990
(*Buteo jamaicensis*)						
Common buzzard	8	10^8	Oral	0.1	30–45	Brochier et al. 1989
(*B. buteo*)						
Kestrel	4	10^8	Oral	0.1	30–45	Brochier et al. 1989
(*Falco tinnunculus*)						

Table 2. Continued.

Taxa	Number	Dose (pfu)[b]	Route[c]	VNA[d] (range, IU/ml)	Observation period (days)	Reference
Carrion crow (*Corvus corone*)	17	10^8	Oral	0.1	28	Brochier et al. 1989
Order charadriiformes						
Family laridae						
Ringbill gull (*Larus delawarenis*)	2	$10^{7.9 \text{ or } 8.1}$	Oral	0.1–1.4	90	Artois et al. 1990
Order strigiformes						
Family strigidae						
Great horned owl (*Bubo virginianus*)	8	10^8	Oral	0.2–0.7	30	Artois et al. 1990
Order passeriformes						
Family grallinidae						
Magpie (*Pica pica*)	7	10^8	Oral	0.1	28	Brochier et al. 1989
Family corvidae						
Jay (*Garrulus glandarius*)	2	10^8	Oral	0.1	28	Brochier et al. 1989

[a] Animal experiments were conducted from 1983–1992.
[b] PFU = plaque forming unit = tissue culture infectious dose.
[c] Oral = vaccine administered via needle-less syringe directly onto the tongue: Oral + = scarification of the oral cavity and deposition of vaccine; ID = intradermal; SC = subcutaneous; IM = intramuscular; GI = gastro-intestinal deposition via endoscope; FP = footpad; Bait = vaccine offered free choice in bait.
[d] Rabies-virus neutralizing antibody (VNA) expressed in international units per milliliter, determined by a rapid fluorescence focus-inhibition test or fluorescence inhibition microtest. ND = not done. Range given, if available, otherwise sero-conversion is indicated by >0.5 IU/ml followed by number sero-positive over total number in group (in parenthesis).
[e] Second (booster) dose administered six months after primary dose.

cating potentially significant bait contact by crows; although this has not been observed with a fishmeal polymer bait intended for use with raccoons in the United States (Rupprecht unpublished data). Lastly, vaccine safety testing was conducted in members of the avian taxa Falconiformes and Strigidae because of the possibility of indirect vaccine exposure through consumption of animals that may have recently contacted vaccine. Thus, the selected array of non-target species in which V-RG vaccine safety evaluations were conducted was not exhaustive; rather, it was designed to represent those species in close contact with humans or wildlife species at highest risk for bait contact.

Initially, the overall objectives were to conduct V-RG vaccine safety evaluations in captivity in as broad a range of taxonomic groups as possible, rather than in maximal numbers of a few limited species (Table 2). The husbandry of exotic species involves many unknowns, such as specific nutrient requirements, adaptation to commercial feeds, effects of confinement, artificial lighting and other environmental variables, and the close presence of humans and conspecifics, which can adversely affect viable numbers available for vaccine testing. For example, Artois et al. (1990) demonstrated that several of their experimental voles and 11 of 13 gulls from both the control and V-RG vaccine groups expired during the course of the experiment from diseases unrelated to V-RG virus administration. In their gulls, postmortem examination revealed heavy infestations of one or more parasites (microfilaria, kidney nematodes, renal coccodiosis) and two were infected with *Salmonella typhimurium*; histopathology did not reveal any lesions consistent with vaccine virus infection. Thus, the number of exotic species tested may be limited by the number available from the wild and successful adaptation to captive conditions. Unsuccessful adaptation to captivity may preclude certain species from safety testing in confinement.

Additionally, unlike inbred strains of laboratory animals, a homogeneous population of each wild species was not available for experimental use. The age, sex, body condition and source of animals were often varied for V-RG vaccine safety testing. A cross-sectional representation of wildlife populations was selected: ages ranged from very young (i.e., weanlings) to aged; body condition varied from good to fair; parasite burdens were minimal to severe. The majority of these experimental animals were not necessarily in prime condition. Additionally, captive conditions are a source of stress upon previously free-ranging individuals. These combined factors provided rigorous conditions in which to test vaccine safety. If untoward effects were to be expected in field applications of vaccine, some indication of the potential for harmful effects due to the vaccine would have been expected in the individuals experiencing these adverse conditions of captivity. In studies such as these, the V-RG recombinant virus vaccine was evaluated for safety in over 40 warm-blooded vertebrate species primarily by the oral route of administration, but also by the intradermal, intramuscular, subcutaneous, intestinal, ocular and intranasal routes, to mimic potential accidental routes of inoculation in the wild. For example, the intramuscular or subcutaneous routes mimic the bite of a conspecific after consuming a vaccine-laden bait; intradermal introduction simulates licking abrasions immediately after contacting vaccine. There has been no vaccine-associated morbidity or mortality, and no gross pathological lesions observed in over 350 individual animals representing some 20 taxonomic families. There has been no demonstration of generalized contact-transfer of vaccine between vaccinated and control animals housed together, with rare exceptions (Blancou et al. 1986, Rupprecht et al. 1988). Moreover, in vaccine pathogenicity studies, virus recovery was limited to local tissues, such as tonsils, buccal mucosa and retropharyngeal lymph nodes, following oral administration, within a limited time period (Rupprecht and Kieny 1988, Thomas et al. 1990). Taken as a whole, these extensive laboratory safety experiments documented the innocuity of V-RG vaccine in all species tested to date, as well as its effectiveness as an oral immunogen against severe street rabies virus challenge in a majority of the species tested. The logical extensions of these laboratory safety evaluations were limited field trials of the vaccine to evaluate its safety in complex natural ecosystems.

The first North American V-RG vaccine field trial began on August 20, 1990, on Parramore Island, a barrier island off the eastern shore of Virginia (Hanlon et al. 1989). The primary objective of this limited field trial was to evaluate the fauna potentially at risk of vaccine contact for evidence of vaccine-related adverse effects. Notable features of the study, such as a high density of raccoons (the target species) and the distribution of a high density of vaccine-laden baits, provided for an intensive evaluation of a free-ranging, but readily live-trapped raccoon population, following free access to the V-RG vaccine. During the first week following bait distribution, bait disturbance rates were remarkably high. Concurrently, bait contact was approximated at 80 percent based upon two biomarkers, sulfadimethoxine and tetracycline. Despite the evidence supporting high bait contact rate among the raccoon population in this study during the subsequent year of live-trapping, no gross lesions suggestive of a vaccine-related etiology were identified in over 800 live-trapped raccoons and nearly 600 live-trapped small mammals. Moreover, there were no significant demographic changes or differences in the raccoons within the vaccination versus control/surveillance area suggestive of vaccine-related adverse effects.

Proceeding from the biosecurity of the laboratory to an island, and then to the mainland, the next study site was chosen to more closely approximate the complex ecosystem for intended V-RG vaccine application, while still maintaining biosecurity through the relative geographical barriers of a watershed surrounded by steep inclines. In contrast to the Parramore study, the objectives of this study were to evaluate the rate of vaccine-laden bait contact and potential vaccine-related adverse effects among non-target species (Table 3). While Parramore Island had a relatively depauparate species diversity (Hanlon et al. 1989), the Pennsylvania site had a rich diversity of species, including additional rodents and carnivores, insectivores, and the opossum. During the study, live-trapped and radio-collared raccoons, and other commonly live-trapped furbearers demonstrated no adverse effects associated with risk of vaccine

Table 3. Previous V-RG field trials[a] in the U.S.

	Virginia	Pennsylvania
Site	Parramore Island	State Game Lands #13
Initiation	1990	1991
Treatment area	300 ha	1,000 ha
Bait density	10/ha	5/ha
Intended hosts	Raccoons	Non-target species
Rabies status	Absent	Present

[a]Both studies involved the field assessment of a V-RG virus (10^8 pfu/ml) distributed within a fishmeal polymer bait cylinder.

contact. Additionally, over 150 non-target individuals, representing eight different species, were evaluated for the biomarker tetracycline, with only two positive, and there were no gross lesions suggestive of V-RG viral-related etiology.

While the overall objective in current oral wildlife rabies vaccination theory is to effect disease control by self-administration of an immunizing dose of vaccine safely and cost-effectively to a free-ranging animal population, a number of complicated attributes make direct comparisons difficult between various international programs, even on the same continent (Table 4); variables between Canada and the United States minimally include the host species and the basic biologicals used. Additionally, control programs are dynamic and are tailored to alteration, dependent upon the previous seasonal result.

The future of oral rabies vaccination in the United States is uncertain. At present, it is in its infancy, viewed largely as an experimental concept only. Major research and practical questions do remain, such as: determination of the relationship between animal population density and the minimum density of vaccine/baits needed; clarification of the level of herd immunity necessary to eliminate the disease under a variety of complex environmental circumstances; delineation of the utility of aerial versus hand distribution of baits, and central-place versus spatial-baiting techniques; application of the strategic concept to other important vectors, such as the skunk; identification of long-term, self-sustaining funding sources that do not substantially detract from other needed programs; integration and harmonization of academicians, government regulatory officials, the general public and corporate leaders to upgrade from cottage industry to larger scale; and enumeration of the ultimate cost-analysis of rabies elimination, considering biological, ethical, economic and socio-political viewpoints collectively. Currently, the United States is the only major developed country with endemic terrestrial rabies, the bio-technological capacity to control the disease in wildlife, but no coordinated national control policy in place. Whether progressive control of this fatal zoonotic disease occurs will depend in part upon the combined energies of a few dedicated multi-disciplinary specialists in the years ahead.

Table 4. Oral wildlife rabies vaccination in North America.

	Canada	United States
Primary species	Red fox	Raccoon
Vaccine	ERA[a]	V-RG[b]
Bait	Sachet/Cube	Fishmeal polymer cylinder
Biomarkers	Tetracycline	SDM[c]/Tetracycline
Bait density	~12–50/km^2	~190–1,000/km^2
Scale (to date)	>1.2 million baits	~100,000 baits
Initiation year	1985	1990
Distribution method	1° aerial	1° hand
Areas treated	>50,000 km^2	~800 km^2
Location	Ontario	Virginia, Pennsylvania, New Jersey
Rabies status (treatment areas)	Enzootic	Free/Front
Program mode	Control	Experimental
Regulatory opinion	Generally accepted	Controversial

[a]Attenuated rabies vaccine strain.
[b]Vaccinia-rabies glycoprotein recombinant virus.
[c]Sulfa-dimethoxine.

References

Artois, M., K. M. Charlton, N. D. Tolson, G. A. Casey, M. K. Knowles, and J. B. Campbell. 1990. Vaccinia recombinant virus expressing the rabies virus glycoprotein: Safety and efficacy trials in Canadian wildlife. Can. J. Vet. Res. 54:504–507.

Bachmann, P., R. N. Bramwell, S. J. Fraser, D. A. Gilmore, D. H. Johnston, K. F. Lawson, C. D. MacInnes, F. O. Matejka, H. E. Miles, M. A. Pedde, and D. R. Voight. 1990. Wild carnivore acceptance of baits for delivery of liquid rabies vaccine. J. Wildl. Dis. 26:486–501.

Baer, G. M. 1985. Rabies vaccination of wildlife and domestic animals other than dogs.Pages 270–275 *in* E. Kuwert, C. Merieux, H. Koprowski and K. Bogel, eds., Rabies in the tropics. Springer-Verlag, NY.

Baltazar, R. S., J. Blancou, M. Artois, J. Bailly and A. Dardaine. 1987. Resultats de l' administration par voie orale au mouton de deux vaccins contenant un virus de la rage modif (SAD B19) ou un recombinant du virus de la vaccine et de la rage (187 X P). Ann. Med. Vet. 131:481–486.

Blancou, J., M. P. Kieny, R. Lathe, J. P. Lecocq, P. P. Pastoret, J. P. Soulebot and P. Desmettre. 1986. Oral vaccination of the fox against rabies using a live recombinant vaccinia virus. Nature 332:373–375.

Blancou, J., M. Artois, B. Brochier, I. Thomas, P.-P. Pastoret, P. Desmettre, B. Languet and M.-P. Kieny. 1989. Innocuité et efficacité du virus recombinant vaccine-rage administé par voie orale chez le renard, le chien et le chat. Ann. Rech. Vét. 20:195–204.

Brochier, B., B. Languet, J. Blancou, I. Thomas, M.-P. Kieny, J. P. Lecocq, P. Desmettre and P. P. Pastoret. 1988a. Innocuité du virus recombinant vaccine-rage chez quelques especes non-cibles. Pages 118–123 *in* P.-P. Pastoret, B. Brochier, I. Thomas and J. Blancou, eds., Proc. CEC Symposium: Vaccination to control rabies in foxes, Brussels, November, 1987. Office for official publications of the European Communities, Brussels-Luxembourg.

Brochier, B., B. Languet, J. Blancou, M. P. Kieny, J. P. Lecocq, F. Costy, P. Desmettre and P.-P. Pastoret. 1988b. Use of recombinant vaccinia-rabies virus for oral vaccination of fox cubs (*Vulpes vulpes*, L) against rabies. Vet. Micr. 18:103–108.

Brochier, B., I. Thomas, A. Lokem, A. Ginter, J. Kalpers, A. Paquot, F. Costy, P.-P. Pastoret. 1988c. A field trial in Belgium to control fox rabies by oral immunisation. Vet. Record 123:618–621.

Brochier, B., J. Blancou, I. Thomas, B. Languet, M. Artois, M.-P. Kieny, J.-P. Lecocq, F. Costy, P. Desmettre, G. Chappuis and P.-P. Pastoret. 1989. Use of recombinant vaccinia-rabies glycoprotein virus for oral vaccination of wildlife against rabies: Innocuity to several non-target bait consuming species. J. Wildl. Dis. 25:540–547.

Brochier, B., I. Thomas, B. Bauduin, T. Leveau, P.-P. Pastoret, B. Languet, G. Chappuis, P. Desmettre, J. Blancou and M. Artois. 1990. Use of a vaccinia-rabies recombinant virus for the oral vaccination of foxes against rabies. Vaccine 8:101–104.

Chappuis, G. and N. A. Kovalev. 1991. The rabies-vaccinia recombinant: From concept to application. Page S6–2 *in* Proceedings of the International Conference on Medical Biotechnology, Immunization and AIDS, June 12–18, 1991, Leningrad, U.S.S.R.

Debbie, J. G. and K. Bogel. 1988. Public health aspects of current oral rabies vaccines. Rev. Infect. Dis. 10:S670–671.

Hable, C. P., A. N. Hamir, D. E. Snyder, R. Joyner, J. French, V. Nettles, C. Hanlon and C. E. Rupprecht. 1992. Prerequisites for oral immunization of free-ranging raccoons (*Procyon lotor*) with a recombinant rabies virus vaccine: Study site ecology and bait system development. J. Wildl. Dis. 27:64–79.

Hanlon, C. L. D. E. Hayes, A. N. Hamir, D. E. Snyder, S. Jenkins, C. P. Hable and C. E. Rupprecht. 1989. Proposed field evaluation of a rabies recombinant vaccine for raccoons (*Procyon lotor*): Site selection, target species characteristics, and placebo baiting trials. J. Wild. Dis. 25:555–567.

Johnston, D. H., D. R. Voight, C. D. MacInnes, P. Bachmann, K. F. Lawson andC. E. Rupprecht. 1988. An aerial baiting system for attenuated or recombinant rabies vaccine for foxes, raccoons and skunks. Rev. Infect. Dis. 10:S660–664.

Kieny, M.-P., R. Lathe, R. Drillien, D. Spehner, S. Skory, D. Schmitt, T. J. Wiktor, H. Koprowski and J.-P. Lecocq. 1984. Expression of rabies virus glycoprotein from a recombinant vaccinia virus. Nature 312:163–166.

Koprowski, H. 1988. Glimpses into the future of rabies research. Rev. Infect. Dis. 10:S810–813.

Pastoret, P. P., B. Brochier, B. Languet, I. Thomas, A. Paquot, B. Bauduin, M. P. Kieny, J. P.

Lecocq, J. DeBruyn, F. Costy, H. Antoine and P. L. Desmettre. 1988. First field trial of fox vaccination against rabies using a vaccinia-rabies recombinant virus. Vet. Record 123:481–483.

Rupprecht, C. E., T. J. Wiktor, A. N. Hamir, B. Dietzschold, W. H. Wunner, L. T. Glickman and H. Koprowski. 1986. Oral immunization and protection of raccoons (*Procyon lotor*) with a vaccinia-rabies glycoprotein recombinant virus vaccine. Proc. Nat. Acad. Sci. 83:7,947–7,950.

Rupprecht, C. E., D. H. Johnston, A. Hamir, B. Dietzschold and H. Koprowski. 1987. Preliminary studies on the immunization and field baiting trials of raccoons against rabies. Pages 389–392 *in* R. M. Chanock, R. A. Lerner and F. Brown, eds., Vaccines '87. Cold Spring Harbor Laboratory, NY.

Rupprecht, C. E. and M. P. Kieny. 1988. Development of a vaccinia-rabies glycoprotein recombinant virus vaccine. In J. B. Campbell and K. M. Charlton, eds., Rabies. Kluwer Academic Publ., Boston, MA.

Rupprecht, C. E., A. N. Hamir, D. H. Johnston and H. Koprowski. 1988. Efficacy of a vaccinia-rabies glycoprotein recombinant virus vaccine in raccoons (*Procyon lotor*). Rev. Infect. Dis. 10:S803–809.

Rupprecht, C. E., B. Dietzschold, J. H. Cox and L. G. Schneider. 1989. Oral vaccination of raccoons (*Procyon lotor*) with an attenuated (SAD-B_{19}) rabies virus vaccine. J. Wildl. Dis. 25:548–554.

Rupprecht, C. E., K. M. Charlton, M. Artois, G. A. Casey, W. A. Webster, J. B. Campbell, K. F. Lawson and L. G. Schneider. 1990. Ineffectiveness and comparative pathogenicity of attenuated rabies virus vaccine for the striped skunk (*Mephitis mephitis*). J. Wildl. Dis. 26:99–102.

Rupprecht, C. E., C. A. Hanlon, L. B. Cummins and H. Koprowski. 1992. Primate responses to a vaccinia-rabies glycoprotein recombinant virus vaccine. Vaccine 10:368–374.

Schneider, L. G., J. H. Cox, W. W. Mueller and K.-P. Hohnsbeen. 1988. Current oral rabies vaccination in Europe—an interim balance. Rev. Infect. Dis. 10:S654–659.

Thomas, I., B. Brochier, B. Languet, J. Blancou, D. Perharpre, M. P. Kieny, P. Desmettre, G. Chappuis and P.-P. Pastoret. 1990. Primary multiplication site of the vaccinia-rabies glycoprotein recombinant virus administered to foxes by the oral route. J. Gen. Virol. 71:37–42.

Tolson, N. D., K. M. Charlton, R. B. Stewart, J. B. Campbell and T. J. Wiktor. 1987. Immune response in skunks to a vaccinia virus recombinant expressing the rabies virus glycoprotein. Can. J. Vet. Res. 51:363–366.

Tolson, N. D., K. M. Charlton, G. A. Casey, C. E. Rupprecht,K. F. Lawson and J. B. Campbell. 1988. Immunization of foxes against rabies with a vaccinia recombinant virus expressing the rabies glycoprotein. Arch. Vir. 102:297–301.

Wandeler, A. I., S. Capt, A. Kappeler and R. Hauser. 1988. Oral immunization of wildlife against rabies: Concept and first field experiments. Rev. Infect. Dis. 10:S649–653.

Wiktor, T. J., R. I. Macfarlan, K. J. Reagan, B. Dietzschold, P. J. Curtis, W. H. Wunner, M.-P. Kieny, R. Lathe, J.-P. Lecocq, M. Mackett, B. Moss and H. Koprowski. 1984. Protection from rabies by a vaccinia virus recombinant containing the rabies virus glycoprotein gene. Proc. Nat. Acad. Sci. 81:7,194–7,198.

Wiktor, T. J., R. I. Macfarlan, B. Dietzschold, C. E. Rupprecht and W. H. Wunner. 1985. Immunogenic properties of vaccinia recombinant virus expressing the rabies glycoprotein. Ann. Inst. Pasteur/Virol. 136E:405–411.

Brucellosis, Wildlife and Conflicts in the Greater Yellowstone Area

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Introduction

Conflicts between wildlife and cattle in western Wyoming probably began to occur when the first agricultural settlers arrived in Jackson Hole in 1884. At that time, many traditional winter ranges of elk (*Cervus elaphus nelsoni*) were converted to hay fields for cattle feed during winter or to town sites, such as Jackson. In some cases, elk migration routes to historic winter ranges were blocked by a multitude of fences, roadways, communities, ranches and hunters. In 1910, the situation became so acute in Jackson Hole that the Wyoming Legislature appropriated $5,000 to feed elk near Jackson. This was done in response to complaints about hungry elk consuming hay stored for cattle feed and in anticipation of excessive elk deaths due to winter starvation. In 1912, federal legislation created the National Elk Refuge, and winter feeding of elk on an artificial diet of hay was well on its way to becoming a poor substitute for native winter ranges and incomplete resolution of elk and cattle conflicts (Boyce 1989).

Marked changes also were occurring within and on the fringes of the rest of the vast wilderness area occupying parts of Wyoming, Montana and Idaho that is now known as the Greater Yellowstone Area (GYA). In fact, Congress had already (1872) designated Yellowstone National Park as the nation's first National Park in order to protect the numerous and unique natural wonders of the area, including wildlife. Congress also designated much of the land adjacent to Yellowstone as the first National Forest Preserve. Simultaneously, cattle grazing was becoming one of the regions important economic mainstays (Keiter 1991).

Introduction of Brucellosis into the Greater Yellowstone Area

At that time, brucellosis was poorly understood as a cattle disease and unknown in wildlife. In fact, the etiologic agent of bovine brucellosis, *Brucella abortus*, was isolated from an aborted fetus by a Danish veterinarian less than a century ago (Timoney et al. 1988). However, frequent elk and cattle contact during winter months of those years undoubtedly led to transmission of brucellosis from infected cattle to elk. This transmission would have been unimportant in the absence of the concentration of elk on feedgrounds because the infected elk would have been unlikely to transmit brucellosis to others in the absence of feedgrounds (Thorne et al. 1991b).

Elk, of course, are the dominant wild ruminant of the GYA, numbering approximately 95,000. But to many people, bison (*Bison bison*) are an equally important wildlife component of the region. Bison seem to enjoy a mystic quality in the mind of much of the public, which is likely associated with the species brush with extinction before the turn of the century. No other North American mammal has been once so numerous, and so ruthlessly persecuted by modern man, and then saved from extinction by man's actions. One of the few refuges where bison escaped total slaughter was in the heart of Yellowstone National Park, and the Park now hosts the largest free-ranging bison population in the United States. Yellowstone's bison probably exist in a relationship with their habitat that more closely resembles their historic role than any other bison herd in the United States; but they, like elk of the GYA, harbor brucellosis (Meagher 1973).

It is not known how Yellowstone's bison became infected with brucellosis, but it undoubtedly occurred when they were struggling against extinction early this century. In the early 1900s, a few bison were brought into Yellowstone to augment the small existing population. These bison and a few bison captured in Yellowstone were held under semidomesticated ranch-like conditions while increasing in numbers (Meagher 1973). In all likelihood, brucellosis was brought into Yellowstone with those early outside bison or was introduced during the ranching period, and it was then transmitted to the native bison when the introduced bison were released.

Now, nearly 100 years after bovine brucellosis was unknowingly transmitted to wildlife and feedgrounds were established in western Wyoming, stockgrowers and wildlife managers struggle to solve problems resulting from the potential for transmission in the other direction—from wildlife to cattle. Brucellosis turned out to be a legacy that now haunts both wildlife managers and stockgrowers, and serves as a major source of conflict between wildlife and cattle (Thorne et al. 1991a, 1991b).

Bovine Brucellosis Eradication

Brucellosis is an important bacterial disease of cattle with worldwide distribution. Abortion is the most important effect of brucellosis in cattle, but it often causes retained placenta and permanent or temporary infertility. Transmission among cattle occurs by direct contact of susceptible animals with *B. abortus* in contaminated reproductive products, such as fetal fluids, placentas, aborted fetuses and full term calves born to infected cows (Nicoletti 1980).

Brucellosis was made the target of a Federal-State-Producer Cooperative Brucellosis Eradication Program in 1940. The program's objective is to eradicate *B. abortus* in the United States and thereby eliminate the economic losses experienced by livestock industries associated with brucellosis and prevent human infections, known as undulant fever. The program currently costs over $60 million annually and has cost well over $1 billion since its inception. It has been extremely successful and cattle of 30 states are now free of brucellosis, resulting in tremendous savings to livestock producers. Wyoming and Montana achieved bovine brucellosis-free status in 1985 and Idaho was declared free in 1990, major accomplishments for the cattle producers and Livestock Boards of these states.

The Cooperative Brucellosis Eradication Program is administered by USDA/APHIS/Veterinary Services with considerable input, cooperation and expenditures by the states and the livestock industry. The eradication program depends upon several major components (Crawford et al. 1990). Surveillance, based on tests of blood or milk, is used to detect infected herds. Epidemiologic investigations are then conducted to determine sources of infection in cattle herds and to detect movement of infection to new herds.

When an infected herd is discovered, the entire herd is blood tested and all positive animals are sent to slaughter in order to remove them from the herd. This test and slaughter approach reduces opportunities for inter- and intraherd transmission of brucellosis by eliminating infected sources. Retesting is required until all infected animals have been removed. Test and slaughter, along with vaccination, are the cornerstones of the brucellosis eradication program.

Vaccination of calves less than one year of age provides resistance to infection and generally does not result in false positive blood tests due to the vaccine after they mature. Adult vaccination is more likely to result in positive blood tests and, therefore, may be allowed only under certain circumstances, such as in the face of extensive exposure or infection in a cattle herd that was not previously adequately calfhood vaccinated.

The vaccine used in cattle, called strain 19 vaccine, is a living strain of *B. abortus* that causes brief infection and long lasting immunity following injection. Infection rates following exposure to field strain *B. abortus* average 30 percent in vaccinated cattle versus 80 percent in non-vaccinated animals. Similarly, vaccinated cattle experience 25 percent abortion rates versus 70 percent abortion in unvaccinated cattle. Though strain 19 vaccination markedly reduces infection and abortion rates, no vaccine is perfect (Nicoletti 1990). If the exposure to *B. abortus* experienced by a vaccinated cow is great enough, vaccine induced immunity can be overwhelmed. A major advantage to vaccination is that, if enough cows within a herd are vaccinated, even if one or two cows contract brucellosis, the disease can be contained and the number of infected cattle following an outbreak will be minimal (Nicoletti 1990).

The last major components of the brucellosis eradication program are quarantine and depopulation. Quarantine is used immediately following detection of an outbreak to stop movement of cattle from an infected herd and prevent spread of brucellosis to other herds. Under extreme circumstances, a state or portion of a state may be quarantined for failure to comply with the rules and regulations of the eradication program. Quarantine is a powerful tool to force compliance because of the hardship it imposes on producers. Depopulation involves slaughter of all cattle in an infected herd, regardless of the infection status of individual animals. Depopulation is the quickest and most certain method of eliminating infection, and it is most frequently used in brucellosis-free states.

Brucellosis in Elk

Many years of research by the Wyoming Game and Fish Department at its Sybille Wildlife Research and Conservation Education Unit (Thorne et al. 1987a, 1987b, Thorne et al. 1979) demonstrated that 50–70 percent of the female elk that become infected with *B. abortus* lose their first calf following infection. Retained placenta and associated infertility apparently do not occur in elk like they do in cattle.

Studies at Sybille also demonstrated that brucellosis can be transmitted from infected elk to susceptible cattle under conditions of very close association between the two species and when infected elk experience a birthing event, such as an abortion

(Thorne et al. 1979). These conditions could occur during late winter and early spring if infected elk feed on cattle feedgrounds, and such circumstances should be discouraged. Brucellosis transmission from elk to cattle is extremely unlikely to occur at any other time or circumstance, including normal calving on traditional elk calving ranges (Thorne et al. 1991b).

The response of elk to strain 19 vaccine is similar to that of cattle (Thorne et al. 1981, Herriges et al. 1989). In controlled studies at Sybille, 38 percent of 66 vaccinated female elk and 69 percent of 35 unvaccinated elk lost their calves after exposure to *B. abortus*. A means of remotely delivering strain 19 vaccine to feedground elk has been developed by a Minnesota firm, BallistiVet, Inc. This system uses an air-powered rifle that implants a bioabsorbable methylcellulose bullet loaded with lyopholyzed strain 19 vaccine (Angus 1989) in the muscles of a hindquarter. Paint ball guns, also powered by compressed air, can be used to mark vaccinated elk so they are not revaccinated the same year. This system has proven effective on some of Wyoming's elk feedgrounds (Herriges et al. 1989, Herriges et al. 1991).

Brucellosis is detected in feedground elk primarily through tests of blood samples collected from elk captured in corral traps (Thorne et al. 1978a, Morton et al. 1981), a difficult and expensive process. Brucellosis has been documented in elk at 18 of 23 feedgrounds in northwest Wyoming, and it can be assumed that all feedground herds are infected. Seropositive rates average 37 percent among adult females (Herriges et al. 1991). Each year 23,000–25,000 elk use these feedgrounds; the largest is the National Elk Refuge with 7,500–9,000 elk.

During the last 22 years, over 1,300 nonfeedground elk have been tested in Wyoming through sampling of hunter-killed elk and limited trapping. No elk outside of the Greater Yellowstone Area tested positive. This is in agreement with studies on elk elsewhere in the absence of elk feedgrounds (Adrian and Keiss 1977, McCorquodale and DiGiacomo 1985). Within the Greater Yellowstone Area but outside of the feedground complex, surveys have shown a 1–2 percent seropositive rate (Montana Department of Fish, Wildlife and Parks unpublished data). Six of 401 (1.5 percent) hunter-killed, antlerless elk tested in Wyoming within the Shoshone National Forest on the east side of Yellowstone during 1990 and 1991 were seropositive. Dispersal of elk from feedgrounds is the likely source of these few seropositive elk. Elk do not seem to be capable of sufficient intraspecific transmission of brucellosis to maintain the disease in the population when not concentrated on feedgrounds. A high rate of exposure occurs only when an elk aborts on a crowded feedground.

During normal calving, elk typically seek seclusion from all other animals, including other elk. In addition, they meticulously clean up the calf, placenta and fetal fluids in order to avoid attracting predators (Geist 1982). These behaviors—calving in seclusion and cleaning up reproductive products potentially contaminated with *B. abortus*—almost completely preclude the likelihood of an elk transmitting brucellosis to another animal when it has the opportunity to follow normal calving behavior.

Brucellosis in Bison

Bison, on the other hand, have a stronger herding instinct and sometimes rely on their size and aggressiveness of the herd to protect newborn calves. Therefore, they often do not seek seclusion for a birthing event (Lott 1991) and other members of the herd are exposed to brucellosis when an infected bison aborts or calves. Controlled studies on the effects of brucellosis in bison at Texas A&M University (Davis et al. 1990c, Davis et al. 1991) suggested bison are more susceptible to brucellosis than elk or cattle. Nearly all of the female bison aborted their first calf following infection with *B. abortus*. Brucellosis was readily transmitted from infected bison to unvaccinated cattle when confined together in small pens (Davis et al. 1990c). When adult females were vaccinated with strain 19, abortion and infection rates were reduced in comparison with non-vaccinated bison to a greater extent than in cattle and elk studies (Davis et al. 1991). Unfortunately, the vaccine itself caused many pregnant bison to abort (Davis et al. 1991). Strain 19 vaccine did not appear to be effective when administered to calves (D. S. Davis unpublished data). Studies with different vaccine doses have not been conducted. Strain 19 vaccination of privately owned bison is still required in states where it is required in cattle, indicating apparent faith in its use by state and federal animal health officials.

The Jackson bison herd, which summers in Grand Teton National Park and winters on the National Elk Refuge has been shown to be highly infected with brucellosis (Williams et al. In review). This small herd of about 160 bison probably became infected when they began feeding with elk on the National Elk Refuge in the mid-1970s. Yellowstone National Park is inhabited by over 3,000 bison distributed in three subpopulations. Both the Jackson and Yellowstone bison herds continue to increase in numbers, despite high abortion rates demonstrated in bison by the Texas A&M studies. Long-lived bison have a sufficiently high reproductive potential that the loss of one calf by nearly every cow would slow, but not prevent, population growth. However, few abortions have been recorded for a Yellowstone bison since the 1930s (M. M. Meagher personal communication: 1992), and this gives rise to the question whether brucellosis-induced abortion in Yellowstone bison is rare because they have acquired some immunity to abortion or whether aborted fetuses are simply consumed by scavenging animals before they can be discovered.

Wildlife, Brucellosis and Conflicts in the Greater Yellowstone Area

Presence of brucellosis in elk and bison of the GYA does not prevent population growth and is, therefore, of limited biological concern. Apparently, calf loss among bison due to brucellosis is insignificant. Among Wyoming's feedground elk, we estimate 5 to 12 percent reduction in reproductive potential due to brucellosis. This makes feedground management inefficient, but elk have been successfully managed in spite of brucellosis for many years. Despite limited biological consequences, elk and bison of the GYA are subject to a variety of socioeconomic conflicts centering around bovine brucellosis and the Cooperative Brucellosis Eradication Program (Boyce 1989, Davis 1990a, 1990b, Gloyd 1990, Thorne et al. 1991a, 1991b).

The threat of transmission of brucellosis from infected wildlife to cattle, although remote, is real. Although Davis (1990b) stated there have been four instances in Wyoming where elk and/or bison have been shown epidemiologically to be sources of bovine brucellosis, there has, in fact, never been a proven case of bovine brucellosis demonstrated to be linked to free-ranging elk or bison in Wyoming or elsewhere. The greatest opportunity for transmission occurs when infected pregnant elk or bison winter or feed with cattle on cattle feedgrounds, or feed and walk on stored hay just before it is fed to cattle. Under these circumstances, abortion by an infected wild animal also is required as a source of contamination. Vaccination of cattle provides the most effective protection (Nicoletti 1990), and in the GYA elk and bison should not be allowed to feed with cattle during late winter.

Occurrence of brucellosis in a cattle herd, no matter what the source of transmission, certainly is a significant hardship to the affected owner. An extensive outbreak in a brucellosis-free state like Wyoming would likely result in a demand by animal health regulators for depopulation, which can result in loss of unique bloodlines and learned grazing practices of the herd. If the outbreak is not widespread, the herd will be quarantined for a period of time while it goes through a series of tests, with slaughter of reactor animals at each test, until the infection is totally eliminated (Crawford et al. 1990). If there is spread from the original herd to additional herds, the entire state could be impacted through loss of its brucellosis-free status. Loss of status would result in market and movement restrictions, including inconvenient and expensive preshipment blood tests for all producers.

Brucellosis is very costly to an affected cattle producer; and preventive measures, such as blood tests and vaccination, are expensive. Consequently, some stockmen demand compensation, which, if granted, would likely come from state or federal wildlife or land management agencies (Thorne et al. 1991b). Damage claims and lawsuits in excess of $1 million were filed against the Wyoming Game and Fish Department and four federal agencies because of a 1988 outbreak of cattle brucellosis for which no bovine source was identified. The cattle herd was within the margin of the Greater Yellowstone Area but outside the elk feedground complex. The herd grazed on public land during the summer, as do most cattle in the GYA. At the time of this writing, the courts have not rendered decisions. Additional lawsuits can be expected in the event of future bovine brucellosis outbreaks, because, in a brucellosis-free state, it is too easy to blame any bovine brucellosis outbreak on wildlife.

In 1990, the six senators from the states surrounding the Greater Yellowstone Area cosponsored legislation to provide funding for brucellosis related expenses in those states, apparently on the assumption that all brucellosis comes from wildlife from Yellowstone National Park and it is appropriate for the Department of Interior to compensate stockgrowers for costs due to a cattle disease in wildlife (Waltman 1990). It did not win approval. Federally mandated compensation might be popular with some producers, but it would likely be universally unpopular with conservation organizations, sportsmen and the tax-paying public. Costs would be great, because the argument could easily be made that all brucellosis related expenses, such as preshipment tests, market surveillance and vaccination, anywhere in the three states were necessary because of wildlife in and around Yellowstone National Park. Of more concern would have been the precedents established by legislated compensation which would: (1) support some stockgrower's beliefs they should be compensated for alleged costs of operating on public lands; (2) establish that the federal government should compensate ranchers operating on public land for alleged losses caused by wildlife; and (3) suggest that ranchers operating on public lands are entitled to certain rights derived from their use of public lands and compensation if wildlife infringes on those rights (Waltman 1990).

Should the courts rule that state or federal governments are liable for costs of a brucellosis outbreak in cattle or should legislation compel the federal government to compensate for expenses related to bovine brucellosis because the disease also occurs in publicly owned wildlife from public lands, a major conflict between the livestock industry and sportsmen and conservation organizations can be predicted. Federal land management agencies might be forced to restrict livestock grazing on some public lands. Landowners, in turn, can be expected to reduce support for wildlife that use their private lands, especially during winter. Both wildlife and stockgrowers will be big losers in this conflict surrounding brucellosis, an introduced disease, in free-ranging wildlife of the GYA.

Brucellosis may soon be eradicated from all cattle in the United States. But it is unlikely brucellosis will be eradicated from wildlife of the GYA in the near future, if ever. Once cattle brucellosis is eradicated, or nearly eradicated, surveillance programs will be abandoned or greatly reduced in scope. Simultaneously, strain 19 vaccination of cattle will be discouraged or no longer permitted, and the national cattle population will become very susceptible to expensive brucellosis outbreaks.

It may be that the nation will have to accept that brucellosis cannot be completely eradicated from the United States, at least not within the desired time frame, because of brucellosis in wildlife of the GYA. Several possible situations might result, none of which would be desirable. Expensive cattle disease surveillance and vaccination programs for bovine brucellosis would have to be maintained indefinitely, defeating the purpose of the eradication attempt. Because of the persistent reservoir of brucellosis, other countries that have rid themselves of brucellosis might apply sanctions against the United States in the international livestock market. Many or all the states outside the GYA could be expected to impose movement restrictions on Wyoming, Montana and Idaho cattle, requiring at least one preshipment blood test prior to interstate transport. This de facto quarantine would place severe penalties on cattlemen of the affected states. Further animosity on the part of state and national livestock industries toward wildlife of the GYA would occur.

On the other hand, it would be naive to assume that all the hardships associated with failure to eradicate brucellosis would be borne by the livestock industry and tax-paying public, or that all conflicts would cease if such a failure was accepted. Certainly, free-ranging wildlife of the GYA would be negatively impacted by the continued presence of brucellosis, and we can reasonably speculate on some of these impacts. Bison would indefinitely continue to be destroyed as they leave the national parks or expand their range into multiple-use public lands or onto private lands, as they have been destroyed north of Yellowstone and in Wyoming (Thorne et al. 1991a). There would be permanent constraints on the size of bison and elk populations in order to stabilize the risk and area of potential brucellosis transmission to cattle. And population control by translocation of elk and bison from the GYA would not be acceptable. Attempts to reduce the reliance of elk on winter feedgrounds would be difficult while those elk harbor a high prevalence of brucellosis because of the potentially increased risk of brucellosis transmission to cattle. There would be extensive pressure to considerably reduce feedground elk populations—to the point that they would not impact hay stored or provided for cattle and it would not be necessary to provide supplemental winter feed. Elk feeding on cattle feedlines within the feedground area might not be tolerated and would have to be immediately removed by hazing, trapping or shooting. Some subpopulations of elk which winter within or near the feedground complex on native ranges near cattle feedlines may be reduced, or at least not allowed to expand, because of the potential for conflict with cattle when forced to lower elevations during severe winters. We could speculate on other impacts of the continued presence of brucellosis, but the most important would be animosity toward wildlife.

Solutions

It seems logical that state and federal wildlife management agencies responsible for the wildlife of the GYA should attempt to control and, if possible, eradicate brucellosis from the wildlife under their shared jurisdictions and reduce the likelihood of transmission to cattle. Because brucellosis in wildlife initially came from cattle and because it is the Cooperative Brucellosis Eradication Program, developed for cattle, that makes brucellosis in wildlife important, it is incumbent upon Veterinary Services, state livestock boards and the livestock industry to play a major role in assisting with solving the problem of brucellosis in wildlife of the GYA. Indeed, these various entities are working toward a solution of the problem, albeit not as rapidly, enthusiastically or cooperatively as they should be.

The components of the Cooperative Brucellosis Eradication Program were developed and modified over a long period of time and designed to eliminate infection from cattle herds as quickly as possible. None of the current components of the eradication program was designed with wildlife in mind. And none of the current components of the eradication program, either singularly or collectively, can be applied to free-ranging wildlife or expected to rapidly eradicate brucellosis without eradicating the wildlife hosts of brucellosis or destroying their ecological relationships in the GYA. Therein lies the source of much conflict—the various entities working with the problem are dealing with components of an eradication program designed for cattle. Some believe they will work for free-ranging wildlife, while others do not and resist their application to wildlife. Obvious examples of the results of these conflicts are the lawsuits filed against Wyoming and the federal government, demands for quarantine of Yellowstone National Park, killing of large numbers of bison that stray into Montana from Yellowstone Park, and protests and lawsuits by animal rights activists and antihunters. Wildlife, stockgrowers and wildlife enthusiasts all continue to lose.

So what are the solutions to these conflicts caused by brucellosis, wildlife and cattle in the GYA? In the absence of cooperation and patience by all affected constituencies, there may be none. But many solutions have been considered or suggested and all deserve examination:

Some would like to ignore the problem of brucellosis in wildlife, but stockgrowers and animal health officials feel it has been ignored for too long. In light of the investment and progress of the Cooperative Brucellosis Eradication Program and the likely long-term impacts upon the local and national livestock industries and upon wildlife of the GYA, it is irresponsible to ignore the problem.

Elimination of cattle grazing in the GYA is another extreme solution. This is popular with the "cattle-free by 93" crowd, but is not likely to occur and is not desirable. Loss of public grazing opportunities would result in a great deal of upheaval as stockgrowers are put out of business. In most cases, cattle are better neighbors to wildlife than the alternatives when traditional ranching landowners must sell out or convert to other sources of income, such as subdivisions and summer homes, golf courses, fast food restaurants, etc. The response to a move to eliminate public lands grazing likely would be decreased tolerance of wildlife on private lands and, probably, a refusal to allow recreational use of private lands. Though removal of cattle from public lands might reduce slightly the opportunity for transmission of brucellosis to cattle, it would not solve the problem—cattle and brucellosis-infected wildlife would still remain in the GYA.

Eradication or elimination of all elk and bison from the GYA is on the opposite extreme of a continuum of solutions (Davis 1990a). Most suggestions for test and slaughter (Davis et al. 1991), using cattle methods, actually would result in depopulation or near depopulation of all elk or bison. Obviously elimination of all the elk and bison of the GYA would solve the brucellosis problem, and it may be the only way to completely eradicate *B. abortus* from the United States. But such an approach would be biologically and logistically impossible and totally unacceptable to most of the American public and much of the international community.

Elimination of elk feedgrounds is frequently suggested as a means of solving the brucellosis problem. However, rapidly closing elk feedgrounds would create havoc as hungry elk went to cattle feedlots and hay stackyards, causing extensive damage to hay and likely transmitting brucellosis to cattle. Because feedgrounds are enormously popular with the public and hunting outfitters, serve in many cases to reduce damage to privately owned hay, and often are necessary to maintain current elk numbers, it is unlikely that very many of the 23 established feedgrounds will ever be eliminated. Certainly, no new elk feedgrounds should be established in the GYA, and even short-term feeding should be discouraged.

The Wyoming Game and Fish Department has initiated what it has called a Brucellosis-Feedground-Habitat process to help solve the brucellosis problem. This is a multi-faceted approach utilizing information and education, wildlife vaccination, habitat improvement, modified feedground operation, and alternative damage control methods. The last three components are very important and designed to carefully reduce the number of elk or length of time elk use feedgrounds in order to reduce the opportunities for elk to elk transmission of brucellosis. Each elk herd unit and each feedground will be closely evaluated to determine if methods to improve habitat and control elk damage to stored hay can be used to reduce elk dependence on winter feedgrounds. Though this approach will be expensive and time consuming, it is not nearly as drastic as elimination of all feedgrounds, and it is realistic and should help lessen the brucellosis problem.

Wildlife vaccination is a popular and achievable approach, at least for feedground elk. Critics say vaccination alone will never result in eradication of brucellosis (Davis et al. 1991, Peterson et al. 1991a, Keiter and Boyce 1991), and it may not, but the critics are thinking in terms of eradication of brucellosis from cattle herds in the shortest possible time. Eradication of brucellosis from free-ranging wildlife by vaccination over a long period of time has never been tested, but it now seems to be the only feasible approach in the GYA.

The development of Wyoming's elk brucellosis vaccination program has followed a reasonable course. Beginning in 1970, baseline studies were conducted at Sybille to determine the effects of the disease in elk and the potential for transmission to cattle. Standards for interpretation of serologic tests were developed with artificially and naturally infected elk, and over 3,400 feedground elk and 1,300 non-feedground elk have been tested to define disease distribution and obtain prevaccination prevalence data. After finding much similarity of the disease in elk and cattle, strain 19 vaccine was tested in elk and found to be similar in effectiveness to that in cattle. The feasibility of vaccine delivery was tested and vaccination subsequently implemented on a small scale while techniques and equipment were improved. Vaccination was expanded to include 14 feedgrounds in 1991–1992; over 21,000 doses have been ballistically delivered to elk. The elk vaccination program is expensive, costing $80,000 to $100,000 each year. Currently, Veterinary Services provides expert advice and pays for about two-thirds of the vaccination costs and Wyoming Game and Fish contributes the remainder.

Plans were made for program evaluation through blood tests, but snow conditions did not allow trapping for blood sampling during 1991 and 1992. Although vaccination will result in blood test reactions among a few elk which are indistinguishable from those of infected animals, several factors should allow eventual evaluation: (1) studies at Sybille indicated that only a small proportion of vaccinated elk remain blood test positive at one year post-vaccination; (2) this proportion is smaller in animals vaccinated as calves, so cessation of vaccination of adults will result in few persistent vaccinal titers (Herriges et al. 1989); and (3) serologic tests are being developed that should distinguish vaccinal titers from those due to infection.

The goal of this admittedly ambitious program has been to control brucellosis (i.e., reduce prevalence of infection and abortion) and reduce the risk of transmission to cattle. Increased elk calf production also will be a benefit. Although various methods could be used to reduce the risk of transmission to cattle (and could be used concurrently with vaccination), vaccination remains the only feasible alternative to control brucellosis in elk as long as they continue to be fed.

Vaccination of bison is more problematic (Davis et al. 1991). Although the Jackson bison herd easily could be vaccinated during winter while on the National Elk Refuge, it would be much more difficult to vaccinate Yellowstone bison which are dispersed over a large area and not easily approached. The apparently low effectiveness of strain 19 in calf bison and the vaccine's potential for causing abortions when administered to pregnant females need to be considered in planning a vaccination program for bison. In a highly infected and accessible bison herd, such as the Jackson herd, vaccination is probably appropriate. Vaccine-induced abortions would be few, and any that did occur would be non-contagious and preferrable to field strain abortions. Peterson et al. (1991a, 1991b) simulated the effects of vaccination in the Jackson bison herd and found significant reductions in prevalence possible. Though their simulations indicated vaccination alone would not reduce prevalence below 10 percent, the assumption was made that transmission rate would remain constant even as prevalence decreased, an unlikely scenario even in the presence of infected elk.

In the cases of both elk and bison, vaccination is the best tool currently available to attempt to control brucellosis, but it cannot be applied or evaluated in cattle terms. Additional research on improved doses and vaccines, and a commitment to long-term application and evaluation will be needed. The effectiveness of vaccination of elk and bison in the field is difficult to predict. However, in much of wildlife management, programs often need to be implemented before all desirable information can be gathered and all outcomes completely known.

Separation of brucellosis infected elk or bison from cattle is a difficult, but generally achievable solution that would reduce the chances of transmission but do nothing to eliminate brucellosis from wildlife. Tough decisions would have to be made by wildlife and land management agencies and cattle producers regarding how far they want to go to keep infected wildlife and cattle separated. The only real dangerous time is during winter and spring for elk, when they may abort, and possibly a little later into early summer for bison. Should access to public grazing allotments be delayed? What should be done about hungry feedground elk that end up in the winter with cattle on private land instead of on an elk feedground? Should they be trapped and removed? Should they be shot without any delay? Should cattle haystacks and feedgrounds be fenced to keep wildlife out during winter? Who should construct, pay for and maintain these fences? Should all wandering bison immediately be shot when they leave the national parks and risk coming in contact with cattle? Should the groomed snowmobile roads in Yellowstone National Park be closed because they provide an efficient route for bison to leave the Park when they otherwise would be confined to the Park by deep snow?

Vaccination of cattle and continued surveillance of cattle grazing in the GYA are certainly the most realistic and effective methods to prevent a major, possibly national, brucellosis outbreak. Cattle producers of the GYA are aware of the presence of brucellosis and most already vaccinate their calves. Surveillance programs for market and slaughter cattle have been set up through the Cooperative Brucellosis Eradication Program. These surveillance techniques are not infallible but are effective. However, as with all disease eradication programs, the brucellosis eradication program will eventually call for cessation of cattle vaccination and de-emphasizing surveillance. In not too many years, Wyoming, Montana and Idaho may be in opposition to all other states wanting to eliminate calfhood vaccination and surveillance. Certainly, control of brucellosis in wildlife of the GYA will not keep pace with bovine brucellosis eradication, and the three affected states must be allowed some concessions for the special risk they face and allowed some forms of continuing protection through vaccination and surveillance.

Wyoming Governor Mike Sullivan has appointed a statewide Brucellosis Task Force made up of cattlemen, sportsmen and representatives of affected state agencies to propose solutions to the conflicts caused by brucellosis, wildlife and cattle in Wyoming. The Task Force has recognized that the problem involves the entire GYA and affects all the federal and state wildlife management, land management, animal health agencies, and stockgrower and conservation organizations in the three affected states. The Task Force is considering recommending the inclusion of all these groups in an administrative level tristate interagency task force to provide impetus and policy decisions to solve the brucellosis problem. A technical advisory committee would help the interagency task force, and an information and education subcommittee would serve as an information dissemination and reporting service.

Innovative solutions designed for free-ranging wildlife and the GYA will have to be developed and implemented. This will require cooperation of all involved landowners and state and federal agencies, long term commitment and continuing research. In the absence of such commitment, patience and cooperation, the American public may have to choose between eradication of brucellosis in the United States or the continued existence of free-ranging elk and bison in the GYA. Wildlife and livestock managers and the public have the choice of working together to minimize conflicts and associated impacts or allowing the conflicts to occur at an accelerated pace until they are resolved by our elected representatives in Washington, D.C.

References

Adrian, W. J. and R. E. Keiss. 1977. Survey of Colorado's wild ruminants for serologic titers to bruncellosis and leptospirosis. J. Wildl. Dis. 13:429–431.

Angus, R. D. 1989. Preparation, dosage delivery, and stability of a *Brucella abortus* strain 19 vaccine ballistic implant. Proc. U.S. Animal Health Assoc. 93:656–666.

Boyce, M. S. 1989. The Jackson elk herd, intensive wildlife management in North America. Cambridge Univ. Press, Cambridge. 428 pp.

Crawford, R. P., J. D. Huber, and B. S. Adams. 1990. Epidemiology and surveillance. Pages 131–151 *in* K. Nielsen and J. R. Duncan, eds., Animal brucellosis. C.R.C. Press, Boca Raton, FL. 453 pp.

Davis, D. S. 1990a. Brucellosis in wildlife. Pages 321–334 *in* K. Nielsen and J. R. Duncan, eds., Animal brucellosis. C.R.C. Press, Boca Raton, FL. 453 pp.

———. 1990b. Role of wildlife in transmitting brucellosis. Pages 373–385 *in* L. G. Adams, ed., Advances in brucellosis research. Texas A&M Univ. Press, College Station. 501 pp.

Davis, D. S., J. W. Templeton, T. A. Ficht, J. D. Williams, J. D. Kopec, and L. G. Adams. 1990. *Brucella abortus* in captive bison. I. Serology, bacteriology, pathogenesis, and transmission to cattle. J. Wildl. Dis. 26:360–371.

Davis, D. S., J. W. Templeton, T. A. Ficht, J. D. Huber, R. D. Angus, and L. G. Adams. 1991. *Brucella abortus* in bison. II. Evaluation of strain 19 vaccination of pregnant cows. J. Wildl. Dis. 27:258–264.

Geist, V. 1982. Adaptive behavioral strategies. Pages 219–278 *in* J. W. Thomas and D. E. Toweill, eds., Elk of North America: Ecology and management. Stackpole Books, Harrisburg, PA. 398 pp.

Gloyd, J. S. 1990. Agencies on collision course over brucellosis in Yellowstone. J. Am. Vet. Med. Assoc. 196:1,745–1,746.

Herriges, J. D., E. T. Thorne, S. L. Anderson, and H. A. Dawson.1989. Vaccination of elk in Wyoming with reduced dose strain 19 *Brucella*: Controlled studies and ballistic implant field trials. Proc. U.S. Animal Health Assoc. 93:640–655.

Herriges, J. D., E. T. Thorne, and S. L. Anderson. 1991. Brucellosis vaccination of free-ranging elk (*Cervus elaphus*) on western Wyoming feedgrounds. Pages 107–112 *in* R. D. Brown, ed., The biology of deer. Springer-Verlag, New York, NY. 596 pp.

Keiter, R. B. 1991. An introduction to the ecosystem management debate. Pages 3–18 *in* R. B. Keiter and M. S. Boyce, eds., The Greater Yellowstone Ecosystem, redefining America's wilderness heritage. Yale Univ. Press, New Haven and London. 428 pp.

Keiter, R. B. and M. S. Boyce. 1991. Greater Yellowstone's future: Ecosystem management in a wilderness environment. Pages 379–413 *in* R. B. Keiter and M. S. Boyce, eds., The Greater Yellowstone ecosystem, redefining America's wilderness heritage. Yale Univ. Press, New Haven and London. 428 pp.

Lott, D. F. 1991. American bison socioecology. Applied Animal Behavior Science. 29:135–145.

McCorquodale, S. M. and R. F. DiGiacoma. 1985. The role of wild North American ungulates in the epidemiology of bovine brucellosis: A review. J. Wildl. Dis. 21:351–357.

Meagher, M. M. 1973. The bison of Yellowstone National Park. National Park Service Scientific Monograph Series No. 1. U.S. Govt. Print. Off., Washington, D.C. 161 pp.

Morton, J. K., E. T. Thorne, and G. M. Thomas. 1981. Brucellosis in elk. III. Serologic evaluation. J. Wildl. Dis. 17:23–31.

Nicoletti, P. 1980. The epidemiology of bovine brucellosis. Advances in Vet. Sci. and Comp. Med. 24:69–98.

Nicoletti, P. 1990. Vaccination. Pages 283–299 *in* K. Nielsen, J. R. Nielsen, and J. R. Duncan, eds., Animal brucellosis. C.R.C. Press, Boca Raton, FL. 453 pp.

Peterson, M. J., W. E. Grant, and D. S. Davis. 1991a. Simulation of host-parasite interactions within a resource management framework: Impact of brucellosis on bison population dynamics. Ecological Modeling 54:299–320.

Peterson, M. J., W. E. Grant, and D. S. Davis. 1991b. Bison-brucellosis management: Simulation of alternative strategies. J. Wildl. Manage. 55:205–213.

Timoney, J. F., J. H. Gillespie, F. W. Scott, and J. E. Bargugh. 1988. The genus *Brucella*. Pages 135–152 *in* Hagan and Bruner's Microbiology and Infectious Diseases of Domestic Animals. Comstock Publ. Associates, Ithaca and London. 951 pp.

Thorne, E. T., J. K. Morton, and G. M. Thomas. 1978a. Brucellosis in elk. I. Serologic and bacteriorologic survey in Wyoming. J. Wildl. Dis. 14:74–81.
Thorne, E. T., J. K. Morton, F. M. Blunt, and H. A. Dawson. 1978. Brucellosis in elk. II. Clinical effects and means of transmission as determined through artificial infections. J. Wildl. Dis. 14:280–291.
Thorne, E. T., J. K. Morton, and W. C. Ray. 1979. Brucellosis, its effect and impact on elk in western Wyoming. Pages 212–222 *in* M. S. Boyce and L. O. Hayden-Wing, eds., North American elk: ecology, behavior and management. Univ. Wyoming, Laramie. 294 pp.
Thorne, E. T., T. J. Walthall, and H. A. Dawson. 1981. Vaccination of elk with strain 19 *Brucella abortus*. Proc. U.S. Animal Health Assoc. 85:359–374.
Thorne, E. T., M. Meagher, and R. Hillman. 1991a. Brucellosis in free-ranging bison: Three perspectives. Pages 275–287 *in* R. B. Keiter and M. S. Boyce, eds., The Greater Yellowstone ecosystem, redefining America's wilderness heritage. Yale Univ. Press, New Haven and London. 428 pp.
Thorne, E. T., J. D. Herriges, and A. D. Reese. 1991b. Bovine brucellosis in elk: Conflicts in the Greater Yellowstone Area. Pages 296–303 *in* A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps., Proc. Elk Vulnerability Symp., Montana St. Univ., Bozeman.
Waltman, J. R. 1990. Comments of the National Wildlife Federation on S. 1767, a bill to reimburse Montana and individuals for expenses incurred to test cattle for brucellosis organisms carried outside Yellowstone National Park by elk and bison, and for other purposes. Fisheries and Wildlife Division, National Wildlife Federation. 4 pp. Mimeo.
Williams, E. S., E. T. Thorne, S. A. Anderson, and J. D. Herriges, Jr. In Revision. *Brucella abortus* biovar 1 induced abortion in a free-ranging bison (*Bison bison*). J. Wildl. Dis.

Relocation of Wildlife: Identifying and Evaluating Disease Risks

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Introduction

In his epic treatise, Leopold (1933) listed "artificial replenishment (restocking and game farming)" as the fourth of five stages in the sequential evolution of game management. In the context of wildlife management in North America, relocation of wildlife has been conducted primarily to: (1) restore native species in portions of their range where they had been extirpated, (2) supplement existing low density native populations, (3) establish species in areas where they were not indigenous, and (4) solve nuisance animal problems. In addition, wildlife often have been relocated to meet the objectives of scientific research, zoological collections, or personal hobbies. Wildlife relocation has been the key component in the success of many earlier restoration and management programs involving game species as exemplified by wild turkeys (*Meleagris gallopavo*) (Lewis 1987), white-tailed deer (*Odocoileus virginianus*) (Downing 1987), and ring-necked pheasants (*Phasianus colchicus*) (Dahlgren 1987). Contemporary wildlife programs continue to rely on relocation in both game and nongame management including, for example, the recovery of endangered species such as the red wolf (*Canis rufus*) (Phillips and Parker 1988), peregrine falcon (*Falco peregrinus*) (Barclay and Cade 1983), and red-cockaded woodpecker (*Picoides borealis*) (Odum et al. 1982, Odum 1983).

Beyond agency-sponsored wildlife relocation programs, wild species also are often relocated within the private sector. Private sector relocations include movement of both bona fide wild animals and release of game farm animals. Current examples are relocation of foxes and coyotes (*Canis latrans*) to stock fox-chasing enclosures (Clark and Widner 1987, Baker 1990, Poten 1991) and releases of pen-raised gamebirds such as bobwhites (*Colinus virginianus*) (Brennan 1991). However, relocations within the private sector, both sanctioned and unsanctioned, have come under increasing regulatory restrictions by wildlife agencies as potential problems with these activities have been identified.

Historically, minimal attention has been given to the potential disease implications of wildlife relocation, whether relocations occurred within the public or private sectors. Although some early authors mentioned the possibility of disease introduction through wildlife relocation (Leopold 1933, Grange 1949, Allen 1954), literally millions of wild and pen-raised animals have been relocated and released without much, if any, attention to potential disease risks. In fairness, it must be acknowledged that for many years relatively little was known about pathogenic organisms among wildlife let alone accurate data on their prevalences, distributions, pathogenicities, or host susceptibilities. Perhaps the most widely espoused warning with regard to disease risks has been the admonishment by turkey biologists that releases of pen-raised turkeys constituted health risks to native wild populations (Bailey and Rinell 1968, Wunz 1971, Mosby 1973, Williams 1981). Based on the data available during the period, risk of disease appeared to have been used as a theoretical justification for discouraging a faulty restoration technique since disease problems were undocumented.

We have encountered the philosophy that, because large numbers of animals have been moved in the past without catastrophic high mortality epizootics, disease risks through relocation are not really significant. Some specific examples of disease problems closely linked to wildlife relocation clearly indicate that the spread of disease via the relocation of wildlife is of more than theoretical concern. A major problem with bovine tuberculosis and bovine brucellosis, which has existed for at least six decades in wood bison (*Bison bison athabascae*) in the Wood Buffalo National Park in Canada, has been attributed to the relocation infected plains bison from the United States (Reynolds et al. 1982, Gainer 1982, Broughton 1983). The current, seven-state mid-Atlantic epizootic of rabies among raccoons (*Procyon lotor*) is strongly linked to translocation of raccoons (Nettles et al. 1979, Smith et al. 1984, Jenkins and Winkler 1987).

Contemporary wildlife scientists have come to recognize that the relocation of wild animals never consists of the movement of a single species. Rather, it always entails relocation of a ''biological package'' consisting of the animal itself (host) and its passenger organisms, potentially including viruses, bacteria, fungi, protozoans, helminths, arthropods or other pathogens.

The continuing relocation of wildlife, within both the public and private sectors, verifies that the potential for initiation of disease problems remains omnipresent. Specific examples from current wildlife relocation activities serve to illustrate the concerns. Recently, red foxes (*Vulpes vulpes*) from an interstate relocation attempt by private citizens were documented to harbor *Echinococcus multilocularis*, the tapeworm which causes aveolar hydatid disease in humans (Davidson et al. 1992). Numerous wild swine (*Sus scrofa*) populations are known to have pseudorabies and swine brucellosis (Zygmont et al. 1982, Nettles 1984, Corn et al. 1986, Pirtle et al. 1989, USDA 1991), yet these animals often are relocated without any provisions for disease prevention. The increased use of pen-raised mallards (*Anas playtyrhynchos*) at regulated shooting areas has rekindled concerns (Hayes and Davidson 1978, Nettles and Thorne 1988) for the initiation of duck plague among wild waterfowl.

Methods

In response to the need to better evaluate potential disease risks that may be associated with wildlife relocation, including release of pen-raised stock, a prototypic disease risk assessment system was developed. The system has been utilized under actual relocation scenarios to assess the potential disease risks of relocating wild-caught raccoons, foxes and coyotes, as well as the disease risks of releasing pen-raised turkeys and bobwhites.

Origin and Development of the System

During the 1970s, many southeastern state wildlife agencies were faced with the large-scale purchase, importation and release of raccoons by private raccoon clubs.

The legality of this activity varied among states; however, a common denominator was that major sources of supply were private animal dealers in Florida and Texas. At the time, Florida and southern portions of Georgia were recognized as the only focus of raccoon rabies in the United States (Prather et al. 1975). Wildlife agencies had various concerns regarding this practice, but one of primary importance was the potential for introduction of raccoon rabies. Rabies often was used as justification for prohibition of raccoon importation. However, conclusive data to substantiate this risk, such as actual demonstration of rabies in translocated raccoons, was not available. The lack of data on disease risks associated with raccoon importation complicated defense of state wildlife agencies' policies prohibiting this activity.

In 1976, the Tennessee Wildlife Resources Agency confiscated a shipment of 100 raccoons illegally imported from Florida. Tennessee requested that the Southeastern Cooperative Wildlife Disease Study (SCWDS) examine them for rabies and other important diseases. This action provided the first opportunity to gather data on the pathogens that were actually present among raccoons being translocated. The necropsy and testing protocols used on this group of raccoons were based on existing literature regarding parasites and diseases of raccoons, and were designed to detect most previously reported pathogens. Following this initial work, a research effort was initiated to develop disease and parasite profiles of translocated raccoons and to use these data to assess disease risks that might be associated with raccoon translocation.

Description of the System for Raccoons

A decision was made to devise a comprehensive health evaluation protocol not limited to rabies. Furthermore, the procedures for pathogen detection were devised to disclose not only organisms important to the health of raccoons, but also to include those important among other wildlife, domestic livestock, pets and humans. The risk assessment included evaluation of the potential for two distinct disease scenarios. The most obvious was the possibility that an "exotic" pathogen could be introduced and become established in a new geographic area. A second possibility was that the release of infected raccoons could cause an artificial intensification of a enzootic or preexisting disease (Schaffer 1979, Schaffer et al. 1981).

The rationale for evaluation of the risk posed by the organisms detected consisted of a two-tiered process (Schaffer 1979, Schaffer et al. 1981). The first step in the process was an evaluation of the ability of the organism to persist at release sites. This was accomplished by determination of the epizootiologic requirements of the disease or parasite as reported in the literature. Organisms were believed to be more likely to become established at release sites if they (1) had a widespread geographic distribution, (2) had a direct transmission cycle or a widespread distribution of vectors/intermediate hosts, (3) had a high prevalence and intensity of infection in translocated raccoons, and (4) were infective for other species of animals at release sites. A subjective four category scale was devised to rate the probability of establishment. The categories were: (1) excellent, for those known to already be enzootic at release sites; (2) possible, for those with direct transmission or those with vectors/intermediate hosts known to be present on release sites; (3) improbable, for those requiring specific vectors/intermediate hosts not present at release sites; and (4) unknown, for those with unknown epizootiology.

The second step in the process was an assessment of the pathologic capabilities of the various organisms within raccoons, other wildlife species, domestic animals and humans, based on reports in the scientific literature. The categories for this assessment were: (1) pathogenic, for those known to produce disease; (2) nonpathogenic, for those studied well enough to determine that they never produce illness; and (3) unknown, for those with insufficient study to evaluate pathogenicity (Schaffer 1979, Schaffer et al. 1981).

Ultimate assessment of the risk posed by each pathogen was then based on a combination of its establishment and pathogenicity rating. Pathogens with either a low probability of establishment or a lack of pathogenicity were considered to pose little risk. Conversely, those which exhibited both a reasonable probability of establishment and pathogenicity in raccoons or other hosts were considered to pose a significant risk. Risk could not be predicted for those with an unknown ranking. Finally, it was noted that the risk assessments were not absolutely predictable and that biological factors in the release areas might favor exotic pathogens normally considered harmless, thereby producing unforeseen disease syndromes.

Results and Discussion

Past Applications of the System

As noted above, the first use of the system was to gain a more in-depth understanding of the disease risks posed by private sector raccoon translocation. This was accomplished through study of additional translocated raccoons that were either seized by state wildlife agencies or anonymously purchased from suppliers. These studies disclosed potential risks from hematotropic protozoans parasites (Schaffer et al. 1978), helminth parasites (Schaffer et al. 1981), *Salmonella* and *Leptospira* infections (SCWDS unpublished data), rabies (Nettles et al. 1979), canine distemper (SCWDS unpublished data), and parvovirus infections (Nettles et al. 1980). Collectively, these findings, in conjunction with the manner of private sector transport of raccoons (Nettles and Martin 1978), clearly showed that indiscriminate translocation of wild raccoons was biologically hazardous. Unfortunately, the dangerous consequences of this practice were rather quickly confirmed by an epizootic of raccoon rabies in the mid-Atlantic states. The detection of rabid animals in translocated raccoons (Nettles and Martin 1978, Nettles et al. 1979), combined with monoclonal antibody studies demonstrating mid-Atlantic rabies virus isolates to be indistinguishable from those in the original Florida epizootic (Smith et al. 1984), provide convincing evidence that the epizootic originated from the relocation of rabid raccoons (Jenkins and Winkler 1987).

Schorr et al. (1988) subsequently utilized this same disease risk assessment system to evaluate the disease status of pen-raised wild turkeys. Diseases of major concern identified were histomoniasis ("blackhead disease"), syngamiasis, avian pox, mycoplasmosis and salmonellosis. Schorr et al. (1988) concluded that these diseases were threats to wild and domestic turkeys and urged that "release of pen-raised wild turkeys be discouraged, if not prohibited." SCWDS (unpublished data) also has provided disease risk assessments on groups of pen-raised bobwhites presented to state wildlife agencies for release to conduct bird dog field trials. Organisms of concern in some of these groups included avian pox virus, *Histomonas meleagridis* and *Heterakis gallinarum* (vector of histomoniasis). Avian pox and histomoniasis previously had been assigned a ''high risk'' rating from release of pen-raised bobwhites (Davidson et al. 1982).

The latest application of the system was with private sector importantion of red foxes and coyotes from the midwestern United States to stock fox chasing enclosures in the Southeast (Davidson et al. 1992). This study of confiscated, illegally imported foxes and coyotes disclosed infections of *Echinococcus multilocularis*, the etiologic agent of aveolar hydatid disease in humans, among the red foxes. This finding was judged to constitute a significant risk since this zoonotic tapeworm does not occur in the Southeast. Its introduction and spread on several Japanese islands has been linked to development of a fox ranching industry (Inukai et al. 1955, Rausch 1956, 1986), and its occurrence in the upper Midwest and adjacent Canadian provinces is believed to have been due to movement of canid definitive hosts from the Arctic by man (Wilson and Rausch 1980, Rausch 1986).

Finally, on two occasions, we have utilized existing information from the scientific literature to apply the basic concepts of this process to estimate disease risks without actual examination of animals. In one instance, potential disease risks of a proposed snowshoe hare (*Lepus americanus*) relocation program were categorized for a state wildlife agency (McKenzie and Nettles 1981). The second involved a preliminary evaluation of the potential disease problems that might be associated with release of pen-raised waterfowl for hunting purposes (SCWDS unpublished files).

Overview and Recommendations

The disease risk evaluation system described provides a conceptual approach for identifying and subjectively categorizing risks rather than providing a means of specifically quantifying them. Nevertheless, it has provided information valuable to wildlife agencies in both the development and defense of policies on the translocation of certain species. Although the operational performance of the system has not been validated by experimental study, the raccoon rabies episode exemplifies its ability to identify risks, albeit by virtue of the rabies epizootic.

Applications to date have involved assessments of animal relocation activities that already were underway. In the future, a proactive application before animals are relocated would be preferable, since this would afford an opportunity to identify and possibly prevent potential problems. In this regard, development of specific guidelines for disease testing would be helpful for those species which are relocated frequently and in large numbers. An example would be the Wildlife Disease Association's disease monitoring guidelines for wild turkey relocation programs (Amundson 1985, Wildlife Disease Association 1985).

However, there are problems that need to be overcome to provide adequate and timely health evaluation services to ensure avoidance of disease problems from relocation of wildlife. One obvious problem is the availability of sufficient diagnostic and laboratory support to provide the disease evaluation services. Although there are several agency and university laboratories staffed with personnel specializing in wildlife diseases, we doubt that they have the resources to provide these services in every relocation situation where they are indicated. Augmentation of resources in this area should receive more attention.

Another problem is inadequate data on the geographic distribution, host susceptibilities and pathogenic capabilities of pathogens among many wildlife populations.

Basic information on these subjects is an integral part of the evaluation system described, and without this foundation, one is forced to start from "ground zero." In contrast, with sufficient baseline data, the disease risk evaluations can be done entirely "on paper" without the need for examining animals. For example, enough is known on the life cycle, distribution, prevalence and pathogenicity of the white-tailed deer meningeal worm (*Parelaphostrongylus tenuis*), which causes fatal neurologic disease in other native cervids and certain exotic ungulates (Anderson and Prestwood 1981), to accurately evaluate the risk of parelaphostrongylosis from white-tailed deer relocation programs. Therefore, we should alter our tendency to categorize parasite and disease projects as "just another survey" or "just another pathologic description" and view them in the holistic context of contributing to disease prevention programs.

Finally, although this discussion has focused on the potential for initiation or spread of disease by relocation of animals and their passenger pathogens, its antithesis also exists. In this case, the principal concern is not for initiation of disease problems originating from the relocated animal, but rather whether the relocated animal will contract enzootic diseases at the release site. This scenario is particularly important with highly valuable animals such as endangered species, but it also can be a factor in the success of any wildlife relocation program. For example, eastern woodrats (*Neotoma floridana*) became infected with *Baylisascaris procyonis*, a neurotropic roundworm of raccoons, and developed neurologic disease following release in former range in New York where *B. procyonis* occurs (W. B. Stone personal communication: 1992). Introductions of elk (*Cervus canadensis*), caribou (*Rangifer tarandus*), black-tailed deer (*O. hemonius columbianus*) and moose (*Alces alces*) in the eastern United States all have had problems to some extent with neurologic disease caused by the white-tailed deer meningeal worm, which is enzootic in much of eastern North America (Anderson and Prestwood 1981). The procedures described can be reversed to evaluate the risk of diseases occurring at release sites to relocated animals.

In order to integrate the described or a similar disease risk evaluation component into wildlife relocation activities, we provide the following recommendations:

1. consider disease potentials before initiating an agency sponsored relocation program or before allowing wildlife relocation by the private sector;
2. as a minimum, incorporate a literature review to identify potential disease risks;
3. presample the source population for those pathogens identified as potential problems; and
4. necropsy and/or test a subsample of individuals being relocated.

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References

Allen, D. L. 1954. Our wildlife legacy. Funk and Wagnalls, New York, NY. 422 pp.

Amundson, T. E. 1985. Health management in wild turkey restoration programs. Proc. Nat. Wild Turkey Symp., Edgefield, SC. 5:285–294.

Anderson, R. C. and A. K. Prestwood. 1981. Lungworms. Pages 266–317 *in* W. R. Davidson et al., eds., Diseases and parasites of white-tailed deer. Tall Timbers Research Station, Misc. publ. No. 7. Tallahassee, FL.

Bailey, R. W. and K. T. Rinell. 1968. History and management of the wild turkey in West Virginia. West Virginia Dept. Nat. Resour., Bull. No. 6. Charleston. 59 pp.

Baker, B. 1990. Covert investigations related to South Carolina fox pens. Minutes S.E. Furbearer Workshop, Robbinsville, NC, May 20–23, 1990. 4:23–24.

Barclay, J. H. and T. J. Cade. 1983. Restoration of the peregrine falcon in the eastern United States. Pages 3–40 *in* S. A. Temple, ed., Bird conservation I. Univ. Wisconsin Press, Madison.

Brennan, L. A. 1991. How can we reverse the northern bobwhite population decline? Wildl. Soc. Bull. 19:544–555.

Broughton, E. 1983. Wood Buffalo National Park: A different perspective. Wildl. Dis. Newsl. Suppl. J. Wildl. Dis. 19(3):1–2.

Clark, J. and M. Widner. 1987. Fox pens in the Southeast. Minutes S.E. Furbearer Workshop, State Wildlife Refuge, Louisiana, November 16–19, 1987. 1:4–7.

Corn, J. L., P. K. Swiderek, B. O. Blackburn, G. A. Erickson, A. B. Thiermann, and V. F. Nettles. 1986. Survey of selected diseases in wild swine in Texas. J. Amer. Vet. Med. Assoc. 189:1,029–1,032.

Dahlgren, R. B. 1987. The ring-necked pheasant. Pages 305–311 *in* H. Kallman et al., eds., Restoring America's wildlife. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C. 394 pp.

Davidson, W. R., F. E. Kellogg, and G. L. Doster. 1982. An overview of disease and parasitism in southeastern bobwhite quail. Proc. Nat. Bobwhite Quail Symp. 2:57–63.

Davidson, W. R., M. J. Appel, G. L. Doster, O. E. Baker, and J. F. Brown. 1992. Diseases and parasites of red foxes, gray foxes, and coyotes from commercial sources selling to fox-chasing enclosures. J. Wildl. Dis. 28:in press.

Downing, R. L. 1987. Success story: White-tailed deer. Pages 45–57 *in* H. Kallman et al., eds., Restoring America's wildlife. U.S. Dept. Interior, Fish and Widl. Serv., Washington, D.C. 394 pp.

Gainer, B. 1982. Wood Buffalo Park has problems. Wildl. Dis. Newsl. Suppl. J. Wildl. Dis. 18(4):1.

Grange, W. B. 1949. The way to game abundance. Charles Scribner's Sons, New York, NY. 365 pp.

Hayes, F. A. and W. R. Davidson. 1978. Waterfowl diseases: Status, contributing factors, and control. Proc. 3rd Internat. Waterfowl Symp., New Orleans, LA. 3:45–58.

Inukai, T., J. Yamashita, and H. Mori. 1955. Most probable route of introduction of *Echinococcus* into the island of Rebun. J. Fac. Agric., Hokkaido Univ. 50:134–139.

Jenkins, S. R. and W. G. Winkler. 1987. Descriptive epidemiology from an epizootic of raccoon rabies in the middle Atlantic states, 1982–1983. Am. J. Epidemiol. 126:429–437.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, NY. 481 pp.

Lewis, J. B. 1987. Success story: Wild turkey. Pages 31–43 *in* H. Kallman et al., eds., Restoring America's Wildlife. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C. 394 pp.

McKenzie, M. E. and V. F. Nettles. 1981. Translocation of the snowshoe hare: Disease and parasite considerations. SCWDS, Coll. Vet. Med., Univ. Georgia, Athens. 30 pp.

Mosby, H. S. 1973. The changed status of the wild turkey over the past three decades. pages 71–76 *in* G. C. Sanderson and H. C. Schultz, eds., Wild turkey management: Current problems and programs. Univ. Missouri Press, Columbia.

Nettles, V. F. 1984. Pseudorabies in wild swine. Proc. Annu. Meet. U.S. Anim. Health Assoc. 88:505–506.

Nettles, V. F. and W. M. Martin. 1978. General physical parameters and health characteristics of translocated raccoons. Proc. Annu. Conf. S.E. Assoc. Fish Wildl. Agen. 32:71–74.

Nettles, V. F. and E. T. Thorne. 1988. Guidelines for responding to duck plague outbreaks in captive/semi-captive flocks. Proc. U.S. Anim. Health Assoc. 92:507–513.

Nettles, V. F., J. E. Pearson, G. A. Gustafson, and J. L. Blue. 1980. Parvovirus infection in translocated raccoons. J. Amer. Vet. Med. Assoc. 177:787–789.

Nettles, V. F., J. H. Shaddock, K. Sikes, and C. R. Reyes. 1979. Rabies in translocated raccoons. Amer. J. Public Health 69:601–602.

Odum, R. R. 1983. Georgia's red-cockaded woodpecker relocation experiment: A 1983 update. Pages 106–108 *in* D. A. Wood, ed., Red-cockaded woodpecker Symposium II Proc. Florida Game Freshwater Fish Comm., Tallahassee.

Odum, R. R., J. Rappole, J. Evans, D. Charbonneau, and D. Palmer. 1982. Red-cockaded woodpecker relocation experiment in Georgia. Wildl. Soc. Bull. 10:179–203.

Phillips, M. K. and W. T. Parker. 1988. Red wolf recovery: A progress report. Conserv. Biol. 2:139–141.

Pirtle, E. C., J. M. Sacks, V. F. Nettles, and E. A. Rollor, III. 1989. Prevalence and transmission of pseudorabies virus in an isolated population of feral swine. J. Wildl. Dis. 25:605–607.

Poten, C. J. 1991. America's illegal wildlife trade. National Geographic 180(3):106–132.

Prather, E. C., W. J. Bigler, G. L. Hoff, and J. A. Tomas. 1975. Rabies in Florida: History, status, trends. Florida Dept. Health Rehabil. Serv. Mono. 14. 122 pp.

Rausch, R. L. 1956. Studies on the helminth fauna of Alaska. XXX. The occurrence of *Echinococcus multilocularis* Leukart 1863, on the mainland of Alaska. Amer. J. Trop. Med. Hyg. 5:1086–1092.

———. 1986. Life-cycle patterns and geographic distribution of *Echinococcus* species. Pages 44–80 *in* R. C. A. Thompson, ed., The biology of *Echinococcus* and hydatid diseases. George Allen & Unwin, London.

Reynolds, H. W., R. D. Glaholt, and A. W. L. Hawley. 1982. Bison. Pages 972–1007 *in* J. A. Chapman and G. A. Feldhamer, eds., Wild Mammals of North America, Johns Hopkins Univ. Press, Baltimore, MD. 1,147 pp.

Schaffer, G. D. 1979. Helminth parasites of translocated raccoons (*Procyon lotor*) in the southeastern United States. M.S. thesis. Univ. Georgia, Athens. 93 pp.

Schaffer, G. D., W. R. Davidson, V. F. Nettles, and E. A. Rollor, III. 1991. Helminth parasites of translocated raccoons (*Procyon lotor*) in the southeastern United States. J. Wildl. Dis. 17:217–227.

Schaffer, G. D., W. L. Hanson, W. R. Davidson, and V. F. Nettles. 1978. Hematotrophic parasites of translocated raccoons in the Southeast. J. Amer. Vet. Med. Assoc. 173:1,148–1,151.

Schorr, L. F., W. R. Davidson, V. F. Nettles, J. E. Kennamer, P. Villegas, and H. W. Yoder. 1988. A survey of parasites and diseases of pen-raised wild turkeys. Proc. Annu. Conf. S.E. Assoc. Fish Wildl. Agen. 42:315–328.

Smith, J. S., J. W. Summer, L. F. Roumillat, G. M. Baer, and W. G. Winkler. 1984. Antigenic characteristics of isolates associated with a new epizootic of raccoon rabies in the United States. J. Infect. Dis. 149:769–774.

U.S. Department of Agriculture. 1991. Wild pigs: Hidden dangers for farmers and hunters. USDA Agric. Inform. Bull. No. 620. Washington, D.C. 6 pp.

Wildlife Disease Association. 1985. Advisory statement on disease monitoring in wild turkeys. Wildl. Dis. Newsl., Suppl. J. Wildl. Dis. 21:1–3.

Williams, L. E. 1981. The book of the wild turkey. Winchester Press, Tulsa, OK. 181 pp.

Wilson, J. F. and R. L. Rausch. 1980. Alveolar hydatid disease: A review of clinical features of 33 indigenous cases of *Echinococcus multilocularis* infection in Alaskan Eskimos. Amer. J. Trop. Med. Hyg. 29:1,340–1,355.

Wunz, G. 1971. Evaluation of game-farm and wild trapped turkeys in Pennsylvania. Pennsylvania Game News 1:20–44.

Zygmont, S. M., V. F. Nettles, E. B. Shotts, Jr., W. A. Carmen, and B. O. Blackburn. 1982. Brucellosis in wild swine: A serologic and bacteriologic survey in the southeastern United States and Hawaii. J. Amer. Vet. Med. Assoc. 181:1,285–1,287.

Overcoming Disease Problems in the Black-footed Ferret Recovery Program

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Introduction

Diseases are important in management of many free-ranging species, but their potential impact is heightened when a species is endangered and the habitat it occupies is limited. Conservation of endangered species requires thorough understanding of the interaction of diseases and their hosts so that negative impacts may be avoided or reduced.

Although the literature contains considerable information on the occurrence of specific diseases in free-ranging and captive wild animals (Davis et al. 1981, Thorne et al. 1982, Forrester 1992), the epizootiology, impact on populations and possible management options for infectious diseases in free-ranging populations are seldom understood. This lack of knowledge is especially acute regarding endangered species. Overcoming wildlife disease problems in endangered species requires understanding of species susceptibility to disease of both captive and free-ranging animals, and knowledge of dynamics of diseases in the wild.

Infectious diseases have played a significant role in the recent history of the black-footed ferret (*Mustela nigripes*) (Thorne and Williams 1988, Williams et al. 1988). Canine distemper, a viral disease, poses the greatest disease threat to black-footed ferret survival and is a major concern in the management of captive animals and the reintroduction program. An attempt at captive breeding in the 1970s was unsuccessful (Carpenter 1985), in part, due to death of four wild-caught females from canine distemper caused by an attenuated canine distemper vaccine (Carpenter et al. 1976). In 1985, the last known population of free-ranging black-footed ferrets was nearly extirpated due to canine distemper (Thorne and Williams 1988, Williams et al. 1988, Thorne and Oakleaf 1991). Six animals captured for captive breeding died of canine distemper contracted by two of them in the wild (Williams et al. 1988). Animals salvaged from the wild in the face of that epizootic constitute the foundation of the present captive population (Thorne and Belitsky 1989, Thorne and Oakleaf 1991). The captive population also was impacted by canine distemper because it placed the captive breeding program in a crisis situation and prevented ability to select founders to maximize genetic variability.

Sylvatic plague, caused by the bacteria *Yersinia pestis*, is common in colonial rodents in much of the western United States (Barnes 1982). This disease is of major concern to managers of reintroduced black-footed ferrets because of the serious effects it may have on prairie dog (*Cynomys* spp.) populations, which are the primary prey of black-footed ferrets. One hundred percent morbidity and mortality in a colony of Gunnison's prairie dogs (*C. gunnisoni*) was documented following introduction of plague (Rayor 1985), though morbidity may be less in white-tailed prairie dog (*C. leucurus*) colonies studied in Wyoming (Menkens and Anderson 1991). Reduced numbers of white-tailed prairie dogs, due to sylvatic plague in the Meeteetse complex in Wyoming, precluded reintroduction of black-footed ferrets into the site from which they originated (Parrish and Luce 1991). Domestic ferrets (*M. putorius furo*) and Siberian polecats (*M. eversmanni*), species closely related to black-footed ferrets, are not susceptible to plague induced illness and presumably, black-footed ferrets also are resistent (Williams et al. 1991).

This paper will describe the strategies used for disease management in the black-footed ferret recovery program as it moves from primary focus on animals in captivity to both captive and free-ranging populations.

Disease Management of Captive Black-footed Ferrets

Management for Disease Prevention

Black-footed ferrets are currently being bred in several zoos (Conservation and Research Center, National Zoological Park, Front Royal, Virginia; Henry Doorly Zoo, Omaha, Nebraska; Louisville Zoo, Louisville, Kentucky; Cheyenne Mountain Zoo, Colorado Springs, Colorado; Phoenix Zoo, Phoenix, Arizona; and the Metropolitan Toronto Zoo soon will receive black-footed ferrets) and at the Wyoming Game and Fish Department's Sybille Wildlife Research and Conservation Education Unit, Wheatland, Wyoming. The captive population was divided in 1989, as soon as possible in order to reduce the impact of catastrophe, including epizootic disease. All facilities used to house black-footed ferrets have been designed to minimize the potential for introduction of pathogens, and cooperative agreements between the U.S. Fish and Wildlife Service, Wyoming Game and Fish Department and cooperating zoos require stringent disease prevention. Because black-footed ferrets are frequently moved between institutions, each one is strictly managed as an isolation unit.

Disease prevention procedures are variable depending on the facility; those used at Sybille will be detailed. Access to the facility is limited and persons feeling ill are not allowed to come in contact with ferrets. All persons not living on-site are required to shower and don clothing from the facility. Hands are disinfected prior to entering black-footed ferret rooms or handling ferrets. Face masks are worn in the presence of ferrets to prevent exposing them to human influenza or other human diseases. Most equipment and supplies brought into the facility are doubled bagged so that the outer bag can be discarded prior to entry, or items are topically disinfected.

A foot bath containing virucidal disinfectant must be used by anyone entering the ferret facilities.

Black-footed ferret rations are prepared within the isolation or "post-shower" portion of the facility. Assuring safe food for black-footed ferrets is important because many diseases of captive animals are related to nutritional deficiencies or excesses or food-borne pathogens. Batches of commercially purchased food are fed at a large domestic ferret facility prior to feeding to black-footed ferrets, which should allow early detection of problems in the feed. Periodic nutritional testing of prepared rations is conducted. Prairie dogs and domestic rabbits to be used as ferret food are held in quarantine to assure they are clinically healthy and carcasses are inspected after slaughter. Abnormal organs are tested to determine the cause of the problem and affected animals are not used for food. Kidneys of domestic rabbits are discarded to reduce the possibility of exposing black-footed ferrets to the protozoan parasite, *Encephalitozoon cuniculi*, which has caused disease in Siberian polecats (Novilla et al. 1980). Hamsters are raised in-house in complete isolation from all other animals. Feeding of ferrets, which are nocturnal, is done in the late afternoon to minimize time that the food is at room temperature before being consumed.

Some husbandry techniques are specifically directed at disease prevention. Tools used for cleaning are disinfected frequently to reduce potential disease transmission between cages via urine or fecal contamination. Special attention is given to frequent cleaning of nest boxes containing growing kits.

Incorporated into the facility are isolation rooms, separated from the main animal rooms, that can be used for quarantine or housing sick animals. The main animal area is divided into four rooms, which allows for some separation of groups of animals for management or disease control if necessary.

Veterinary care for black-footed ferrets is available at all times because the veterinarian lives on site. All sick animals are examined, treatments instituted and specimens collected as appropriate for diagnostic evaluation at the Wyoming State Veterinary Laboratory in Laramie. All animals that die are examined by necropsy and appropriate diagnostic tests, including gross and microscopic studies, hematology, bacteriology, parasitology, virology, electron microscopy, toxicology, and serology. This has allowed documentation of the causes of morbidity and mortality of captive black-footed ferrets.

Less obvious approaches to disease prevention also are taken. Captive propagation of black-footed ferrets is managed to reduce inbreeding and maximize retention of genetic variability (Ballou and Oakleaf 1989, Thorne and Oakleaf 1991); black-footed ferrets have low average heterozygosity (O'Brien et al. 1989). Among the many justifications for intensive genetic management is to reduce the consequences of limited genetic variation, including increased disease susceptibility. This problem has been demonstrated in cheetahs (*Acinonyx jubatus*), which have increased susceptibility to feline infectious peritonitis in comparison to outbred domestic cats. This is believed to be due to monomorphism at the major histocompatibility complex (O'Brien et al. 1985). Inbreeding seems unlikely to be responsible for the susceptibility of black-footed ferrets to canine distemper virus, considering the susceptibility to this agent by all members of the genus *Mustela*. Mortality of outbred domestic ferrets to canine distemper is essentially 100 percent (Bernard et al. 1984), and black-footed ferrets from two geographically separate populations (South Dakota and Wyoming) displayed high susceptibility to the disease (Carpenter 1976, Williams et al.

1988). However, inbreeding could influence susceptibility of black-footed ferrets to other diseases.

Diseases of Major Concern and Management Procedures

Canine distemper. Canine distemper causes 100 percent mortality in black-footed ferrets (Williams et al. 1988) and prevention of this disease is imperative. Canine distemper is common in domestic dogs and in many wild canids, procyonids and mustelids (Budd 1981). The virus is relatively unstable in the environment and is inactivated rapidly at room temperature and in sunshine (Appel 1987). The shower and clothing change required of personnel is intended to prevent introduction of canine distemper virus via humans and their clothing; however, employees are cautioned not to contact strange or sick dogs or other susceptible wild species. The entire captive breeding facility is surrounded by 8-foot chain-link fence to prevent entrance of stray dogs or wild animals onto the grounds. Stray dogs in the vicinity are removed immediately.

The perfect canine distemper vaccine currently does not exist for use in black-footed ferrets. Loss of black-footed ferrets during the 1970s to vaccine-induced canine distemper indicated that attenuated vaccines could not be assumed safe. Currently, black-footed ferrets are vaccinated with a killed canine distemper vaccine and adjuvant (provided, respectively, by Dr. Max Appel, Cornell University and Fort Dodge Laboratories, Fort Dodge, Iowa) which is known to induce seroconversion (Williams et al. 1988); however, duration of protection and efficacy in the face of challenge are not known. During the last three years, the killed vaccine and a commercially available attenuated canine distemper vaccine (FrommD, Solvay Veterinary), licensed for use in dogs, have been evaluated using black-footed ferret × Siberian polecat hybrids prior to testing the attenuated vaccine in black-footed ferrets (Williams et al. unpublished data). The killed vaccine provided protection against challenge for most vaccinated hybrids, but the duration of humoral immunity was relatively short. On the other hand, the attenuated vaccine provided complete protection to challenge and probable life-long immunity, but it induced immunosuppression that could predispose vaccinated animals to infection by other pathogens. Evaluation of the attenuated vaccine in black-footed ferrets is not yet complete.

Coccidiosis. Coccidiosis in black-footed ferrets is caused by protozoan parasites that infect the intestinal tract. Two species, *Eimeria ictidea* and *E. furonis*, (Jolley et al. unpublished data) have been identified in captive and free-ranging black-footed ferrets (Williams et al. 1988). These parasites are common and generally do not cause significant illness. However, occasionally coccidiosis may cause diarrhea and even mortality, and acute coccidiosis is an important cause of death of kits during the stressful weaning process (Williams et al. unpublished data). A possible third species is very uncommon and has not been studied in detail. Daily cleaning of nest boxes and disinfection of tools between cages helps prevent coccidiosis. Highest shedding of coccidial oocysts in feces occurs in mother/litter groups when the kits are from two–six months of age (Berk et al. unpublished data). This also is the age at which greatest mortality occurs. Frequent monitoring of feces for oocysts is conducted during late spring and summer with particular attention to mother/litter groups. This allows determination of when treatment should be instituted using sulfadimethoxine (Albon, Hoffmann-LaRoche, Nutley, New Jersey) in the food.

Neonatal mortality. Litters are visually monitored via video and direct examination during the first few weeks of life. Infectious diseases have not been a significant problem in neonatal black-footed ferrets; however, some diseases of domestic ferret kits are serious problems for commercial producers. Occasional sick young black-footed ferrets have been treated with antibiotics.

Neoplasia. Tumors are common in captive black-footed ferrets and have been the most common cause of death of aged ferrets (Williams et al. unpublished data). A similar high prevalence of neoplasia was reported in the aged captive black-footed ferrets captured in South Dakota and housed at the Patuxent Wildlife Research Center (Carpenter 1985). The most common malignant neoplasms in black-footed ferrets have been derived from sweat or sebaceous glands, especially on the caudal portion of the body. Other neoplasms include squamous cell carcinoma, olfactory neuroblastoma, mammary adenocarcinoma and hepatic cystadenocarcinoma. To prolong the reproductive life of the captive black-footed ferrets, all animals are examined periodically for neoplasms, with special attention to the posterior portions of the animal. Biopsy or excisions are performed as appropriate. Recent literature has indicated that neoplasia is relatively common in domestic ferrets (Goad and Fox 1988, Dillberger and Altman 1989); lymphosarcoma is the most common tumor (Goad and Fox 1988). Lymphosarcoma has not been proven to be induced by a virus in domestic ferrets, though this is suspected (Goad and Fox 1988, Dillberger and Altman 1989). In other species that commonly are affected by lymphosarcoma (cats, cattle), species-specific retroviruses are the cause (Moulton and Harvey 1990). Because many retroviruses cause insidious diseases with long incubation periods, are transmitted horizontally and vertically, and would be impossible to eliminate from a population of endangered species, it is critical that black-footed ferrets not be exposed to such viruses. Strict quarantine procedures should protect the colony.

Aleutian disease. Aleutian disease is a common and serious disease of commercially-raised mink (*Mustela vison*), caused by an environmentally resistent parvovirus. It also has been reported in domestic ferrets (Fox et al. 1988), and evidence of infection has been detected in Siberian polecats (Williams et al. unpublished data). Lesions suggestive of Aleutian disease have never been observed in black-footed ferrets and there has been no serologic evidence of infection in any animals tested. Undoubtedly, black-footed ferrets are susceptible to this disease, but the likely outcome of infection is not known. Aleutian disease is especially serious in mink which are homozygous for the aa genotype (Pearson and Forham 1987); the small degree of genetic variability of black-footed ferrets (O'Brien et al. 1989) could cause them to be especially susceptible. Aleutian disease would be impossible to eliminate from populations of endangered species. Commercial mink and ferret operations use test and slaughter, and depopulation for management of Aleutian disease (Fox et al. 1988). No vaccine is available. Prevention of black-footed ferret exposure to this pathogen is the only management strategy acceptable at the present time. This requires strict isolation, and because of the very resistent nature of the virus, special attention must be paid to preventing introduction of this virus into captive or wild colonies, or into environments which might receive black-footed ferrets.

Other diseases. Other infectious diseases recognized in the captive black-footed ferret population include campylobacteriosis, salmonellosis and actinomycosis. Fleas are occasionally found on the ferrets. All of these diseases may be treated using standard veterinary methods. Some additional diseases that strict quarantine is designed to prevent include rotavirus infection, which can cause severe diarrhea and high mortality in domestic ferret neonatal kits (Fox et al. 1988), human influenza, that causes respiratory disease and occasional mortality in domestic ferrets (Fox et al. 1988), and other infectious agents that have not been described previously as causing disease in black-footed ferrets or related species. The last category is important when managing an endangered species, because relatively little is known about their diseases. The cost of a mistake could have serious ramifications, including potential loss of the species or severe compromise of its recovery. Therefore, extensive disease prevention strategies must be followed, and avoidable risks involving diseases are not felt to be acceptable.

Disease Management During Reintroduction of Black-footed Ferrets

Prereintroduction Carnivore Disease Surveys

Study of animals which may harbor diseases of an endangered species in reintroduction sites is a key factor in planning the release of those animals back to the wild (Woodford and Kock 1991), and forms a basis for disease management of endangered species, such as the Florida panther (*Felis concolor coryi*) (Roelke et al. 1991). Areas identified for black-footed ferret reintroduction are occupied by many species that harbor pathogens that could infect ferrets. These diseases, in some cases, could be devastating, in other cases the effect on black-footed ferrets is unknown, and in many cases little or no adverse effect on ferrets would be expected. Sympatric species of primary interest are coyotes (*Canis latrans*) and badgers (*Taxidea taxus*), and secondarily red fox (*Vulpes vulpes*) and weasels (*Mustela frenata, M. ermina*), which are frequent inhabitants of prairie dog towns. Raccoons (*Procyon lotor*), striped skunk (*Mephitis mephitis*) and mink also are important and would be most common in riparian areas adjacent to prairie dog towns.

Survey of carnivores provided information on the status of canine distemper and sylvatic plague in advance of the 1991 reintroduction in the Shirley Basin release area (Williams et al. 1992), and other surveys have been conducted at Meeteetse (Williams 1987 unpublished data) and in the Badlands/Conata Basin of South Dakota (Williams et al. unpublished data). Carnivores were collected via aerial gunning, trapping, shooting and vehicular collision. Diagnostic techniques included serology to detect antibodies indicating exposure to specific diseases and necropsy to detect evidence of active disease. In addition, full use is made of carcasses to study other diseases and parasites of carnivores to provide data on what infectious agents could be expected to infect released black-footed ferrets.

Diseases of Major Concern and Management Procedures

Canine distemper. The objective of carnivore surveys is to determine if canine distemper is active in the area prior to release of black-footed ferrets. Presence of active canine distemper would alter reintroduction plans for the immediate area. Serologic studies, concentrating on juveniles, provide information on the occurrence of active distemper in the months prior to black-footed ferret release in September and October. Necropsy provides a chance to identify active cases of canine distemper that would not be detected by use of serology alone. Because of the long-term commitment to black-footed ferret reintroduction, it is hoped these canine distemper studies in prairie ecosystems may lead to understanding of the epizootiology of this disease and allow prediction of outbreaks. Dynamics of canine distemper in these systems has not been studied, though serologic surveys of coyotes and numerous carnivores examined in veterinary diagnostic laboratories have demonstrated that canine distemper is common in the wild (Budd 1981).

All black-footed ferrets released into the wild are vaccinated against canine distemper. Currently, the killed vaccine is being used and it likely will only provide short-duration protection against the virus. Boosters will be given when animals are captured for monitoring purposes. Hopefully, in the future, use of other vaccines will provide long-duration protection, without the need for booster inoculations.

Sylvatic plague. Surveillance for plague is important because of the impact plague may have on populations of prairie dogs. There are several methods for monitoring for the presence of sylvatic plague. Predators, with the important exception of the felids, are resistent to clinical disease; however, they do become infected and seroconvert by developing anti-plague antibodies. Thus, carnivores, which eat rodents, become excellent indicators of the activity of plague (Barnes 1982, Hopkins and Gresbrink 1982). Serosurveys of carnivores at Shirley Basin and Meeteetse indicated plague is common; surveys in South Dakota showed plague is not present in the area studied (Williams et al. unpublished data).

Another technique for plague monitoring is collection and testing of flea vectors for the plague bacillus. These tests are relatively expensive and time consuming; but, they provide epizootiologic information that cannot otherwise be obtained and which could be important in understanding the dynamics of the disease in a particular location. When plague is active in prairie dog colonies, a small number of carcasses usually are found on the surface. These can be tested at diagnostic laboratories for plague. Though many factors are considered, the suitability of release sites for ferrets is primarily determined by local populations of prairie dogs, which are studied extensively in the months prior to ferret release (Hnilicka and Luce 1992). A combination of carnivore serology, monitoring prairie dog numbers, and submission of prairie dog and ground squirrel (*Spermophilus elegans*) carcasses found during census activities appears to be adequate for monitoring for plague activity.

Other diseases. Obviously, many other potential pathogens are present in environments into which black-footed ferrets will be released. In most cases, it is possible to extrapolate from the effect these diseases have on related species to predict the expected effects on black-footed ferrets. No doubt, released black-footed ferrets will be exposed to many diseases they have not experienced while in captivity. Some of these diseases may have detrimental effects on individual animals and could be important in the early stages of reintroduction, but most probably will not be important in established populations of ferrets. It is important that diseases and infections of released black-footed ferrets be carefully monitored during initial reintroductions. This will allow managers to determine if any of these diseases cause a severe enough impact to justify special management.

The following diseases and parasites are relatively common in carnivores in prairie ecosystems and may need special consideration during black-footed ferret reintroductions. Tularemia is a bacterial disease that is apparently maintained in lagomorph populations, but infection of carnivores is common (Bell and Reilly 1981, Williams et al. 1992). It is not known if tularemia will cause significant disease in black-footed ferrets; however, disease and mortality has been reported previously in mink (Bell and Reilly 1981).

Serologic evidence of Aleutian disease has been found in free-ranging skunks (Ingram and Cho 1974, Williams et al. unpublished data). It is not known if the virus circulating in the wild could induce disease in black-footed ferrets. Pre-reintroduction serologic surveys can be used to determine if the virus has been active in the area and alert managers to the need to monitor released ferrets for evidence of infection.

A wide variety of parasites will infect black-footed ferrets following release. The coccidia that are normally carried by captive black-footed ferrets will go with them to the wild, and are unlikely to cause a problem under free-ranging conditions. A filariid nematode of badgers, *Filaria taxideae*, is common in some reintroduction sites (Williams et al. 1992, unpublished data), and will likely infect black-footed ferrets. It causes dermatitis in badgers (Keppner 1970) and domestic ferrets (Williams unpublished data), and likely would cause similar lesions in black-footed ferrets. However, parasites infecting abnormal hosts occasionally cause considerable damage and even mortality. Heartworm, *Dirofilaria immitis*, also a filariid nematode, could influence survival of individual black-footed ferrets; a single heartworm can kill a domestic ferret (Fox 1988), but it is rare in Wyoming. Heartworm is common in domestic dogs in some states and has been found in coyotes (Custer and Pence 1981). The parasite is transmitted via mosquitoes, thus the habitat preferences of black-footed ferrets for dry prairie dog towns will probably help protect the animals from infection due to lack of contact with the vectors.

Reintroduction Techniques and Disease Prevention

The reintroduction protocol used in 1991 for black-footed ferrets called for a 10-day acclimation period in small elevated cages equipped with natal nest boxes familiar to the ferrets (Oakleaf et al. 1991). Obviously, healthy animals will have the greatest chance to survive in the wild after release and this 10-day period allowed observation of the animals to detect complications following transport or those which developed while on-site. All released ferrets were vaccinated using the killed canine distemper vaccine with appropriate boosters. Pre- and post release husbandry, and salvage of sick or dead black-footed ferrets has been designed to prevent diseases and to minimize the possibility of iatrogenically transmitting infectious agents to healthy ferrets (Oakleaf et al. 1991). These procedures should be followed for future reintroductions. Careful monitoring of released black-footed ferrets for diseases and parasites should be conducted whenever possible. Also, in order to understand causes of mortality in the wild, all carcasses should receive thorough necropsy examination. This also may provide useful data for evaluation of release techniques.

Long-term Disease Considerations in Black-footed Ferret Recovery

Considering the ubiquitousness of canine distemper, there is no doubt that epizootics will occur in carnivores living in areas with reestablished colonies of black-footed ferrets. Many black-footed ferrets may die in these outbreaks, but the species will be secure via other free-ranging and captive colonies. What will be the appropriate management response to an epizootic of canine distemper? Can we learn enough about canine distemper in prairie ecosystems to predict impending epizootics? After populations of black-footed ferrets have been successfully recovered, the focus of disease interest can change from concern about single individuals and populations to understanding the role disease plays in free-ranging populations. Long-term monitoring of carnivores for diseases will greatly increase our understanding of the dynamics and importance of many infectious disease in prairie ecosystems and to black-footed ferrets specifically.

Greater understanding of sylvatic plague dynamics in prairie dog populations will be critical for recovery of the black-footed ferret. Adequate habitat for black-footed ferrets is limited to large prairie dog colonies. If plague significantly decreases the prey population, these sites may no longer be suitable for ferret reintroduction, even if other factors are favorable. How fast can populations of prairie dogs be expected to recover? Will plague act as a limiting factor on prairie dog populations in some areas? Will plague ever disappear once introduced into large prairie dog complexes? How does prairie dog species affect the dynamics of plague? There is some evidence that very large prairie dog complexes may be able to "tolerate" plague, in the sense that it causes considerable local mortality, but moves slowly enough over large geographic areas to allow for population recovery between epizootics. These questions will only be answered by long-term studies.

Translocation of individual black-footed ferrets for genetic management of reintroduced populations will be necessary in the long-term, because of the fragmented nature of the habitat available. Likely, animals will be moved between free-ranging and captive populations. Thus, black-footed ferrets, captive and free-ranging, will be managed as a "metapopulation" (Lande and Barrowclough 1987, Gilpin 1987). This concept is very important for the genetic management of endangered species and small populations; however, disease considerations will be necessary to assure serious or unexpected pathogens are not transplanted along with genes. Development of disease management protocols will be obvious for some diseases, such as canine distemper, but are not so clear at the present time for other diseases black-footed ferrets may contract in captivity or in the wild. Adequate diagnostic tests for some diseases may need to be developed and tested in black-footed ferrets in order to adequately screen animals that are moved among populations.

Conclusions

Overcoming disease problems in captive and free-ranging populations are related but different. Maintenance and effective breeding of endangered wild animals in captivity requires attention to both individual and population health. Because most individuals in very small populations of endangered species are genetically valuable, the maximum number of offspring must be produced. Thus, the individual becomes the unit of concern and extensive veterinary intervention is warranted. At a population level, the effects and dangers of some diseases are magnified in captivity because of increased density, artificial diets and stress. These require management techniques directed at all members of the captive population and to facility design and use.

Management of diseases during the reintroduction process, with the goal of species recovery (U.S. Fish and Wildlife Service 1988), will be directed more toward populations, with less intervention for individuals. However, during the transition period, it will be necessary to maximize individual survival as the basis for establishing self-sustaining populations. This will undoubtedly require some intervention, along with disease control and prevention.

Monitoring and study of the effects of diseases on free-ranging populations should continue after reintroduced populations are established. Intervention in the face of disease threats may be desirable, but those decisions should be made with detailed knowledge of the biology, including disease influences, on free-ranging black-footed ferrets. The movement of animals between population for genetic purposes will require special disease consideration and development of carefully designed protocols for quarantine and disease testing.

There is no excuse for lack of caution about diseases or taking unnecessary risks in this species that has been so impacted by disease. Historically, there has been relatively little concern among wildlife managers, with respect to moving pathogens with translocated animals. Awareness of potential disease problems and having the interest to prevent those problems will help assure recovery of black-footed ferrets.

References

Appel, M. 1987. Canine distemper virus. Pages 133–159 *in* M. J. Appel, ed., Virus infections of carnivores. Elsevier Science Publ., New York, NY. 500 pp.

Ballou, J. D. and R. Oakleaf. 1989. Demographic and genetic captive breeding recommendations for black-footed ferrets. Pages 247–267 *in* U. S. Seal, E. T. Thorne, M. Bogan, and S. Anderson, eds., Conservation biology and the black-footed ferret. Yale Univ. Press, New Haven, CT. 302 pp.

Barnes, A. M. 1982. Surveillance and control of bubonic plague in the United States. Symp. Zool. Soc. London. 50:237–270.

Bell, F. J. and J. R. Reilly. 1981. Tularemia. Pages 213–237 *in* J. W. Davis, L. H. Karstad, and D. O. Trainer, eds., Infectious diseases of wild mammals. 2nd ed. Iowa St. Univ. Press, Ames. 446 pp.

Bernard, S. L., J. R. Gorham, and L. M. Ryland. 1984. Biology and diseases of ferrets. Pages 385–397 *in* J. G. Fox, B. J. Cohen, and F. M. Loew, eds., Laboratory animal medicine. Academic Press, NY. 750 pp.

Budd, J. 1981. Distemper. Pages 31–44 *in* J. W. Davis, L. H. Karstad, and D. O. Trainer, eds., Infectious diseases of wild mammals. 2nd ed. Iowa St. Univ. Press, Ames. 446 pp.

Carpenter, J. W. 1985. Capfive breeding and management of black-footed ferrets. Pages 12.1–12.13 *in* S. H. Anderson and D. B. Inkley, eds., Black-footed ferret workshop proceedings. Wyoming Game and Fish Dept. Cheyenne.

Carpenter, J. W., M. J. G. Appel, R. C. Erickson, and M. N. Novilla. 1976. Fatal vaccine-induced canine distemper virus infection in black-footed ferrets. J. Am. Vet. Med. Assoc. 169:961–964.

Custer, J. W. and D. B. Pence. 1981. Ecological analysis of helminth populations of wild canids from the Gulf Coast prairies of Texas and Louisiana. J. Parasitol. 67:289–307.

Davis, J. W., L. H. Karstad, and D. O. Trainer. 1981. Infectious diseases of wild mammals. 2nd ed. Iowa St. Univ. Press, Ames. 446 pp.

Dillberger, J. E. and N. H. Altman. 1989. Neoplasia in ferrets: Eleven cases with a review. J. Comp. Pathol. 100:161–170.

Forrester, D. J. 1992. Parasites and diseases of wild mammals in Florida. Univ. Press Florida, Gainesville. 459 pp.

Fox, J. G. 1988. Parasitic diseases. Pages 235–247 *in* Biology and diseases of the ferret. Lea and Febiger, Philadelphia, PA. 345 pp.

Fox, J. G., R. C. Pearson, and J. R. Gorham. 1988. Viral and chlamydial diseases. Pages 217–234 *in* Biology and diseases of the ferret. Lea and Febiger, Philadelphia, PA. 345 pp.

Gilpin, M. E. 1987. Spatial structure and population vulnerability. Pages 125–139 *in* M. E. Soule, ed., Viable population for conservation. Cambridge Univ. Press, New York, NY. 189 pp.

Goad, M. E. P. and J. G. Fox. 1988. Neoplasia in ferrets. Pages 274–288 *in* Biology and diseases of the ferret. Lea and Febiger, Philadelphia, PA. 345 pp.

Hnilicka, P. and B. Luce. 1992. Habitat evaluation of the Shirley Basin/Medicine Bow black-footed ferret management area in 1991 completion report. Endangered and nongame bird and mammal investigations. Wyoming Game and Fish Dept., Cheyenne. In press.

Hopkins, D. D. and R. A. Gresbrink. 1982. Surveillance of sylvatic plague in Oregon by serotesting carnivores. Am. J. Public Health 72:1,295–1,297.

Ingram, D. G. and H. J. Cho. 1974. Aleutian disease in mink: Virology, immunology and pathogenesis. J. Rheumatol. 1:74–92.

Keppner, E. J. 1970. Studies on the taxonomy and life history of *Filaria taxideae* n. sp. (Filarioidea: Filariidea) from Wyoming. Ph.D. diss., Dept. Zoology, Univ. Wyoming, Laramie. 148 pp.

Lande, R. and G. F. Barrowclough. 1987. Effective population size, genetic variation, and their use in population management. Pages 87–123 *in* M. E. Soule, ed., Viable population for conservation. Cambridge Univ. Press, New York, NY. 189 pp.

Menkens, G. E., Jr. and S. H. Anderson. 1991. Population dynamics of white-tailed prairie dogs during an epizootic of sylvatic plague. J. Mammal. 72:328–331.

Moulton, J. E. and J. W. Harvey. 1990. Tumors of the lymphoid and hematopoietic tissues. Pages 231–307 *in* J. E. Moulton, ed., Tumors in domestic animals. 3rd ed. Univ. California Press, Berkely. 672 pp.

Novilla, M. N., J. W. Carpenter, and R. P. Kwapien. 1980. Dual infection of Siberian polecats with *Encephalitozoon cuniculi* and *Hepatozoon mustelis* n. sp. Pages 353–363 *in* R. J. Montali and G. Migaki, eds., The comparative pathology of zoo animals. Smithsonian Inst. Press, Washington, D.C. 684 pp.

Oakleaf, B., B. Luce, E. T. Thorne, and D. Biggins. 1991. Black-footed ferret reintroduction in Wyoming: Project description and protocol. Wyoming Game and Fish Dept., U.S. Fish and Wildl. Serv. and Bureau of Land Manage. 62 pp.

O'Brien, S. J., J. S. Martenson, M. A. Eichelburger, E. T. Thorne, and F. Wright. 1989. Genetic variation and molecular systematics of the black-footed ferret. Pages 21–23 *in* U. S. Seal, E. T. Thorne, M. Bogan, and S. Anderson, eds., Conservation biology and the black-footed ferret. Yale Univ. Press, New Haven, CT. 302 pp.

O'Brien, S. J., M. E. Roelke, L. Marker, A. Newman, C. A. Winkler, D. Meltzer, L. Colly, J. F. Evermann, M. Bush, and D. E. Wildt. 1985. Genetic basis for species vulnerability in the cheetah. Science 227:1,428–1,434.

Parrish, T. and B. Luce. 1991. Evaluation of potential black-footed ferret reintroduction sites in Wyoming completion report. Pages 16–27 *in* Wyoming Game and Fish Department, ed., Endangered and nongame bird and mammal investigations. Wyoming Game and Fish Dept., Cheyenne. 247 pp.

Pearson, R. C. and J. R. Gorham. 1987. Pages 361–369 *in* M. J. G. Appel, ed., Virus infections of carnivores. Elsevier Science Publ., NY. 500 pp.

Rayor, L. S. 1985. Dynamics of a plague outbreak in Gunnison's prairie dog. J. Mammal. 66:194–196.

Roelke, M. E., D. J. Forrester, E. R. Jacobson, and G. V. Kollias. 1991. Rationale for surveillance and prevention of infectious and parasitic disease transmission among free-ranging and captive Florida panthers (*Felis concolor coryi*). Pages 185–195 *in* R. E. Junge, ed., Proc. Am. Assoc. Zoo Vet., Calgary, Alberta. 396 pp.

Thorne, E. T. and D. W. Belitsky. 1989. Captive propagation and the current status of free-ranging black-footed ferrets in Wyoming. Pages 223–234 *in* U. S. Seal, E. T. Thorne, M. Bogan, and S. Anderson, eds., Conservation biology and the black-footed ferret. Yale Univ. Press, New Haven, CT. 302 pp.

Thorne, E. T., N. Kingston, W. R. Jolley, and R. C. Bergstrom, eds. 1982. Diseases of wildlife in Wyoming. 2nd ed. Wyoming Game and Fish Dept., Cheyenne. 353 pp.

Thorne, E. T. and B. Oakleaf. 1991. Species rescue for captive breeding: Black-footed ferret as an example. Symp. Zool. Soc., London 62:241–261.
Thorne, E. T. and E. S. Williams. 1988. Disease and endangered species: The black-footed ferret as a recent example. Conserv. Biol. 2:66–74.
U.S. Fish and Wildlife Service. 1988. Black-footed ferret recovery plan. U.S. Fish and Wildl. Serv., Denver, CO. 154 pp.
Williams, E. S. 1987. Disease survey of carnivores near Meeteetse. Completion report. Pages 93–106 *in* Wyoming Game and Fish Department, ed., Endangered and nongame bird and mammal investigations. Wyoming Game and Fish Dept., Cheyenne. 189 pp.
Williams, E. S., J. Cavender, C. Lynn, K. Mills, C. Nunamaker, A. Boerger-Fields, B. Luce, and S. Anderson. 1992. Survey of diseases of coyotes and badgers in Shirley Basin, Wyoming in 1991. *In* Endangered and nongame bird and mammal investigations. Wyoming Game and Fish Dept., Cheyenne. In Press.
Williams, E. S., E. T. Thorne, M. J. G. Appel, and D. W. Belitsky. 1988. Canine distemper in black-footed ferrets (*Mustela nigripes*) in Wyoming. J. Wildl. Dis. 25:385–398.
Williams, E. S., E. T. Thorne, T. J. Quan, and S. L. Anderson. 1991. Experimental infection of domestic ferrets (*Mustela putorius furo*) and Siberian polecats (*M. eversmanni*) with *Yersinia pestis*. J. Wildl. Dis. 27:441–445.
Woodford, M. H. and R. A. Kock. 1991. Veterinary considerations in re-introduction and translocation projects. Symp. Zool. Soc., London. 62:89–99.

Influence of Disease on a Population Model of Mid-continent Mallards

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Introduction

On numerous occasions, waterfowl deaths caused by disease were highly visible to wildlife managers and to the general public. Thousands of birds died during duck plague, avian botulism and avian cholera outbreaks. Undoubtedly, some disease occurred in waterfowl populations throughout their evolution; however, knowledge of disease epizootiology primarily developed during the past 40–50 years (Wobeser 1981) for diseases that cause massive die-offs (e.g., avian cholera, avian botulism and duck plague). Other diseases, such as avian tuberculosis, aspergillosis, parasite infection and lead poisoning, also occur at chronic levels, but the data remain meager on many of these less spectacular causes of mortality and sublethal forms of disease. However, because chronic losses occur throughout the year, their cumulative effect, as well as the large die-offs, are a potential threat to waterfowl populations (Bellrose 1976, Wobeser 1981).

Previous studies (Anderson 1975) demonstrated that 50 percent of the annual mortality in mallard (*Anas platyrhynchos*) populations is from nonhunting causes. In addition to disease, these causes include predation, accidental deaths, inclement weather and other factors (Stout and Cornwell 1976), which can be confounded by disease. Determination of mortality rates from diseases has been difficult because many biases and inconsistencies are associated with the available data. Assessment of disease prevalence and magnitude of losses is complicated by the spatial and temporal variability of many diseases, the logistic difficulty of studying highly mobile waterfowl populations, and the potentially confounding influences of predation and scavenging on detecting disease-related mortality. Unless losses are so extensive that they direct attention to a particular area, mortality from disease is easily overlooked (*see* Zwank et al. 1985). Even when die-offs are evident, mortality from disease may be underestimated because sick waterfowl become debilitated, seek seclusion in dense cover and are removed by efficient predators or scavengers prior to human detection.

Our objective was to evaluate the possible effects of three of the most common diseases (Friend 1985), avian cholera, avian botulism and lead poisoning, on the population dynamics of mid-continental mallards. We used data from disease outbreaks to develop preliminary estimates of mortality rates and their temporal pattern. A computer model was used to integrate these mortality estimates with other mallard life history characteristics, evaluate the potential effects of these diseases on mallard demographics and assess the need for better information on the effects of disease on mallards.

Mallard Population Model

The Mallard Annual Cycle Model (Koford et al. 1992) was developed to integrate information on factors affecting the population dynamics of mallards in the mid-continental United States. The model considers only female mallards, because males do not seem to be limiting to productivity. Females use 15 geographic areas, with several types of nesting and foraging habitat. Attributes for each individual female in the model include age, body mass, reproductive status, molt status, geographic location, lead exposure and others. Most attribute values change stochastically, and geographic transitions are influenced by individual attributes and environmental conditions (e.g., habitat, temperature, water conditions). Stochastic and deterministic events cause mortality or other attribute changes on a daily basis for each individual. The daily probability of mortality is the sum of the daily probabilities from hunting, crippling, predation, lead poisoning, botulism and avian cholera. Thus, the model considers that all sources of mortality are additive and does not presently incorporate a mechanism for compensatory mortality. Because the model encompasses the entire year, it can be used to evaluate cross-seasonal population effects.

We used the model to evaluate the importance of diseases on mallard populations by comparing results from a base model (with baseline disease mortality) to those produced by changing the daily probabilities of disease mortality. Our primary interest was changes in the annual rate of population growth ($\lambda_2 - \lambda_1$) during 10-year simulations with an initial population of 1,000 birds. Each of these simulations was replicated 10 times to obtain an average measure of population growth for each scenario. Standard deviations of the population growth rates for these replicates were usually 0.01–0.02. Therefore, we considered changes of 0.03–0.04 to indicate important differences. In addition to population trend, we also evaluated other changes in model results, including crude rates of cause-specific mortality and lead exposure, changes in body mass, and changes in nesting success.

Disease Mortality Factors

Lead Poisoning

Hazardous levels of lead ingested and absorbed into body tissues results in lead poisoning. Lead pellets from shot shells are the most common source of lead poisoning in migratory birds (Friend 1987a). Mortality depends primarily on the dose (number of pellets ingested) and the diet (U.S. Fish and Wildlife Service [USFWS] 1986). Lead poisoning can cause death in waterfowl within 17–21 days after ingestion of a lethal dose (1–2 pellets) of lead, but acute mortality also may occur in birds that consume an overwhelming dose of lead. Mallards that survive lead ingestion usually void the lead within 20 days and remain at risk to subsequent exposure. Lead poisoning in waterfowl usually increases during autumn migration, peaks after the hunting season and remains prominent during the winter and early spring (Bellrose 1959, Sanderson and Bellrose 1986, USFWS 1986, National Wildlife Health Research Center [NWHRC] unpublished data).

Ingestion of lead shot by mallards harvested in the Mississippi flyway is among the highest reported, and has been consistently documented at about 8 percent between 1938–54 (Bellrose 1959) and 1974–82 (Sanderson and Bellrose 1986). Ingestion of lead shot by mallards has been lower (3–4 percent) in wintering areas of the Central Flyway (Sanderson and Bellrose 1986, USFWS 1986). However, estimates of lead exposure derived from gizzard analysis may provide conservative estimates of lead exposure (Anderson and Havera 1985) and these estimates require correction for the increased vulnerability of lead-exposed mallards to hunting. Bellrose (1959) estimated a correction factor of 1.65 from band returns, and other researchers estimated hunting vulnerability at 2–3.5 (M. Heitmeyer personal communication), 2.0 for geese (DeStefano 1989:23–24), and 1.0 (Ankney and Dennis 1982). For our analysis, we used a 2.0 correction factor to obtain an estimated 4.0 percent natural rate of exposure to lead. We combined mortality estimates for number of ingested shot (Bellrose 1959) with the distribution of ingested shot (Bellrose 1959) to obtain a weighted probability of mortality of 0.18 for all mallards ingesting lead shot. The resulting 20-day mortality rate ($0.04 \times 0.18 = 0.0072$) was converted to an average daily probability of mortality (0.0004), which was then adjusted for seasonal changes in lead exposure (Table 1). In addition to mortality from lead poisoning, ducks that ingest lead also lose body mass (Sanderson and Bellrose 1986). We estimated mass loss for ducks that did not die from lead ingestion at 0.84 percent of body mass per day for 20 days (Sanderson and Bellrose 1986:18–19).

Avian Botulism

Avian botulism is caused by ingestion of a neurotoxin produced by the bacterium *Clostridium botulinum* type C, which is widely distributed in wetlands and found in marsh invertebrates (Jensen and Allen 1960, Duncan and Jensen 1976). Waterfowl inadvertently ingest type C botulism toxin while feeding, and die from paralysis or from drowning (Rosen 1971a). Avian botulism has been recognized as a major killer of wild waterfowl since the early 1930s (Giltner and Couch 1930, Kalmbach and Gunderson 1934), and continues to cause die-offs which vary greatly among years, sites and species. Losses of more than 1,000,000 birds have occurred during localized outbreaks in a single year (Locke and Friend 1987). In endemic areas, losses of 5,000 birds or more can frequently occur. Avian botulism occurs almost yearly, and losses are extensive in mallard breeding areas on the prairies (Locke and Friend 1987). Frequent losses also occur in Minnesota, Wisconsin, Illinois, Iowa and Nebraska. Avian botulism is the primary disease affecting mallards during the post-breeding phase of the annual cycle. Outbreaks occur primarily during July through September, but can occur in December and January or occasionally during early spring (Locke and Friend 1987). Control of this disease has focused on regulating water levels and on collecting avian carcasses to prevent further botulism toxin production. Recent experimental studies indicated that, during some outbreaks daily carcass pickup can reduce botulism mortality rates for mallards four to five times (Reed and Rocke 1992).

Avian Cholera

Most species of waterfowl are susceptible to avian cholera, an infectious disease caused by the bacterium, *Pasteurella multocida* (Rosen 1971b). The earliest documented record of avian cholera in North American wild ducks was reported in Texas (Quortrup et al. 1946), and periodic outbreaks among ducks have occurred since that time (Petrides and Bryant 1951, Rosen 1971b, Brand 1984). Avian cholera epizootics usually occur at waterfowl concentration areas, most commonly in the Pacific and

Central flyways, where mortality may exceed 1,000 birds per day, and death may follow exposure by 6–12 hours (Friend 1987b). Avian cholera mortality has occurred annually since 1975 (Zinkl et al. 1977) in Nebraska's Rainwater Basin, where mallards are the most frequently affected species (Windingstad et al. 1984, 1988). Avian cholera mortality in mallards also was reported in northwest Missouri and southwest Iowa during 1963 (Vaught et al. 1967), and this area has become enzootic for avian cholera (Brand 1984, NWHRC unpublished data, Windingstad et al. in press). In other circumstances, however, the disease may become a chronic infection without causing mass mortality (Botzler 1991). Losses can occur at any time of the year, but typically occur during the non-breeding season when waterfowl are concentrated. Central flyway outbreaks peak in winter and continue during spring migration.

Avian Botulism and Cholera Mortality

We obtained reports of avian cholera and botulism losses of mallards during 1979–88 in the Central and Mississippi flyways from federal wildlife refuges and wetland management districts, state wildlife agencies, the Canadian Wildlife Service, and Ducks Unlimited—Canada. Epizootic files at the NWHRC also were reviewed to obtain additional information on losses of mallards from disease. Daily mortality rates during outbreaks were calculated from 124 reports, with estimates of the mallard population at risk, dates delimiting the start and end of a mallard die-off, and either the number of retrieved mallard carcasses or the estimated number of dead mallards. Daily mortality rates for each outbreak were estimated by the Mayfield method (Johnson 1979). We log-transformed these daily mortality rates (Heisey and Fuller 1985) to produce normal distributions and calculated seasonal means and approximate standard errors (Table 1). For botulism mortality, we also modified the seasonal mortality rates to account for a linear increase in reported botulism mortality beginning in July, peaking in mid-August and declining until late September (NWHRC unpublished data).

The estimated daily mortality rates for the Mallard Annual Cycle Model represent the conditional probability of mortality given an outbreak and, therefore, likely include two opposing biases. Estimates of disease mortality are conservative because scavengers can dispose of 80–90 percent of the available carcasses within three days (Humburg et al. 1983, Stutzenbaker et al. 1983). Furthermore, carcasses usually are difficult to find. Humburg et al. (1983) located only one-fourth of the carcasses planted in quadrats at Swan Lake Refuge, and Stutzenbaker et al. (1983) reported that less than 10 percent of planted carcasses could be located within 30 minutes. In contrast, not all mallards in the population will be in areas where disease outbreaks occur and, thus, are not exposed to the risk of mortality from disease. Unfortunately, there is no available data on the proportion of mallard populations that is annually exposed to either avian botulism or cholera outbreaks. Because avian botulism is a widespread disease throughout the breeding and post-breeding areas of mid-continent mallard populations, we assumed that the underestimates of daily mortality were approximately balanced by applying the mortality rates to all birds in the population. However, most avian cholera die-offs occurred at endemic areas and are not representative of the entire population of mallards. Therefore, we reduced the estimated avian cholera mortality during the winter (from 0.0008 to 0.0004) and used the coefficient of variation to compute an new standard error (Table 1).

Table 1. Estimated daily mortality rates from diseases in mid-continent mallards, by season and number of die-offs (n) used to estimate mortality.

Season	n	Estimated daily mortality rate	Mortality ±1 SE
Breeding/Post-breeding	87		
(April 1–September 30)			
Botulism		0.0005	0.00040–0.00065
Fall migration	15		
(October 1–December 15)			
Avian cholera		0.0002	0.00010–0.00044
Botulism		0.0001	0.00005–0.00022
Lead poisoning		0.0003	0.00005–0.00055
Winter	19		
(December 16–February 28)			
Avian cholera		0.0004	0.00024–0.00070
Lead poisoning		0.0004	0.00015–0.00065
Spring migration	4		
(March 1–March 31)			
Avian cholera		0.0002	0.00010–0.00044
Lead poisoning		0.0002	0.00010–0.00045

Simulation Results

Mortality patterns for the base model (Figure 1) show that disease mortality peaks in the summer and winter. Avian botulism is the primary cause of summer mortality. Disease mortality declines during the fall to early winter, when avian botulism is replaced by avian cholera and lead poisoning. Mortality from lead poisoning and avian cholera increases during the winter and begins to decline from late winter toward early spring. Mortality from these three diseases is at a minimum during the breeding period.

Model Sensitivity

Variation of our seasonal estimates of daily mortality rates for each disease was considerable. Sources of variation among outbreaks included annual differences, spatial differences and minor sampling variation for each outbreak. We conducted a sensitivity analysis to determine whether variation in our estimates of disease mortality had a substantial impact on base model results. The mean daily probability of mortality for each disease was modified by ±1 SE (Table 1), which provided a range of values with a 68 percent chance of containing a mean daily probability of mortality during outbreaks. Differences in average annual population growth rates between the base and modified models were used to evaluate the relative sensitivity of model outputs. Growth rates were most sensitive to mortality rates for avian botulism and avian cholera, and marginally sensitive to mortality rates for lead poisoning (Table 2). Simultaneous changes in all three mortality factors indicated a potential for considerable variation in mortality from disease if estimates of all three factors were highly correlated.

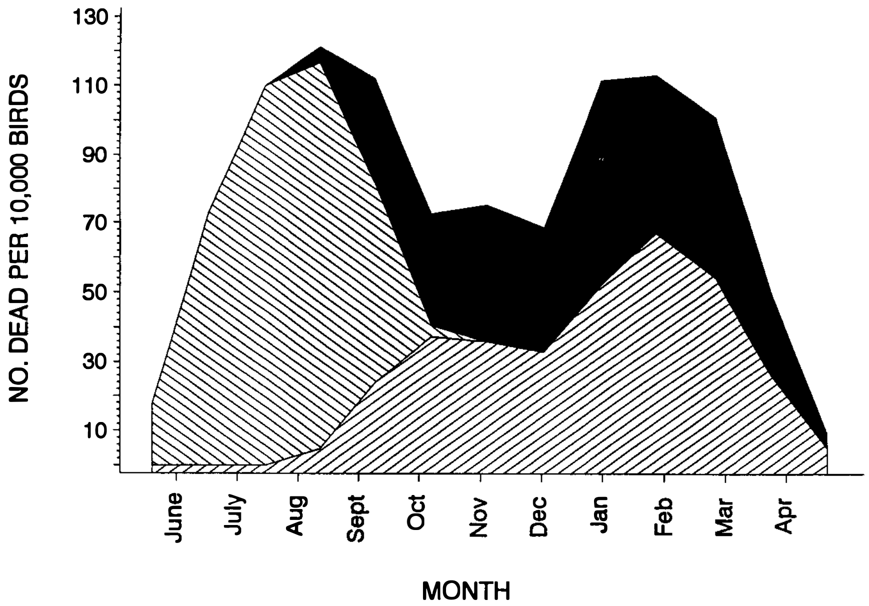

Figure 1. Seasonal (within 28-day intervals) mortality of female mallards from avian botulism (\\), lead poisoning (■) and avian cholera (/). Mortality standardized per 10,000 birds and estimated from the average annual values from two 10-year simulations with initial populations of 1,000 birds.

Lead Poisoning

Bellrose (1959) estimated that 4 percent of the mallards in the Mississippi flyway were lost annually to lead poisoning. Sanderson and Bellrose (1986) estimated that 30–40 percent of all ducks ingest lead in any given year. They also indicated that losses from lead poisoning occur most frequently during winter and spring. Results from our base model generally coincide with these predictions. Base model results indicated an average annual lead poisoning mortality of 4.8 percent with an additional 20.4 percent of the birds ingesting lead shot. Seasonal patterns of lead exposure and

Table 2. Average annual population growth rate changes (λ_2–λ_1) from the base model for 10 simulations, each for 10 years, with an initial population of 1,000 mallards.

			Reduction in mortality	
Mortality factor	−1 SE	+1 SE	50 percent	75 percent
Botulism	+0.035	−0.014	0.048	0.053
Avian cholera	+0.029	−0.018	0.034	0.056
Lead poisoning	+0.023	−0.008	0.045	0.061
Botulism, avian cholera and lead poisoning	+0.062	−0.072	0.100	0.140

lead poisoning in the model began to increase in October, and reach a peak in late December or early January.

The amount of lead poisoning in waterfowl and secondary poisoning in other species has generated considerable controversy in the United States. A national ban on lead shot for waterfowl hunting was instituted beginning in 1991, and should result in decreased levels of lead poisoning in waterfowl. We used the Mallard Annual Cycle Model to simulate the population effects of conversion from lead to nontoxic shot. Reductions in lead shot exposure and lead poisoning by 50 percent and 75 percent resulted in average annual population growth rates of 0.045 and 0.061, respectively, above the base model (Table 2). The lead poisoning mortality rate was reduced from 4.8 percent to 2.5 percent and 1.3 percent by the simulated reduction in available lead shot. The proportion of birds with sublethal lead exposure was correspondingly reduced from 0.204 to 0.106 and 0.055. This reduced exposure also contributed to increased average body mass (measured annually on January 15) of adult females from 1,083 gm (SD=5.8) to 1,094 gm (SD=3.8) and 1,100 gm (SD=4.1) when lead exposure was reduced by 50 percent and 75 percent, respectively. However, body mass of young birds (hatched the previous year) was not substantially increased (1,021 gm to 1,028 gm) when lead exposure was reduced by 75 percent. These increases in average body mass had little cross-seasonal effect on spring productivity; nesting success (proportion of females with a successful nest) increased from 0.24 (SD=0.01) in the base model to 0.26 (SD=0.005) when lead exposure was reduced by 75 percent.

Avian Botulism

Little speculation has been offered regarding the impact of avian botulism on waterfowl populations, perhaps due to the inherent difficulties of assessing population effects (Jensen and Price 1987). The Mallard Annual Cycle Model reported annual botulism mortality of 5 percent in adult birds with a seasonal pattern that begins to increase in late June, and peaks in August to early September (Figure 1). This seasonal pattern of mortality has been reported by other studies (*see* Locke and Friend 1987).

Considerable effort and resources have been expended on carcass removal to control botulism (Parrish and Hunter 1969), but these efforts have received little evaluation (Wobeser 1987, Reed and Rocke 1992). We used model simulations to evaluate the effects of reducing the occurrence of avian botulism outbreaks and to evaluate the potential impact that carcass pickup efforts have on mallard populations. Reduction in the daily probability of botulism mortality by 50 percent and 75 percent had a corresponding effect on annual botulism mortality, and resulted in average annual population growth rate increases of 0.048 and 0.053, respectively, in comparison to the base model (Table 2). We also increased botulism mortality probabilites by two or three times to simulate a reduction in the current management efforts to remove carcasses or haze birds during outbreaks. These simulations showed respective decreases in the average annual population growth rate of 0.035 and 0.076.

Avian Cholera

Little is known about the impact of avian cholera on waterfowl populations (Botzler 1991). Our base model produced annual avian cholera mortality in 4.5 percent of the mallard population. In contrast, Rosen (1971b) estimated that 2 percent of the duck population in California was lost to avian cholera in some years. This estimate may be high, even for duck populations in California, where avian cholera occurs annually (Botzler 1991). However, recent increases in the distribution and frequency of avian cholera into the Central flyway and western Saskatchewan makes assessment of the situation difficult. Disease mortality from the model generally follows the predicted pattern of winter and spring mortality (Figure 1). However, the Mallard Annual Cycle model currently has avian cholera mortality beginning during autumn and continuing into winter.

Birds that die from avian cholera often discharge large volumes of *P. multocida* organisms, which can survive outside the carcass for several months. Considerable efforts have been expended to collect and dispose of waterfowl carcasses, manipulated environmental conditions, or control bird movement to reduce avian cholera losses once an outbreak has been initiated. Although these procedures are logical, no data are available to evaluate the benefits of these activities (Botzler 1991). We simulated the possible impact of decreasing these control activities by increasing avian cholera mortality probabilities by 2 or 3 times the base rates. These simulations reduced average annual population growth by 0.044 and 0.075, respectively. We also evaluated potential management strategies (Habitat manipulation, disinfection of small bodies of water, or vaccination) aimed at preventing avian cholera outbreaks by reducing the daily probability of avian cholera mortality by 50 percent and 75 percent. These reductions in avian cholera mortality produced 0.034 and 0.056 average annual population growth increases over the base model (Table 2).

Lead Poisoning, Avian Botulism and Avian Cholera

The combined effects of disease may account for a large proportion of the nonhunting mortality (Bellrose 1976, Stout and Cornwell 1976). We evaluated the simultaneous reduction of all disease mortality probabilities by 50 percent and 75 percent. These reductions in mortality increased the annual population growth rates by 0.100 and 0.139, respectively (Table 2).

Discussion

Although diseases among wild waterfowl have long been recognized and have received increased attention in recent years, few estimates are available of the annual waterfowl mortality rates from disease. Even reported estimates were usually incomplete, based on crude extrapolations for a single disease, or educated guesses. Determination of mortality rates from diseases in mallards continues to be a difficult undertaking because of the annual variation in mortality from disease, spatial scale of disease outbreaks, the high mobility of waterfowl, difficulty in estimating number of birds that die during outbreaks, interactions between mortality from diseases, predation and scavenging, and other confounding factors. Our estimates of mortality from diseases certainly are susceptible to many of these difficulties and potential biases. Nevertheless, management of wildlife populations is a complicated task, often requiring decisions with such limited data (Cowardin and Johnson 1979). The development of simple models, and the geographic and temporal representation of these models can facilitate logical and orderly development of management and research. In this context, our results can provide a useful starting point to identify potential areas for further research on diseases, to focus on the potential effects of disease on waterfowl and to provide a preliminary evaluation of overall management to reduce mortality from disease.

Sensitivity analyses indicated that more reliable estimates of the daily probability of mortality are needed, especially for avian botulism and avian cholera. Errors in the mean estimates of these daily probabilities could have a substantial effect on model predictions of population growth. The importance of spatial and annual variation in these mortality sources needs further investigation. In addition, improved estimates of the proportion of birds that are at risk to avian botulism and cholera outbreaks are necessary. In contrast, probability estimates of lead poisoning mortality seem sufficiently robust to provide reasonable model predictions. These findings are not surprising because more research has been conducted on the ingestion, mortality and physiological effects of lead poisoning on waterfowl than on avian botulism or avian cholera.

Efforts to manage waterfowl diseases can take several different approaches, depending on the epizootiology of the specific disease. One approach is to reduce the risk of initiating a die-off. Several general strategies for this include manipulation of the environment to produce conditions that are unfavorable to the disease agent, disinfection of disease hotspots, control of bird populations and immunization to reduce the number of susceptible birds. Model simulations indicate that moderate reductions (less than or equal to 50 percent) in mortality rates from lead poisoning, avian cholera or avian botulism are potentially beneficial to mallard population growth. Development of management strategies to achieve these results require research to identify critical factors in the epizootiology of avian cholera and avian botulism.

A second approach to control of disease is to reduce (or manage) mortality after the onset of an outbreak. This is the current method for management of waterfowl diseases and will probably continue because potentially beneficial action is better than doing nothing, and visible action demonstrates good intentions (Peterson 1991). Control actions usually are monitoring and early detection of mortality, carcass collection, water manipulation, and control of bird movement. Results from the model simulations indicated that, if present management has reduced avian botulism and avian cholera mortality by 2 times, these activities could have a noticeable benefit for mallard population levels. However, further research to develop alternatives and evaluate present management is needed.

The primary approach to control of lead shot ingestion and poisoning has been a nationwide conversion to nontoxic (steel) shot, beginning in 1991. Conversion to steel shot can increase the number of waterfowl with ingested steel and presumably decrease the number with lead shot (Calle et al. 1982, DeStefano et al. 1991). However, spent shot on some areas will remain in the environment and continue to be consumed by waterfowl (Mauser et al. 1990, DeStefano et al. 1991). Furthermore, poor compliance with nontoxic shot regulations (Simpson 1989) and continued use of lead shot in Canada (e.g., DeStefano et al. 1991, Schwab and Daury 1989) will provide new sources of lead shot. Habitat manipulations (Sanderson and Bellrose 1986) may be required to reduce the availability of lead shot in selected areas. Model simulations indicated that a 50–75 percent reduction in lead poisoning potentially benefitted mallard population growth. Concurrent reductions in lead exposure also increased mean body mass. An increased body mass of waterfowl is believed to result in increased survival (Haramis et al. 1986, Hepp et al. 1986) and earlier molt

(Pehrsson 1987). In contrast, continued lead ingestion will have negative physiological (Anderson and Havera 1985) and immunological (Rocke and Samuel 1991) effects on waterfowl.

Management to reduce the risk of disease outbreaks or control mortality in mallards will undoubtedly have many positive benefits on other wild bird species. In addition to mallard populations, many other waterfowl, nongame and endangered species are susceptible to avian botulism, avian cholera and lead poisoning. Waterfowl, shorebirds and some mammals commonly are affected by type C botulism (Locke and Friend 1987). Avian cholera naturally infects over 100 wild avian species, and most bird species are probably susceptible (Botzler 1991). As wild waterfowl become increasingly concentrated on a limited habitat base, infectious diseases, such as avian cholera, become an ever greater concern for waterfowl managers. Dabbling ducks, especially the mallard and pintail (*Anas acuta*), have been the primary victims of lead poisoning, although diving ducks, geese and swans also have suffered significant mortality. Furthermore, eagles frequently die from lead poisoning after ingesting lead shot embedded in the flesh of their prey (Friend 1987a).

Our modelling has several important limitations that must be emphasized. Our estimates of mortality from disease (especially avian cholera and avian botulism) are, at best, preliminary. Biases in the magnitude of these estimates could have important implications for our conclusions about the potential population effects of reductions in these mortality sources. In particular, our estimates of avian cholera mortality may be excessive, and represent a worst-case scenario in which a substantial proportion of the mid-continent mallard population is at risk during aivan cholera outbreaks. Modelling results of avian botulism also may represent above average years of botulism outbreaks. Because of these limitations, our results should not be used to represent the average effects of disease on the mid-continent mallard population. Further research and data collection are necessary to validate or improve these mortality estimates. Nor should the present model be viewed as encompassing all diseases of mallard populations. To a limited extent, other diseases also are represented in the estimates associated with avian cholera and botulism. This situation is inevitable because determination of the cause of mortality of all individuals in a die-off is not practical. Whereas other diseases are probably of lesser importance, their potential effect on mortality and population growth in mallards may have been underestimated.

Finally, the role of disease is part of a complex web involving many other ecological factors. In addition to causing direct mortality, diseases may increase the risk of other mortality factors, including hunting and predation (Johnson et al. 1987). The Mallard Annual Cycle Model does not consider such relationships among the various mortality sources. This is an important limitation that results from the paucity of available data on the nature of compensatory mortality in mallards, the specific functional relations between different mortality factors and the importance of density dependence in disease mortality. If density dependence occurs for disease or other mortality sources, our model simulations could exaggerate the benefits of reducing disease loss on mallard population growth. Evidence to support the concept of compensatory hunting mortality for female mallards is presently inconclusive (Burnham et al. 1984), but may be partially compensatory (Johnson et al. 1987). Conroy and Krementz (1990) indicated that predicted relationships between nonhunting mortality and hunting mortality, or population density for the additive or compensatory mortality hypotheses have not been tested. They recommended that experimental management to evaluate hunting mortality (e.g., Anderson et al. 1987) also examine the relationships among harvest, nonhunting mortality and population density. We believe that experimental programs to evaluate the effect of hunting also should consider the importance of different sources of nonhunting mortality (e.g., disease, predation and weather), the density dependent nature of these factors, and identification of factors that can be managed to enhance mallard and other waterfowl populations.

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References

Anderson, D. R. 1975. Population ecology of the mallard. V. Temporal and geographic estimates of survival, recovery, and harvest rates. U.S. Fish and Wildl. Serv. Resour. Publ. 125. Washington, D.C. 110 pp.

Anderson, D. R., K. P. Burnham, J. D. Nichols, and M. J. Conroy. 1987. The need for experiments to understand population dynamics of American black ducks. Wildl. Soc. Bull. 15:282–284.

Anderson, W. L. and S. P. Havera. 1985. Blood lead, protoporphyrin, and ingested shot for detecting lead poisoning in waterfowl. Wildl. Soc. Bull. 13:26–31.

Ankney, D. and D. Dennis. 1982. Determination of presence of lead in samples of waterfowl blood. Final Rept. Canadian Wildl. Serv. Rept. Contract Number OSU81–00280. Ottawa. 5 pp.

Bellrose, F. C. 1959. Lead poisoning as a mortality factor in waterfowl populations. Illinois Nat. Hist. Survey Bull. 27:235–288.

———. 1976. Ducks, geese and swans of North America. Stackpole Books. Harrisburg, PA. 544 pp.

Botzler, R. G. 1991. Epizootiology of avian cholera in wildfowl. J. Wildl. Dis. 27:367–395.

Brand, C. J. 1984. Avian cholera in the Central and Mississippi flyways during 1979–80. J. Wildl. Manage. 48:399–406.

Burnhan, K. P., G. C. White, and D. R. Anderson. 1984. Estimating the effect of hunting on annual survival rates of adult mallards. J. Wildl. Manage. 48:350–361.

Calle, P. P., D. F. Kowalczyk, F. J. Dein, and F. E. Hartman. 1982. Effect of hunters' switch from lead to steel shot on potential for oral lead poisoning in ducks. J. Am. Vet. Med. Assoc. 181:1,299–1,301.

Conroy, M. J. and D. G. Krementz. 1990. A review of the evidence for the effects of hunting on American black duck populations. Trans. N. Am. Wildl. and Nat. Resour. Conf. 55:501–517.

Cowardin, L. M. and D. H. Johnson. 1979. Mathematics and mallard management. J. Wildl. Manage. 43:18–35.

DeStefano, S. 1989. Ecological relationships of lead exposure in Canada geese of the Eastern Prairie population. Ph.D. thesis, Wildlife Resources, Moscow, ID. 97 pp.

DeStefano, S., C. J. Brand, D. H. Rusch, D. L. Finley, and M. M. Gillespie. 1991. Lead exposure in Canada geese of the Eastern Prairie population. Wildl. Soc. Bull. 19:23–32.

Duncan, R. M. and W. I. Jensen. 1976. A relationship between avian carcasses and living invertebrates in the epizootiology of avian botulism. J. Wildl. Dis. 12:116–126.

Friend, M. 1985. Interpretation of criteria commonly used to determine lead poisoning problem areas. U.S. Fish and Wildl. Serv., Fish and Wildl. Leaflet No. 2. Washington, D.C. 4 pp.

———. 1987a. Lead poisoning. Pages 175–189 *in* M. Friend and C. J. Laitman, eds., Field guide to wildlife disease. Vol. 1. General field procedures and diseases of migratory birds. U.S. Fish and Wildl. Serv. Resour. Publ. 167. Washington, D.C. 225 pp.

———. 1987b. Avian cholera. Pages 69–82 *in* M. Friend and C. J. Laitman, eds., Field guide to wildlife disease. Vol. 1. General field procedures and diseases of migratory birds. U.S. Fish and Wildl. Serv. Resour. Publ. 167. Washington, D.C. 225 pp.

Giltner, L. T. and J. F. Couch. 1930. Western duck sickness and botulism. Science 72:660.

Haramis, G. M., J. D. Nichols, K. H. Pollock, and J. E. Hines. 1986. The relationship between body mass and survival of wintering canvasbacks. Auk 103:506–514.

Hepp, G. R., R. J. Blohm, R. E. Reynolds, J. E. Hines, and J. D. Nichols. 1986. Physiological condition of autumn-banded mallards and its relationship to hunting vulnerability. J. Wildl. Manage. 50:177–183.

Heisey, D. M. and T. K. Fuller. 1985. Evaluation of survival and cause-specific mortality rates using telemetry data. J. Wildl. Manage. 49:668–674.

Humburg, D. D., D. Graber, S. Sheriff, and T. Miller. 1983. Estimating autumn-spring waterfowl nonhunting mortality in north Missouri. Trans. N. Am. Wildl. and Nat. Resour. Conf. 48:241–256.

Jensen, W. I. and J. P. Allen. 1960. A possible relationship between aquatic invertebrates and avian botulism. Trans. N. Am. Wildl. and Nat. Resour. Conf. 25:171–180.

Jensen, W. I. and J. I. Price. 1987. The global importance of type C botulism in wild birds. Pages 33–54 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Publ. Springfield, IL. 405 pp.

Johnson, D. H. 1979. Estimating nest success: The Mayfield method and an alternative. Auk 96:651–661.

Johnson, D. H., J. D. Nichols, M. J. Conroy, and L. M. Cowardin. 1987. Some considerations in modeling the mallard life cycle. Pages 9–20 *in* M. W. Weller, ed., Waterfowl in winter. Univ. Minnesota Press, Minneapolis. 624 pp.

Kalmbach, E. R. and M. F. Gunderson. 1934. Western duck sickness: A form of botulism. U.S. Dept. Agric. Tech. Bull. 411. 81 pp.

Koford, R. R., J. R. Sauer, D. H. Johnson, J. D. Nichols, and M. D. Samuel. 1992. A stochastic model of mid-continental mallards. Wildlife 2001: Populations. In press.

Locke, L. N. and M. Friend. 1987. Avian botulism. Pages 83–93 *in* M. Friend and C. J. Laitman, eds., Field guide to wildlife disease. Vol. 1. General field procedures and diseases of migratory birds. U.S. Fish and Wildl. Serv. Resour. Publ. 167. Washington, D.C. 225 pp.

Mauser, D. M., T. E. Rocke, J. G. Mensik, and C. J. Brand. 1990. Blood lead concentrations in mallards from Delevan and Colusa National Wildlife Refuges. California Fish and Game 76:132–136.

Parrish, J. M. and B. F. Hunter. 1969. Waterfowl botulism in the Southern San Joaquin Valley, 1967–68. California Fish and Game 55:265–272.

Pehrsson, O. 1987. Effects of body condition on molting in mallards. Condor 89:329–339.

Peterson, M. J. 1991. Wildlife parasitism, science, and management policy. J. Wildl. Manage. 55:782–789.

Petrides, G. A. and C. R. Bryant. 1951. An analysis of the 1949–50 fowl cholera epizootic in Texas Panhandle waterfowl. Trans. N. Am. Wildl. and Resour. Conf. 16:193–216.

Quortrup, E. R., F. B. Queen, and L. J. Menovka. 1946. An outbreak of pasteurellosis in wild ducks. J. Am. Vet. Med. Assoc. 108:94–100.

Reed, T. M. and T. E. Rocke. 1992. The role of avian carcasses in botulism epizootics. Wildl. Soc. Bull. In press.

Rocke, T. E. and M. D. Samuel. 1991. Effects of lead shot ingestion on selected cells of the mallard immune system. J. Wildl. Dis. 27:1–9.

Rosen, M. N. 1971a. Botulism. Pages 100–117 *in* J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds., Infectious and parasitic diseases of wild birds. Iowa St. Univ. Press, Ames. 344 pp.

———. 1971b. Avian cholera. Pages 59–74 *in* J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds., Infectious and parasitic diseases of wild birds. Iowa St. Univ. Press, Ames. 344 pp.

Sanderson, G. C. and F. C. Bellrose. 1986. A review of the problem of lead poisoning in waterfowl. Illinois Nat. Hist. Survey. Special Publ. 4. Champaign. 34 pp.

Schwab, F. E. and R. W. Daury. 1989. Incidence of ingested lead shot in Nova Scotia waterfowl. Wildl. Soc. Bull. 17:237–240.

Simpson, S. G. 1989. Compliance by waterfowl hunters with nontoxic shot regulations in central South Dakota. Wildl. Soc. Bull. 17:245–248.

Stout, I. J. and G. W. Cornwell. 1976. Nonhunting mortality of fledged North American waterfowl. J. Wildl. Manage. 40:681–693.
Stutzenbaker, C. D., K. Brown, and D. Lobpries. 1983. An assessment of the accuracy of documenting waterfowl die-offs in a Texas coastal marsh. Special Rept. Fed. Aid Proj. W-106-R, Texas Parks and Wildl. Dept., Austin. 21 pp.
U.S. Fish and Wildlife Service, Office of Migratory Bird Management. 1986. Use of lead shot for hunting migratory birds in the United States; Final Supplemental Environmental Impact Statement. Washington, D.C. 340 pp.
Vaught, R. W., H. C. McDougle, and H. H. Burgess. 1967. Fowl cholera in waterfowl at Squaw Creek National Wildlife Refuge, Missouri. J. Wildl. Manage. 31:248–253.
Windingstad, R. M., J. J. Hurt, A. K. Trout, and J. Cary. 1984. Avian cholera in Nebraska's Rainwater Basin. Trans. N. Am. Wildl. and Nat. Resour. Conf. 49:576–583.
Windingstad, R. M., S. M. Kerr, R. M. Duncan, and C. J. Brand. 1988. Characterization of an avian cholera epizootic in wild birds in western Nebraska. Avian Dis. 32:124–131.
Windingstad, R. M., M. D. Samuel, D. Thornburg, and L. C. Glaser. In press. Summary of avian cholera mortality in Mississippi flyway Canada geese. International Canada Goose Symp. April, 1991.
Wobeser, G. A. 1981. Diseases of wild waterfowl. Plenum Press, NY. 300 pp.
———. 1987. Control of botulism in wild birds. Pages 339–348 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Publ. Springfield, IL. 405 pp.
Zinkl, J. G., N. Dey, J. M. Hyland, J. J. Hurt, and K. L. Heddleston. 1977. An epornitic of avian cholera in waterfowl and common crows in Phelps County, Nebraska, in the spring, 1975. J. Wildl. Dis. 13:194–198.
Zwank, P. J., V. L. Wright, P. M. Shealy, and J. D. Newsom. 1985. Lead toxicosis in waterfowl on two major wintering areas in Louisiana. Wildl. Soc. Bull. 13:17–26.

History and Progress in the Study of Hemorrhagic Disease of Deer

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Introduction

Hemorrhagic disease (HD) of deer and other wild ruminants of North America is a term that applies to infection by either of two orbiviruses, epizootic hemorrhagic disease (EHD) virus or bluetongue (BT) virus. These two viruses can be difficult to isolate from field cases, and, for this reason, the generic diagnosis of HD often is used because of the many clinical and epidemiologic similarities between EHD and BT virus infections. Both agents are biologically vectored by biting midges, *Culicoides* spp., and have been responsible for sudden episodes of mortality, particularly in white-tailed deer (*Odocoileus virginianus*). Several excellent reviews are available on this disease entity (*see* Hoff and Hoff 1976, Hoff and Trainer 1978, 1981, Thomas 1981, Gibbs and Greiner 1988). The purpose of this presentation is to chronologically review the history of HD in white-tailed deer and other wild ruminants, in order to put current concepts about HD in perspective and to identify information gaps for this important deer disease syndrome.

Pre-enlightened History

Prior to the discovery that viral agents were responsible for the HD syndrome, there are several accounts of deer mortality that probably should be attributed to EHD or BT viruses. Among the first reports was the observation of dead white-tailed deer along a 100-mile stretch of the Missouri River during the summer of 1901 (Schultz 1979). Features of this mortality included a differential mortality rate for white-tailed deer versus mule deer (*Odocoileus hemionus*), discovery of dead deer near water, and the disappearance of disease after frost. Schulz (1979) reported a similar die-off in 1886.

Shope (1967) and Trainer (1964) provided references for early accounts of deer mortality in Alabama (1949), Kentucky (1949), Missouri (1952–1956), Nebraska (1956), North Carolina (1908–1912, 1930, 1949), Tennessee (1932, 1945), South Dakota (1952) and Washington (1946, 1953). Notable among these were the description of "black tongue" disease in deer (Ruff 1950, Alexander 1954). This terminology is still in use among hunters in the Southeast in conjunction with HD epizootics. Hoof lesions, characteristic of chronic HD, were seen in Alabama in 1935 (Morton 1935). "Foot rot" in mule deer was reported to cause substantial mortality during the 1950s in California, during ongoing BT virus problems in domestic sheep (Rosen et al. 1951, Jessup 1985). An unidentified deer pathogen, termed "Killer X," was reported in the Southeast during the summer/fall periods of 1949 and 1954 (Hayes and Prestwood 1969), and Nebraska had epizootics annually from 1952–1957 (Schildman and Hurt 1984). Fay et al. (1956) reported a die-off of 50 deer in Michigan in 1953. The cause for all of the above mortality events will remain speculative, however, G. Spencer reported to Shope et al. (1960) that the disease observed in Washington in 1946 and 1953 was transmissible from deer to deer via subinoculation of blood.

Chronology of Events

1955

The landmark discovery of EHD virus in white-tailed deer was made by Shope et al. (1955, 1960) during their investigation of a deer die-off in New Jersey. The outbreak started in early August and killed an estimated 500 to 700 deer in three counties. A filterable virus was isolated from affected deer that was transmissible via inoculation to susceptible white-tailed deer. Concurrent with the EHD die-off in New Jersey, a similar outbreak occurred in 10 counties in the Lower Peninsula of Michigan (Fay et al. 1956). One hundred and twelve dead white-tailed deer were confirmed, and a filterable agent was obtained that would reproduce the disease in penned deer. Infection was attempted in a variety of other wild and domestic animals without success (Fay et al. 1956, Shope et al. 1960).

A die-off of white-tailed deer and mule deer (*Odocoileus hemionus*) also occurred in North Dakota, during the spring and summer of 1955. The disease was transmitted experimentally to penned white-tailed deer and pronghorn (*Antilocapra americana*), and from a sick steer to a white-tailed deer. The etiologic agent was not isolated or characterized, and although some of the clinical features of this disease entity resembled HD, the diagnosis given was mucosal disease (Richards et al. 1956).

1956

An EHD virus was isolated from white-tailed deer during a die-off in the late summer/early fall of 1956 in South Dakota (Pirtle and Layton 1961). This virus was termed the "South Dakota" strain and was reported to be pathogenic for white-tailed deer but not mule deer. Shope et al. (1960) conducted comparative studies with the 1955 New Jersey EHD virus isolate and the South Dakota isolate. These two agents produced a similar clinical disease in white-tailed deer; however, the isolates differed on an immunologic basis. Karstad et al. (1961) determined that the 1955 Michigan EHD virus isolate was identical or closely related to the South Dakota strain by immune serum neutralization preceding viral inoculation in white-tailed deer. Unfortunately, the Michigan and South Dakota isolates appear to have been lost.

1959

Post (1960) and Thorne et al. (1982) reported HD in white-tailed deer in Weston County, Wyoming.

1961

Epizootic hemorrhagic disease virus, presumably the "South Dakota" strain, was isolated from mule deer involved in deer mortality in North and South Dakota (Trainer 1964). An HD epizootic was reported in white-tailed deer in Montana (Swenson 1979, Feldner and Smith 1981).

1962

An EHD epizootic occurred in southern Alberta during the summer that killed approximately 450 white-tailed deer, 20 mule deer and 15 pronghorn (Chalmers et al. 1964). Concurrent EHD outbreaks in multiple species occurred in North Dakota (Richards 1964, 1972) and South Dakota (Trainer 1964), and HD activity was noted in Montana (Feldner and Smith 1981) and Wyoming (Chalmers et al. 1964). Crude transmission studies were done with the Alberta isolate by Chalmers et al. (1964), and more detailed work was done with this virus by Ditchfield et al. (1964). Although Ditchfield et al. concluded that the Alberta 1962 EHD virus was serologically identical to the New Jersey strain, later study led to the New Jersey isolate being designated EHD virus serotype 1 (EHDV–1) and the Alberta isolate as EHD virus serotype 2 (EHDV–2) (Barber and Jochim 1975).

1963

Epizootic hemorrhagic disease virus was isolated from white-tailed deer involved in a four-county epizootic in Nebraska (Schildman and Hurt 1984).

1965

Hemorrhagic disease was diagnosed in Weston County, Wyoming, in white-tailed deer (Howe 1966, Thorne et al. 1982).

1966

The first wildlife diagnosis of BT virus occurred in Texas, in both white-tailed deer and desert bighorn sheep (*Ovis canadensis*) (Robinson et al. 1967, Stair et al. 1968, Marburger 1983). The outbreak in deer occurred in a research facility at College Station, Texas, and 8 of 23 deer were affected. Bluetongue virus infection was diagnosed by a fluorescent antibody test. A striking similarity was noted in the gross and microscopic lesions caused by BT virus to those of EHD virus (Stair et al. 1968). Convalescent cases with chronic hoof lesions were observed.

Slightly preceding the diagnosis in white-tailed deer, BT virus infection was diagnosed in desert bighorn sheep (Robinson et al. 1967, Marburger 1983). Subinoculation of a lung tissue preparation from a sick bighorn produced illness in domestic sheep, and convalescent serum from these sheep was protective against BT virus in cell cultures. This outbreak of BT virus was attributed to have caused the decimation of the desert bighorn sheep population on the Black Gap Wildlife Management Area (Marburger 1983).

1967

An outbreak of EHD virus occurred in eastern Washington in which 227 dead deer were reported. Both white-tailed and mule deer were affected (Fosberg et al. 1977). Neutralization tests with the 1967 Washington EHD virus isolate did not show a strain difference when EHDV–1 and EHDV–2 antiserum were used. The virus obtained from the field was used to experimentally infect Columbian black-tailed deer (*Odocoileus hemionus columbianus*). Clinical disease was not produced in black-tailed deer; however, two white-tailed deer infected simultaneously died with classic lesions (Stauber et al. 1977).

1969

Bluetongue virus was isolated from a sentinel white-tailed deer fawn that died on the Welder Wildlife Refuge, San Patricio County, Texas (Hoff et al. 1974).

1970

An EHD epizootic was diagnosed in North Dakota that killed an estimated 1,950 white-tailed deer, plus a few pronghorn and mule deer. This outbreak was in the same area of the Little Missouri River as the one in 1962 (Hoff et al. 1973, Richards 1972). Both outbreaks were associated with long periods of hot, dry weather conditions preceding the mortality. Swenson (1979) and Feldner and Smith (1981) noted the presence of HD in eastern Montana that year.

1971

A region-wide epizootic of HD was observed in white-tailed deer in the southeastern United States (Fox and Pelton 1973, Prestwood et al. 1974, Roughton 1975). Twenty-three counties in seven states—Florida, Georgia, Kentucky, North Carolina, South Carolina, Tennessee and Virginia—were affected, and heavy losses were incurred in localized areas in Florida, Kentucky, Tennessee and Virginia. Epizootic hemorrhagic disease was isolated from deer in Kentucky and North Carolina, and BT virus was recovered from Georgia, Kentucky, North Carolina and Tennessee. Both viruses were isolated from a single deer in Kentucky (Thomas et al. 1974). Epizootic hemorrhagic disease virus was recovered from *Culicoides variipennis* at the outbreak site in Kentucky (Jones et al. 1977). The Kentucky EHD virus isolate was later used to transmit disease among white-tailed deer via *C. variipennis* (Foster et al. 1977).

An HD outbreak of lesser severity, that was assumed to be EHD, was seen in North Dakota (Hoff et al. 1973). Serologic monitoring of the 1971–1972 outbreak area in North Dakota revealed an increase in EHD virus antibody incidence in mule deer and a decrease in white-tailed deer. Eastern Montana also experienced HD mortality in white-tailed deer (Swenson 1979, Feldner and Smith 1981).

1972

Gross necropsy lesions attributed to HD were observed in white-tailed deer from Florida and North Carolina (Couvillion et al. 1981).

1973

Hemorrhagic disease was reported from five counties in Georgia, three counties in Tennessee and one county in North Carolina (Couvillion et al. 1981). Kistner (1975) recorded a die-off of black-tailed deer, mule deer and pronghorn antelope in Oregon that was attributed to BT virus. The BT virus from the deer was not serotyped, but concurrent isolates from sheep and cattle were BT virus serotype 11(Barber and Jochim 1975).

1974

Couvillion et al. (1981) reported HD in white-tailed deer from a single county in each of four states, Alabama, Georgia, North Carolina and Virginia. Subinoculation of tissue extracts from a Chesterfield County, Virginia, deer produced typical disease in pen-raised deer, but virus was not isolated. Penned bighorn sheep succumbed to BT virus in northern California (Kistner 1975). White-tailed deer mortality occurred in August and September in Gratiot and Iosco counties, Michigan. Gross lesions were compatible with HD, and EHD virus was isolated from one deer (J. N. Stuht personal communication: 1980). Deer Losses were reported in Nebraska (Schildman and Hurt 1984).

1975

Hemorrhagic disease cases were seen in several southeastern states. Couvillion et al. (1981) reported deer mortality in six counties in southeastern Arkansas. Losses in Arkansas were estimated between 10 to 33 percent (L. Davis personal communication: 1975). Necropsy cases also were seen in Florida, Georgia and South Carolina. A deer die-off occurred in Bolivar County, Mississippi, which is adjacent to the affected area in Arkansas (H. A. Jacobson personal communication: 1981).

Approximately 1,000 white-tailed deer died due to EHD virus in New Jersey, with most of the losses in the Northwest part of that state (McConnell et al. 1977). Chronic hoof lesions were noted in animals harvested during hunting season later that year. Epizootic hemorrhagic disease virus was isolated from one bovine from the affected area (U.S. Department of Agriculture [USDA] 1976).

Reference was made to an EHDV–2 epizootic in a private herd in Indiana (Feldner and Smith 1981), and HD was reported in Nebraska (Schildman and Hurt 1984).

1976

Hemorrhagic disease cases were diagnosed by necropsy of individual animals from 10 counties in Georgia and 2 counties in South Carolina (Couvillion et al. 1981). Missouri also had an HD outbreak in 1976 (Brannian et al. 1983).

At least 3,200 pronghorn died during a BT virus epizootic in eastern Wyoming (Thorne et al. 1982, 1988). BT virus serotype 17 was recovered. The reproductive rate was depressed following this outbreak. Substantial mule deer losses also were reported (Thorne et al. 1982). An epizootic of HD was reported in McCone and Powder River counties of Montana, during 1976 (Swenson 1979, Feldner and Smith 1981). Loss of 10 to 50 percent of white-tailed deer populations was attributed to HD in Nebraska (Schildman and Hurt 1984). South Dakota had substantial deer mortality in the southern portion of the state and losses were estimated at 40 percent of the deer (L. Rice personal communication: 1992).

1977

Deer mortality with HD lesions occurred in Bolivar, Holmes and Washington counties, Mississippi. Bluetongue virus serotype 17 was demonstrated by a fluorescent antibody cell culture technique from the spleen of one white-tailed deer from Bolivar County (H. A. Jacobson personal communication: 1981). Couvillion et al. (1981) reported necropsy diagnoses of HD in white-tailed deer from three counties in South Carolina and one county in Georgia. Mortality occurred in white-tailed deer in Dawson and Richland counties, Montana, that was attributed to HD (Swenson 1979, Feldner and Smith 1981). Although one-third of the population died, the mortality did not appear to be density dependent (Swenson 1979). Bluetongue virus serotype 17 was isolated from a normal tule elk (*Cervus elaphus nannodes*) from Inyo County, California (Jessup 1985).

1978

Epizootic hemorrhagic disease virus-2 was isolated from a white-tailed deer with HD from eastern Montana (Feldner and Smith 1981). The seropositivity rate for EHD virus antibody was substantially higher for mule deer (73 percent) and cattle (79 percent) versus white-tailed deer (5 percent) in the outbreak area.

Bluetongue virus serotype 10 was isolated from normal pronghorn and tule elk in California (Jessup 1985). White-tailed deer with HD lesions were seen in 11 counties in Georgia, 2 counties in South Carolina and 2 counties in Tennessee (Couvillion et al. 1981).

1979

A serotype 17 BT virus was recovered from one of seven white-tailed deer collected in Noxubee County Mississippi, in June. Subsequent monitoring of hunter-harvested deer in January, 1978, revealed 5 percent of the animals had sloughed hooves (H. A. Jacobson personal communication: 1981). Necropsy examinations revealed HD lesions in deer from three counties in Georgia and one county in South Carolina (Couvillion et al. 1981). In California, BT virus serotype 17 was isolated from a normal pronghorn, and five isolates of BT virus serotype 13 and one isolate of serotype 11 were made from normal tule elk (Jessup 1985).

1980

A widespread outbreak of HD occurred in the southeastern United States that involved 156 counties in eight states—Alabama, Florida, Georgia, Mississippi, Missouri, North Carolina, South Carolina and Virginia (Couvillion et al. 1981). Losses of white-tailed deer were particularly heavy in Missouri (Brannian et al. 1983) and North Carolina (Earley 1982). Epizootic hemorrhagic disease virus was isolated in Georgia, Maryland, Missouri and Virginia (Couvillion et al. 1981, Brannian et al. 1983). Epizootic hemorrhagic disease viruses also were isolated from white-tailed deer in Illinois and Nebraska (J. E. Pearson personal communication: 1981, Schildman and Hurt 1984).

1981

Jessup (1985) isolated serotype 11 BT virus from two mule deer in Kern County, California, that were being monitored as sentinel animals; a serotype 10 BT virus was obtained from a hunter-harvested mule deer on the same area. Jessup also recovered EHDV–1 from a normal black-tailed deer from Lake County, in March, 1981. Mule deer mortality was seen in Marin and Sonoma counties that was attributed to HD.

A virologic survey in Oklahoma white-tailed deer yielded two BT viruses from asymptomatic animals (Kocan et al. 1982).

A regional surveillance questionnaire conducted by the Southeastern Cooperative Wildlife Disease Study (SCWDS) revealed substantial HD activity in the Southeast. Evidence of HD was reported in 112 counties in 14 states (Table 1). Epizootic hemorrhagic disease virus-2 was isolated from white-tailed deer involved in die-offs in Maryland and West Virginia (SCWDS unpublished data: 1981).

Table 1. Reports of hemorrhagic disease (HD) activity in wild ruminants as indicated by an annual surveillance questionnaire (SCWDS unpublished data: 1990).

State	Number of counties per year										
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Alabama	4	12*	8	9*	5	22*	7*	6	21*	11*	20*
Arkansas	0	34*	3*	1	5	8*	3	4	7*	6*	1
California	1*	1*	2*	2*	5*	4*	11*	4*	1*	3*	2*
Colorado	0	0	0	0	2*	0	0	0	0	0	0
Florida	2*	5*	19*	2	13*	8	14	12*	10	5	12
Georgia	58*	18*	53*	7	4	39*	18*	7	60*	12	33*
Idaho	0	0	0	0	0	0	0	0	0	0	1*
Illinois	0	0	0	1	0	0	0	3*	0	0	0
Indiana	0	0	0	0	0	2*	0	3*	0	0	0
Iowa	0	0	0	0	0	0	2*	3*	3*	3*	1
Kansas	0	0	3*	0	0	0	2	0	9*	0	0
Kentucky	1*	8*	0	1*	5	8*	2	13*	18*	2*	6*
Louisiana	0	4*	6*	6	0	10	14*	4*	6*	22*	7*
Maryland	1*	2*	1	0	0	0	0	0	8*	0	0
Mississippi	12	8	4	9	7	50*	9	10	13*	48*	1
Missouri	40*	0	0	0	2*	0	0	0	71*	1*	0
Montana	0	0	0	1*	8*	2*	0	20*	1*	3*	4*
North Carolina	20*	0	3	0	0	2*	4	0	38*	0	7*
North Dakota	0	0	0	0	0	0	0	12*	3*	1*	0
Nebraska	0	0	0	27*	5*	1*	1*	34*	36*	28*	3*
Oklahoma	2*	2*	1	0	1	0	1	1	1	1*	1
Oregon	0	0	0	0	0	1*	2*	3*	3*	7*	3*
South Carolina	34*	4*	20*	3	2*	5	13*	5	15*	3	4
South Dakota	0	0	0	0	2*	0	5*	12*	15*	22*	9*
Tennessee	0	5*	1*	1	1	2*	0	2*	12*	2*	0
Texas	0	3	0	1	0	5	1*	0	0	2	1
Utah	0	0	0	0	0	0	1*	0	2*	1*	1*
Virginia	5*	2*	0	0	2	0	20*	0	19*	6*	5*
Washington	0	0	0	0	0	0	0	5*	0	0	0
West Virginia	0	5*	0	0	0	0	0	0	6*	0	0
Wisconsin	0	0	0	0	0	1	0	0	0	0	0
Wyoming	0	0	0	0	3*	0	0	0	3*	2*	0

*Reports of mortality, a necropsy diagnosis, or a virus isolation; in other years only chronic cases were observed.

1982

California had black-tailed deer mortality in Marin and Sonoma counties attributed to HD (Jessup 1985). The SCWDS surveillance questionnaire, which was expanded from regional to nationwide, produced reports of HD activity in 123 counties in 13 states (Table 1). Most of the reports of HD activity involved chronic lesions in hunter-killed deer. Virus isolations were made in association with deer mortality in Baker County, Georgia, where BT virus serotype 11 was isolated. A BT virus also was isolated from a white-tailed deer from Blount County, Tennessee, that had clinical disease (Wathen and New 1989).

1983

Black-tailed deer mortality attributed to HD was reported in Marin and Sonoma counties, California (Jessup 1985). Bluetongue virus serotypes 11 and 17 and EHDV–1 were isolated from free-ranging or captive bighorn sheep lambs with pneumonia from Riverside County (Jessup 1985).

The SCWDS HD surveillance questionnaire produced reports of disease activity in 69 counties in 13 states (Table 1). The outbreak in Nebraska involved an estimated 52 to 92 deer, all but 3 of which were white-tailed deer. Mortality was widespread in occurrence, but was reported in a short length of time, September 15 to October 22 (G. Schildman personal communication: 1983).

Virus isolation procedures on blood from normal white-tailed deer yielded eight isolates of serotype 11 BT virus (Kocan et al. 1987). These deer were collected during July and August.

1984

Evidence of HD activity was observed in 71 counties in 17 states (Table 1) (SCWDS unpublished data: 1984). California had death losses in Butte, Plumas and Tehama counties (D. A. Jessup personal communication: 1984). Small die-offs evidenced by 12 dead deer were reported in Sedgewick and Phillips counties, Colorado (W. Adrian personal communication: 1984), and 15 dead deer in Atchinson County, Missouri, (N. Giessman personal communication: 1984). Necropsy examination of deer from eight counties in Montana revealed lesions of HD (K. C. Walcheck personal communication: 1984). Death losses and necropsy lesions were seen in five counties in Nebraska (R. Gersib personal communication: 1984).

A major epizootic of serotype 17 BT virus was reported in pronghorn in Wyoming (Thorne et al. 1988). Two hundred and eighty-eight pronghorn, 83 mule deer and 13 white-tailed deer carcasses were found, and the mortality estimate for pronghorn was 600 to 1,000 animals. Deer mortality was believed to be less than 1 percent. An EHDV–2 was isolated from a sick deer in Brule County, South Dakota (H. Shave personal communication: 1984).

1985

During 1985, reports of HD activity were received from 171 counties in 17 states (Table 1).

1986

The HD surveillance questionnaire indicated that 130 counties in 19 states had disease activity (Table 1). A major epizootic occurred in a five-county area in Northern California in black-tailed deer, where an estimated 5,000–8,000 animals died. Serotype 10 BT virus was isolated from a clinical case (Jessup et al. 1989). Unexplained mortality during late summer/early fall was observed in deer in five counties in South Dakota (L. Rice personal communication: 1986). Deer with hoof lesions were commonplace in Florida, Georgia, Louisiana, Mississippi, South Carolina and Virginia.

1987

Hemorrhagic disease activity was reported in 162 counties in 19 states (Table 1). Epizootic hemorrhagic disease virus-2 was isolated from deer in Indiana, Kentucky, North Dakota, Nebraska, South Dakota and Washington, (Osburn and Miller 1988, Nettles et al. 1992). In addition, EHDV–1 was isolated in Washington.

California had a second HD epizootic in black-tailed deer in Lake County that killed about 1,000 animals (Jessup et al. 1989). Adjacent areas in Kentucky and Indiana had moderate mortality (less than 100 deer each) due to EHDV–2 (J. Phillips personal communication: 1987, L. Reynolds-Pruitt personal communication: 1987). Montana had an HD epizootic that was considered to be the "most serious," when compared to other years (K. C. Walcheck personal communication: 1987). Nebraska received 89 reports involving 138 sick or dead white-tailed deer (R. Stutheit personal communication: 1987). Many counties had deer with chronic hoof lesions following this episode. Widespread mortality was reported from North and South Dakota; however, the losses in South Dakota were considered minor (L. Rice quoted in May 1985 "Newsletter of the American Association of Wildlife Veterinarians").

Washington had confirmed deer losses of 138 animals in six counties (D. J. Pierce personal communication: 1987). Extremely dry weather preceded the outbreak. In the Okanagan Valley of British Columbia, a region adjacent to the outbreak area in Washington, EHDV–2 was isolated from white-tailed deer, bighorn sheep, bison (*Bison bison*), elk, mountain goat (*Oreamnos americanus*) and cattle (Dulac et al. 1988). Illness was reported in deer and sheep.

1988

This was a peak year for HD, with 381 counties in 25 states reporting evidence of disease (Table 1). Epizootic hemorrhagic disease virus-2 was isolated from deer in Arkansas, Georgia, Illinois, Iowa, Kentucky, Maryland, Missouri, North Carolina, North Dakota, Virginia and West Virginia. In addition, BT virus was recovered from white-tailed deer in Illinois, South Carolina and South Dakota (Osburn and Miller 1988, 1989, Nettles et al. 1992). Serotypes for the Illinois and South Dakota BT viruses were 17 and 13, respectively. The South Carolina isolate was not typed but was noteworthy because the affected white-tailed deer had a vesicle in its mouth (SCWDS unpublished data: 1988).

Arkansas had reports of 167 dead deer in seven northern counties (M. E. Cartwright personal communication: 1988). Ninety-three dead deer were found in association with a confirmed EHDV–2 case in northern Georgia (K. E. Kammermeyer personal communication: 1988). Chronic hoof lesions were more prevalent in bucks than does in the post-outbreak hunter kill on Georgia wildlife management areas. There were sudden death losses in captive white-tailed deer in Oktibeeha County, Mississippi, that occurred concurrently with confirmed BT virus infection in nearby sheep (H. A. Jacobson personal communication: 1988). Missouri reported losses of 1,410 deer (L. Hanson personal communication: 1988). Nebraska had 90 reports of 140 sick or dead deer (R. Stutheit personal communication: 1988), and North Carolina had about 120 sick or dead animals (J. S. Osborne personal communication: 1988). Virginia reported over 25 dead deer from Bedford County where EHDV–2 was isolated (J. V. Gwynn personal communication: 1988); deer harvest was decreased 56 percent following the outbreak. Approximately 70 deer carcasses were associated with the EHDV–2 outbreak in West Virginia (T. Allen personal communication: 1988). Wyoming had deaths of white-tailed and mule deer in Platte County, and fluorescent antibody tests were positive for BT virus (E. S. Williams personal communication: 1988).

Chronic hoof lesions were predominant in Alabama, Florida, Georgia, Mississippi, Nebraska and Virginia.

1989

Relative to 1988, the reports of HD were fewer in 1989, with 194 counties in 23 states (Table 1). Epizootic hemorrhagic disease virus-1 was recovered from white-tailed deer in Alabama, Arkansas and Louisiana (Nettles et al. 1992). The Alabama isolate was from a single deer taken for scientific study in Montgomery County. Although this deer had lesions, clinical problems were not evident in the population. Chronic hoof lesions were observed in other areas of the state.

Approximately 50 dead deer were seen in Louisiana (J. W. Farrar personal communication: 1989). Mississippi had unexplained summer/fall mortality and/or deer with hoof lesions that were widespread in the southern two-thirds of the state (R. Griffin personal communication: 1989). There were mild losses of deer (less than 30) in five counties in Montana (K. Walcheck personal communication: 1989), and Nebraska had light mortality combined with widespread occurrence of chronic lesions (R. Stutheit personal communication: 1989). An isolation of EHD virus was reported from the Nebraska epizootic (Osburn and Miller 1989). Seven counties in Oregon had reports of dead deer, including body counts of 30 to more than 60 deer each for Gillian, Linn and Klamath counties (C. Wheaton personal communication: 1989). An estimated 250–500 dead deer were observed in South Dakota that were attributed to HD (L. Rice personal communication: 1989).

1990

Nationwide, this year had lessened HD activity, with 122 counties in 20 states (Table 1). The only virus isolations were EHDV–2 isolates from white-tailed deer from Clarke and Houston counties, Georgia (SCWDS unpublished data: 1990). The only large-scale epizootic reported was from South Dakota, where 586 dead deer were found in October and early November (L. Rice personal communication: 1990). Localized die-offs were reported in Kentucky, Montana, North Carolina, Oregon and Utah. Chronic hoof lesions were widespread in Alabama, Florida and Georgia.

The Study of HD

By state and year, there have been over 260 occurrences of HD activity reported in wild ruminants since EHD virus was discovered in 1955. Without doubt, HD is a major infectious disease of white-tailed deer, pronghorn, mule deer and black-tailed deer; and wildlife managers need better information to contend with this malady. The following discussion will focus on some important questions to wildlife management. An attempt will be made to provide pertinent information from past research, and suggestions will be given for future studies.

What Circumstances Create a Die-off?

The data in Table 1 provide evidence that HD mortality in wild ruminants is a sporadic event. Factors responsible for epizootics of mortality as opposed to non-clinical or undetected infections with HD viruses probably include currently undefined interrelationships among the following: (1) virus serotype, strain and dosage; (2) vector competency and abundance; and (3) host-related factors.

Type of virus, virus serotype, strain and dose. Very little information is available to compare pathogenicity among the two EHD and five BT virus serotypes present in North America. Shope et al. (1960) considered EHDV–1 more virulent than the "South Dakota" serotype; however, the infectivity of the inoculum given to the deer was not quantified. Inoculation of white-tailed deer with crude tissue suspensions containing EHD virus from Alberta, Kentucky, Michigan, Montana, New Jersey, South Dakota and Washington all have resulted in high mortality (Chalmers et al. 1964, Debbie and Abelseth 1971, Fay et al. 1956, Feldner and Smith 1981, Fosberg et al. 1977, Foster et al. 1977, Karstad et al. 1961, McConnell et al. 1977, Pirtle and Layton 1961, Shope et al. 1960, Stauber et al. 1977, Wilhelm and Trainer 1969). In domestic animals, differences in severity of disease among BT virus serotypes is considered "marked and unpredictable" (Schultz and Grieder 1987). Unquantified dosages of serotype 10 BT virus caused fatal infections in white-tailed deer also (Vosdingh et al. 1968, Hoff and Trainer 1972). Comparative challenge studies with known dosages of virus serotypes and strains would be helpful to determine if differences exist.

In white-tailed deer, quantified dosages of EHD virus have only been administered to two animals (Hoff and Trainer 1974). These authors also inoculated two white-tailed deer with known amounts of BT serotype 10 virus, and Howerth et al. (1988) infected 10 deer with known amounts of BT serotype 17 virus. Fatal infection was produced in one white-tailed deer with 10^3 $TCID_{50}$ of serotype 10 BT virus, but three deer given 10^4 $TCID_{50}$ did not die (Thomas and Trainer 1970). Quantified dosages of EHD and BT virus also have been given to elk (Hoff and Trainer 1973, Murray and Trainer 1970, and Stott et al. 1982), pronghorn (Hoff and Trainer 1972) and bighorn (Robinson et al. 1974). However, none of these trials were designed to determine dosage thresholds for infection versus clinical disease. Chronic hoof, rumen and oral lesions, although linked circumstantially with HD viruses, have not been produced by experimental infections.

Vector competency and abundance. The viral dose delivered by *Culicoides* may be an important factor in determining fatal infections, as opposed to infections followed by recovery with chronic lesions or no illness. The amount of virus presented to the animal is dependent upon both the concentration of virus delivered by the biting midge and the numbers of infected midges biting the animal. Artificially fed *C. variipennis* can increase EHD virus 1,000-fold to peak virus concentrations of 4.9 $\log_{10}$ $TCID_{50}$ per fly (Boorman and Gibbs 1973). Foster et al. (1977) found that as few as 20 infected *C. variipennis* could induce a fatal EHD virus infection in white-tailed deer; however, viral concentrations were not measured in these flies. Studies done with BT virus in *C. variipennis* have shown that a single fly can contain 10^5 to 10^6 $TCID_{50}$ and that the bite of one fly can transmit infection to a sheep (Mellor 1990). Thus, it would appear that relatively few flies would be required to start or maintain an epizootic. However, research has shown that strains of *C. variipennis* differ greatly in their vector competence for BT viruses. Some fly populations obtain a high rate of infection, while others cannot develop infections (Jones and Foster 1974, 1978).

The production of disease probably is influenced strongly by the numbers of attacking *Culicoides*, and that, in turn, probably is controlled by climatic/geographic factors. Several accounts of HD in deer mention that hot, dry weather preceded the die-off (Richards 1972, Hoff et al. 1973, Brannian et al. 1983, Jessup 1985); however, damp weather also has been associated with outbreaks (McConnell et al. 1977, Hoff and Trainer 1981). The former conditions may enhance transmission by concentrating hosts around damp areas, whereas the latter event could enhance *Culicoides* production when receding water causes an increase in muddy areas for breeding sites (Kline and Greiner 1985). Whichever circumstance applies, sudden "blooms" of *Culicoides* following periods devoid of midge activity may cause animals to be abruptly presented with high virus dosages.

Tropical and subtropical climatic zones are considered endemic for HD viruses because of the continual presence of viruses and vectors without clinical disease (Gibbs and Greiner 1988). In contrast, epidemics of clinical HD in wildlife are observed in more temperate climates. In a 10-year surveillance effort, deer mortality was the predominant observation in the temperate United States (84 percent), whereas chronic HD lesions were most frequent in seven southeastern states (79 percent) (SCWDS unpublished data: 1992).

Host-related factors. Deer that recover from infection with a specific serotype of EHD or BT virus appear to be resistant to reinfection with that serotype, but are susceptible to other serotypes (Shope et al. 1960, Pirtle and Layton 1961, Vosdingh et al. 1968, Hoff and Trainer 1974). Thus, a wild ruminant population with a high antibody prevalence rate for a given virus serotype is assumed to be protected from reinfection until subsequent non-immune generations are produced. Long-term studies are needed to determine if disease cycles in opposition to herd immunity, or is associated with shifts in EHD and BT virus serotype prevalences that occur in the western states (Osburn et al. 1981) and in Georgia (Stallknecht et al. 1991b).

Geographic differences in HD virus antibody prevalence rates, as first noted by Wilhelm and Trainer (1966), generally have an inverse relationship with latitude and are highly associated with physiographic regions (Stallknecht et al. 1991a, SCWDS unpublished data: 1992). Thus, high antibody prevalence rate in deer coincides with absence of disease. This phenomenon was attributed by Hanson (1969) to "circumstances of exposure." Perhaps, juvenile animals in EHD and BT virus-endemic areas are exposed early in life while they still have maternal antibodies, and, therefor, infection serves as a vaccinal exposure. An alternate hypothesis is that genetic resistance has evolved in wild ruminants in HD-endemic areas.

Prestwood et al. (1974) observed that deer mortality attributed to HD was associated with high density populations. Circumstantial evidence of high deer populations is indicated by accounts of record hunter harvests following HD outbreaks (Brannian et al. 1983, Fay et al. 1956), but hunter success also has fallen (McConnell et al. 1977, Earley 1982). In theory, the transmissibility of any infectious agent is enhanced by host density; however, this relationship will be difficult to demonstrate, since the detection of sick or dead animals also will be density dependent. Furthermore, the relative densities of *Culicoides* vectors and the numbers of alternative ruminant hosts, such as sheep, cattle and goats, that are available may influence exposure rate of wild ruminants.

How Do EHD and BT Viruses Overwinter?

For many years, cattle were considered reservoirs for BT virus (Bowne et al. 1968, Bowne 1973). Latent infections were reported in calves infected in utero via biting midges, and virus was recovered up to 11 years later by this method (Luedke et al. 1977a, 1977b, 1977c, 1977d, 1982). The antigenic stimulation, provided by feeding uninfected *Culicoides* on cattle, was observed to intensify blood virus level in carrier cattle (Luedke 1977d). The concept of persistent infection in cattle that is reactivated by biting vectors was logical from an epidemiologic perspective; however, the studies have not been repeated and other work has not demonstrated latent infections in calves (MacLachlan et al. 1984). Currently, there is a trend to consider cattle, sheep and goats as only short-term (up to three months) virus carriers.

Long-term viremias have not been demonstrated by experimental infection in white-tailed deer. Viremias have lasted 16 and 22 days postinfection for EHD and BT viruses, respectively (Hoff and Trainer 1974). Of the other native wild ruminants, elk have had the longest virus infection, with 30 and 190 days reported for EHD virus (Hoff and Trainer 1973) and BT virus (Stott et al. 1982), respectively. Isolation of HD viruses has not been made from free-ranging wild ruminants during winter.

The possibility of transovarial transmission in *Culicoides* has been examined by Jones and Foster (1971) with negative results. Overwinter survival of *Culicoides* undoubtedly occurs in warmer parts of the United States, and BT virus was considered to be maintained overwinter by *Culicoides* and cattle in South Africa (Nevill 1971). Analyses of wind current data has led to the theory that wind-borne *Culicoides* could move BT viruses up to 500 km in 20 hrs (Sellers et al. 1978, 1979, Sellers and Maarouf 1989). Considerable research will be required to determine if HD viruses are being maintained locally, as opposed to being introduced by transported animals or wind-borne flies.

What Are the Impacts of HD?

The early concept was that EHD virus infection produced a 90-percent mortality rate in white-tailed deer (Fay et al. 1956, Shope et al. 1960, Karstad et al. 1961); however, this appears to be an overestimate that was based on experimental infections. Nevertheless, loss of penned deer in Kentucky due to EHD and BT viruses was 62 percent (Roughton 1975), and an estimated 84 percent of white-tailed deer were lost in an HD outbreak in Tennessee (Fox and Pelton 1973). Still, the numerous observations of healthy seropositive animals are good evidence that many wild ruminants do not succumb (Wilhelm and Trainer 1976, Couvillion et al. 1981, Feldner and Smith 1981, Jessup 1985, Stallknecht et al. 1991a, 1991b).

Subtle effects of subclinical EHD or BT virus infections on wild ruminants are not known. Infections of white-tailed does with BT virus was considered to have caused reproductive failure (Thomas and Trainer 1970). It is fortunate that HD virus activity appears to be occurring at a time when wild ruminants are not pregnant. Nevertheless, HD infections do coincide with lactation, and there could be a potential impact on fawn survival even if does only have temporary illness. The possible effects on deer condition and survival as related to chronic lesions have not been adequately evaluated.

Although not a consistent feature of HD, massive testicular hemorrhage has been observed (Karstad et al. 1961, Thorne et al. 1988, SCWDS unpublished data: 1992). How HD-induced testicular lesions could be related to the testicular hypotrophy syndrome reported in Texas (Taylor et al. 1964) is worthy of investigation. Also, incomplete hardening of antler tips may be related to prior vascular damage due to HD viruses.

Another potential impact that is completely unknown would be the effect of a foreign serotype of EHD or BT virus introduced into North America. At present, there are seven serotypes of EHD virus and 19 serotypes of BT virus known to occur elsewhere (Gorman 1990). In addition, there are many exotic species of *Culicoides* other than our endemic *C. Variipennis* that are proven vectors in these other countries (Mellor 1990).

Summary

Infections with EHD or BT viruses produce an important disease syndrome in deer and antelope in North America. Outbreaks of HD are seasonal in late summer/ early fall, and death losses are variable. The sporadic occurrence of wildlife mortality cannot be fully explained, but multiple factors, including virus serotype and dosage, vector competency and abundance, and herd immune status, probably interact. Presence of virus in a given area may be continuous through a midge-ruminant-midge cycle, or HD viruses may be introduced via infected ruminants or wind-borne flies. Although substantial study of HD viruses and their vectors has been done, a greater understanding of EHD and BT virus epidemiology will be required before wildlife managers will have hope of reducing losses to this disease syndrome.

References

Alexander, H. E. 1954. Deer problems, new to Arkansas—an old story elsewhere. Arkansas Game and Fish Commiss., Little Rock. 23 pp.

Barber, T. L. and M. M. Jochim. 1975. Serotyping bluetongue and epizootic hemorrhagic disease virus strains. Proc. Am. Assoc. Vet. Lab. Diagnos. 18:149–157.

Boorman, J. and E. P. Gibbs. 1973. Multiplication of the virus of epizootic haemorrhagic disease of deer in *Culicoides* species (Diptera, Ceratopogonidae). Archives Gesamte Virusforsch 41:259–266.

Bowne, J. G. 1973. Is bluetongue an important disease in cattle? J. Am. Vet. Med. Assoc. 163:911–914.

Bowne, J. G., A. J. Luedke, M. M. Jochim, and H. E. Metcalf. 1968. Bluetongue disease in cattle. J. Am. Vet. Med. Assoc. 153:662–668.

Brannian, R. E., N. Giessman, W. Porath, and G. L. Hoff. 1983. Epizootic hemorrhagic disease in white-tailed deer from Missouri. J. Wildl. Dis. 19:357–358.

Chalmers, G. A., H. N. Vance, and G. J. Mitchell. 1964. An outbreak of epizootic hemorrhagic disease in wild ungulates in Alberta. Wildl. Dis. 42. WD–64–15:1–6.

Couvillion, C. E., V. F. Nettles, W. R. Davidson, J. E. Pearson, and G. A. Gustafson. 1981. Hemorrhagic disease among white-tailed deer in the Southeast from 1971 through 1980. Proc. Ann. Meeting U.S. Animal Health Assoc. 85:522–537.

Debbie, J. G. and M. K. Abelseth. 1971. Pathogenesis of epizootic hemorrhagic disease. I. Blood coagulation during viral infection. J. Infect. Dis. 124:217–222.

Ditchfield, J., J. G. Debbie, and L. H. Karstad. 1964. The virus of epizootic hemorrhagic disease of deer. Trans. No. Am. Wildl. and Nat. Resour. Conf. 29:196–199.

Dulac, G. C., C. Dubuc, A. Afshar, D. J. Myers, A. Bouttard, J. Shaprio, and P. T. Shettigara. 1988. Consecutive outbreaks of epizootic haemorrhagic disease of deer and bluetongue. Vet. Rec. 122:340.

Earley, L. S. 1982. The mystery of the dead deer. Wildlife in North Carolina 46(11):24–27.

Fay, L. D., A. P. Boyce, and W. G. Youatt. 1956. An epizootic in deer in Michigan. Trans. No. Am. Wildl. and Nat. Resour. Conf. 21:173–184.

Feldner, T. J. and M. H. Smith. 1981. Epizootic hemorrhagic disease virus in Montana: Isolation and serologic survey. Am. J. Vet. Res. 42:1,198–1,202.

Fosberg, S. A., E. H. Stauber, and H. W. Renshaw. 1977. Isolation and characterization of epizootic

hemorrhagic disease virus from white-tailed deer (*Odocoileus virginianus*) in eastern Washington. Am. J. Vet. Res. 38:361–364.
Foster, N. M., R. D. Breckon, A. J. Luedke, and R. H. Jones. 1977. Transmission of two strains of epizootic hemorrhagic disease virus in deer by *Culicoides variipennis*. J. Wildl. Dis. 13:9–16.
Fox, J. R. and M. R. Pleton. 1973. Observations of a white-tailed deer die off in the Great Smoky Mountains National Park. Proc. Southeast. Assoc. Game and Fish Commiss. 27:297–301.
Gibbs, E. P. J. and E. C. Greiner. 1988. Bluetongue and epizootic hemorrhagic disease. Pages 39–70 *in* T. P. Monath, ed., The arboviruses: Epidemiology and ecology, Vol. II. CRC Press, Boca Raton, FL.
Gorman, B. M. 1990. Pages 1–19 *in* P. Roy and B. M Gorman, eds., Bluetongue viruses. Current topics in microbiology and immunology 162. Springer-Verlag, NY. 200 pp.
Hanson, R. P. 1969. Koch is dead. Bull. Wildl. Dis. Assoc. 5:150–156.
Hayes, F. A. and A. K. Prestwood. 1969. Some considerations for diseases and parasites of white-tailed deer in the southeastern United States. Pages 32–36 *in* Proc. Symp. White-tailed Deer in the Southern Forest Habitat.
Hoff, G. L. and D. M. Hoff. 1976. Bluetongue and epizootic hemorrhagic disease: A review of these diseases in non-domestic artiodactyles. J. Zoo Anim. Med. 7:26–30.
Hoff, G. L. and D. O. Trainer. 1972. Bluetongue virus in pronghorn antelope. Am. J. Vet. Res. 33:1,013–1,015.
Hoff, G. L. and D. O. Trainer. 1973. Experimental infection in North American elk with epizootic hemorrhagic disease virus. J. Wildl. Dis. 9:129–132.
Hoff, G. L. and D. O. Trainer. 1974. Observations on bluetongue and epizootic hemorrhagic disease viruses in white-tailed deer: (1) Distribution of virus in the blood; (2) Cross-challenge. J. Wildl. Dis. 10:25–31.
Hoff, G. L. and D. O. Trainer. 1978. Bluetongue and epizootic hemorrhagic disease viruses: Their relationship to wildlife species. Adv. Vet Sci. Comp. Med. 22:111–132.
Hoff, G. L. and D. O. Trainer. 1981. Hemorrhagic disease in wild ruminants. Pages 45–53 *in* J. W. Davis, ed., Infectious diseases of wild mammals. Iowa St. Univ. Press, Ames, IA. 446 pp.
Hoff, G. L., S. H. Richards, and D. O. Trainer. 1973. Epizootic of hemorrhagic disease in North Dakota deer. J. Wildl. Mgmt. 37:331–335.
Hoff, G. L., D. O. Trainer, and M. M. Jochim. 1974. Bluetongue virus and white-tailed deer in an enzootic area of Texas. J. Wildl. Dis. 10:158–163.
Howe, D. L. 1966. Diagnosis of diseases in mammals and birds. Pittman-Robertson Proj. Rept. FW-3-R-13, Work Plan 1, Job No. 1W. WY Game and Fish Commiss. Cheyenne, WY. Pages 1–19.
Howerth, E. W., C. E. Greene, and A. K. Prestwood. 1988. Experimentally induced bluetongue virus infection in white-tailed deer: Coagulation, clinical pathologic, and gross pathologic changes. Am. J. Vet. Res. 49:1,906–1,913.
Jessup, D. A. 1985. Epidemiology of two orbiviruses in California's native wild ruminants: Preliminary report. Pages 53–65 *in* T. L. Barber and M. M Jochim, eds., Bluetongue and related orbiviruses. Progress in Clin. Biolog. Res. Vol. 178. Alan R. Liss, Inc., NY. 746 pp.
Jessup, D. A., T. M. Work, and N. Kock. 1989. Outbreaks of hemorrhagic disease in black-tailed deer in California: 1986 and 1987. Page 55 *in* Proc. 38th Ann. Conf. Wildl. Dis. Assoc., Corvallis, OR.
Jones, R. H. and N. M. Foster. 1971. Transovarian transmission of bluetongue virus unlikely for *Culicoides variipennis*. Mosquito News 31:434–437.
Jones, R. H. and N. M. Foster. 1974. Oral infection of *Culicoides variipennis* with bluetongue virus: Development of susceptible and resistant lines from a colony population. J. Med. Entomol. 11:316–323.
Jones, R. H. and N. M. Foster. 1978. Heterogeneity of *Culicoides variipennis* field populations to oral infection with bluetongue virus. Am. J. Trop. Med. Hyg. 27:178–183.
Jones, R. H., R. D. Roughton, N. M. Foster, and B. M. Bando. 1977. *Culicoides*, the vector of epizootic hemorrhagic disease in white-tailed deer in Kentucky in 1971. J Wildl. Dis. 13:2–8.
Karstad, L., A. Winter, and D. O. Trainer. 1961. Pathology of epizootic hemorrhagic disease of deer. Am. J. Vet. Res. 22:227–235.
Kistner, T. P., G. E. Reynolds, L. D. Koller, C. E. Trainer, and D. L. Eastman. 1975. Clinical

and serological findings on the distribution of bluetongue and epizootic hemorrhagic disease viruses in Oregon. Proc. Am. Assoc. Vet. Lab. Diagnos. 18:135–148.

Kline, D. L. and E. C. Greiner. 1985. Observations on larval habitats of suspected *Culicoides* vectors of bluetongue virus in Florida. Pages 221–227 *in* T. L. Barber and M. M. Jochim, eds., Bluetongue and related orbiviruses. Alan R. Liss, Inc., NY. 746 pp.

Kocan, A., A. E. Castro, B. Espe, R. T. Doyle, and S. K. Olsen. 1982. Inapparent bluetongue in free-ranging white-tailed deer. J. Am. Vet. Med. Assoc. 181:1,415–1,416.

Kocan, A. A., A. E. Castro, M. G. Shaw, and S. J. Rogers. 1987. Bluetongue and epizootic hemorrhagic disease in white-tailed deer from Oklahoma: Serologic evaluation and virus isolation. Am. J. Vet. Res. 48:1,048–1,049.

Luedke, A. J., M. M. Jochim, and T. L. Barber. 1982. Serologic and virologic responses of a hereford bull persistently infected with bluetongue virus for eleven years. Proc. Am. Assoc. Vet. Lab. Diagnos. 25:15.

Luedke, A. J., M. M. Jochim, and R. H. Jones. 1977a. Bluetongue in cattle: Effects of *Culicoides variipennis*-transmitted bluetongue virus on pregnant heifers and their calves. Am. J. Vet. Res. 38:1,687–1,695.

Luedke, A. J., M. M. Jochim, and R. H. Jones. 1977b. Bluetongue in cattle: Effects of vector-transmitted bluetongue virus on calves previously infected in utero. Am. J. Vet. Res. 38:1,697–1,700.

Luedke, A. J., M. M. Jochim, and R. H. Jones. 1977c. Bluetongue in cattle: Repeated exposure of two immunological tolerant calves to bluetongue virus by vector bites. Am. J. Vet. Res. 38:1,701–1,704.

Luedke, A. J., R. H. Jones, and T. E. Walton. 1977d. Overwintering mechanism for bluetongue virus: Biologic recovery of latent virus from a bovine by bites of *Culicoides variipennis*. Am. J. Trop. Med. Hyg. 26:313–325.

MacLachlan, N. J., C. E. Schore, and B. I. Osburn. 1984. Antiviral responses of bluetongue virus-inoculated bovine fetuses and their dams. Am. J. Vet. Res. 45:1,469–1,473.

Marburger, R. G. 1983. The king of deer. A Wildlife Publication, Kerrville, TX. 272 pp.

McConnell, P. A., R. C. Lund, and N. R. Boss. 1977. the 1975 outbreak of hemorrhagic disease among white-tailed deer in northwestern New Jersey. Trans. NE Sect. Wildl. Soc. 33:35–44.

Mellor, P. S. 1990. The replication of bluetongue virus in *Culicoides* vectors. Pages 143–161 *in* P. Roy and B. M. Gorman, eds., Bluetongue viruses. Current topics in microbiology and immunology 162. Springer-Verlag, NY. 200 pp.

Morton, W. B. 1935. New disease kills deer. Alabama Game and Fish News. March 1933:14.

Murray, J. O. and D. O. Trainer. 1970. Bluetongue virus in North American elk. J. Wildl. Dis. 6:144–148.

Nettles, V. F., S. A. Hylton, D. E. Stallknecht, and W. R. Davidson. 1992. Epidemiology of epizootic hemorrhagic disease virus in wildlife in the United States. *In* T. E. Walton and B. I. Osburn, eds., Bluetongue, African horse sickness and related orbiviruses. CRP Press, Inc., Boca Raton, FL. In press.

Nevill, E. M. 1971. Cattle and *Culicoides* biting midges as possible overwintering hosts of bluetongue virus. J. Vet. Res. 38:65–72.

Osburn, B. I., B. McGowan, B. Heron, E. Lommis, R. Bushnell, J. Stott, and W. Utterback. 1981. Epizootiologic study of bluetongue: Virologic and serologic results. Am. J. Vet. Res. 42:884–887.

Osburn, B. I. and L. D. Miller. 1988. Report of the Committee on Bluetongue and Bovine Retrovirus. Proc. U.S. Anim. Health Assoc. 92:123–128.

Osburn, B. I. and L. D. Miller. 1989. Report of the Committee on Bluetongue and Bovine Retrovirus. Proc. U.S. Anim. Health Assoc. 93:145–152.

Pirtle, E. C. and J. M. Layton. 1961. Epizootic hemorrhagic disease in white-tailed deer—characteristics of the South Dakota strain of virus. Am. J. Vet. Res. 22:104–108.

Post, G. 1960. Diagnosis of diseases in mammals and birds. Pittman-Robertson Proj. Rept. FW–3–R–7 Work Plan No. 1W. Wyoming Game and Fish Commiss., Cheyenne, WY. Pages 1–22.

Prestwood, A. K., T. P. Kistner, F. E. Kellogg, and F. A. Hayes. 1974. The 1971 outbreak of hemorrhagic disease among white-tailed deer of the southeastern United States. J. Wildl. Dis. 10:217–224.

Richards, S. H. 1964. Epidemic hemorrhagic disease in deer and antelope. A report of the 1962 epizootic in western North Dakota. North Dakota Outdoors 26:18–21.
———. 1972. Epizootic hemorrhagic disease of deer. A comparison of the 1962 and 1970 outbreaks that occurred in western North Dakota. North Dakota Outdoors 34:2–4.
Richards, S. H., I. A. Schipper, D. F. Evelethd, and R. F. Shumaro. 1956. Mucosal disease of deer. Vet. Med. 51:358-362.
Robinson, R. M., T. L. Hailey, R. G. Marburger, and L. Weishuhn. 1974. Vaccination trials in desert bighorn sheep against bluetongue virus. J. Wildl. Dis. 10:228-231.
Robinson, R. M., T. L. Hailey, C. W. Livingston, and J. W. Thomas. 1967. Bluetongue in the desert bighorn sheep. J. Wildl. Manage. 31:165–168.
Rosen, M. N., O. A. Brunetti, A. I. Bischoff, and J. A. Azevedo, Jr. 1951. An epizootic of foot rot in California deer. Trans. No. Am. Wildl. and Nat. Resour. Conf. 16:164–178.
Roughton, R. D. 1975. An outbreak of a hemorrhagic disease in white-tailed deer in Kentucky. J. Wildl. Dis. 11:177-186.
Ruff, F. J. 1950. What is "blacktongue" among deer? Wildlife in North Carolina 14:16–19.
Schildman, G. and J. Hurt. 1984. Wildlife disease and mortality summary, 1950–1983. Work Plan S–83, Pittman-Robertson Proj. W–15–R–40. Nebraska Game and Parks Commiss., Lincoln. 8 pp.
Schultz, J. W. 1979. Floating on the Missouri. Univ. Oklahoma Press, Norman. 142 pp.
Schultz, K. T. and F. B. Grieder. 1987. Immunobiology of bluetongue virus. Vet. Immunol. Immunopathol. 15:115–127.
Sellers, R. F. and A. R. Maarouf. 1989. Trajectory analysis and bluetongue virus serotype 2 in Florida 1982. Canadian J. Vet. Res. 53:100–102.
Sellers, R. F., E. P. J. Gibbs, K. A. J. Herniman, D. E. Pedgley, and M. R. Tucker. 1979. Possible origin of the bluetongue epidemic in Cyprus, August 1977. J. Hyg., Cambridge (1979) 83, 547.
Sellers, R. F., D. E. Pedgley, and M. R. Tucker. 1978. Possible windborne spread of bluetongue to Portugal, June-July 1956. J. Hyg. 81:189–196.
Shope, R. E. 1967. The epidemiology of epizootic hemorrhagic disease of deer. Proc. No. Amer. Wildl. and Nat. Resour. Conf. 32:381–386.
Shope, R. E., L. G. MacNamara, and R. Mangold. 1955. Deer mortality—epizootic hemorrhagic disease of deer. New Jersey Outdoors 6:17.
Shope, R. E., L. G. MacNamara, and R. Mangold. 1960. A virus-induced epizootic hemorrhagic disease of the Virginia white-tailed deer (*Odocolieus virginianus*). J. Experi. Med. 111:155–170.
Stair, E. L., R. M. Robinson, and L. P. Jones. 1968. Spontaneous bluetongue in Texas white-tailed deer. Pathologia Veterinaria 5:164–173.
Stallknecht, D. E., J. L. Blue, E. A. Rollor, V. F. Nettles, W. R. Davidson, and J. E. Pearson. 1991a. Precipitating antibodies to epizootic hemorrhagic disease and bluetongue viruses in white-tailed deer in the southeastern United States. J. Wildl. Dis. 27:238–247.
Stallknecht, D. E., M. L. Kellogg, J. L. Blue, and J. E. Pearson. 1991b. Antibodies to bluetongue and epizootic hemorrhagic disease viruses in a barrier island white-tailed deer population. J. Wildl. Dis. 27:668-674.
Stauber, E. H., R. K. Farrell, and G. R. Spencer. 1977. Nonlethal experimental inoculation of Columbia black-tailed deer (*Odocoileus hemionus columbianus*) with virus of epizootic hemorrhagic deer disease. Am. J. Vet. Res. 38:411–412.
Stott, J. L., L. H. Lauerman, and A. J. Luedke. 1982. Bluetongue virus in pregnant elk and their calves. Am. J. Vet. Res. 43:423–428.
Swenson, J. E. 1979. Effects of a hemorrhagic disease epizootic on a white-tailed deer population in eastern Montana. Proc. Montana Acad. Sci. 38:25–32.
Taylor, D. O. N., J. W. Thomas, and R. G. Marburger. 1964. Abnormal antler growth associated with hypogonadism in white-tailed deer in Texas. Am. J. Vet. Res. 25:179–184.
Thomas, F. C. 1981. Hemorrhagic disease. Pages 87–96 *in* W. R. Davidson, F. A. Hayes, V. F. Nettles, and F. E. Kellogg, eds., Diseases and parasites of white-tailed deer. Misc. publ. No. 7, Tall Timbers Research Sta., Tallahassee, FL 458 pp.
Thomas, F. C. and D.O. Trainer. 1970. Bluetongue virus: (1) in pregnant white-tailed deer and (2) a plaque reduction neutralization test. J. Wildl. Dis. 6:384–388.

Thomas, F. C., N. Willis, and G. Ruckerbaker. 1974. Identification of viruses involved in the 1971 outbreak of hemorrhagic disease in sourtheastern United States white-tailed deer. J. Wildl. Dis. 10:187–189.
Thorne, E. T., N. Kingston, W. R. Jolley, and R. C. Bergstrom. 1982. Diseases of wildlife in Wyoming. Wyoming Game and Fish Dept., Cheyenne. 353 pp.
Thorne, E. T., E. S. Williams, T. R. Spraker, W. Helms, and T. Segerstrom. 1988. Bluetongue in free-ranging pronghorn antelope (*Antilocapra americana*) in Wyoming: 1976 and 1984. J. Wildl. Dis. 24:113–119.
Trainer, D. O. 1964. Epizootic hemorrhagic disease of deer. J. Wildl. Manage. 28:377–381.
USDA Animal and Plant Health Inspection Service. 1976. Deer die-off occurs in New Jersey. Foreign Animal Diseases Report, USDA/APHIS, Washington, D.C. January 1976. 12 pp.
Vosdingh, R. A., D. O. Trainer, and B. C. Easterday. 1968. Experimental bluetongue disease in white-tailed deer. Canadian J. Comp. Med. Vet. Sci. 32:382–387.
Wathen, W. G. and J. C. New. 1989. The White-tailed deer of Cades Cove: Population status, movements and survey of infectious diseases. USDI, National Park Service, Research/Resources Manage. Rept. SER–89/01. Southeast Regional Off., Atlanta, GA. 139 pp.
Wilhelm, A. R. and D. O. Trainer. 1966. A serological study of epizootic hemorrhagic disease of deer. J. Wildl. Manage. 30:777–780.
Wilhelm, A. R. and D. O. Trainer. 1969. Hematologic and virological studies of epizootic hemorrhagic disease of deer. Bull. Wildl. Dis. Assoc. 5:77–80, 89–94.

Environmental Influences on Major Waterfowl Diseases

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Introduction

The decline of North American waterfowl resources since the 1960s is well-known to this audience and need not be detailed to establish that population numbers for several key waterfowl species are at or near their lowest levels since records have been kept. Loss of habitat is an accepted major cause for the decline of waterfowl numbers and the wildlife conservation community is responding with initiatives to prevent further loss of existing wetland acreage, restoration for degraded wetlands and creation of new wetlands. Numerous joint ventures focusing on key waterfowl habitat requirements are being developed under the North American Waterfowl Plan. The importance of habitat loss also is reflected in many of the presentations at this conference on wetland conservation, including one special session devoted solely to that topic.

A basic premise of the focus on wetlands is that restoration of waterfowl populations is habitat dependent. This is a tenable thesis if other factors suppressing waterfowl numbers are dealt with and the habitat base being enhanced sustains waterfowl rather than contributes to their death. My presentation addresses disease as a factor suppressing waterfowl numbers and the relation of habitat quantity and quality with waterfowl disease.

Nonhunting Mortality

Predation and disease are two of several causes of nonhunting mortality. Both are thought to cause losses of sufficient magnitude to suppress waterfowl populations. Large losses from either reflect an imbalance in biological systems that is often strongly associated with habitat quantity and quality. Traditionally, a great amount of attention has been given to combatting predation, and during recent years, habitat management assumed a more prominent role in predator management. In contrast, disease has been given little attention beyond carcass clean-up when major wildlife die-offs occur. There is no sound biological basis for this disparity in response to these two major causes of losses of waterfowl. Appropriate actions can minimize losses of waterfowl from disease as effectively as from predation.

May (1988) commented on the disparity of responses to predation and disease by noting that: ''Given the conspicuous role that diseases have played, and in many parts of the world continue to play, in human demography, it is surprising that ecologists have given so little attention to the way diseases may affect the distribution and abundance of other animals and plants. Until recently, for example, ecology textbooks had chapters discussing how vertebrate and invertebrate predators may influence prey abundance, but in most cases you will search the index in vain for mention of infectious diseases."

May (1988) attributed this disparity to several factors including ecologists finding four- and six-legged predators more engaging, and easier to visualize and study than microbes. A more significant factor is the general lack of understanding in the conservation community of the dynamic relation between habitat conditions and the occurrence and persistence of disease. These relations are primary reasons for the magnitude of wetland loss and degradation in the United States (Dahl et al. 1991) profoundly affecting the geographic distribution, frequency of occurrence and types of diseases in North American waterfowl populations.

Waterfowl Disease

Magnitude of Losses

Changes over time in the frequency of waterfowl die-offs from disease cannot be accurately determined because no appropriate data base exists. Also, changes in reporting patterns confounds interpretation of existing data. Development in 1975 of the National Wildlife Health Research Center and general increased concern about waterfowl die-offs because of declining waterfowl numbers resulted in an unknown amount of increased documentation of waterfowl mortality. Nevertheless, with the exception of rare catastrophic events, available information suggests substantially greater numbers of waterfowl are dying from disease currently than during earlier periods of this century.

Stout and Cornwell (1976) tallied 2,108,880 cases of nonhunting mortality of fledged North American waterfowl during 1930–64. This total was derived from a survey of published literature; unpublished federal reports, including U.S. Fish and Wildlife Service refuge narrative, biological and necropsy reports; completed questionnaires by 326 waterfowl biologists (state, federal, private and university); and waterfowl band recovery data. Mortality was assigned to various categories, including diseases and parasites which accounted for 1,872,243 cases or 87.8 percent of the total. The authors did not speculate on the percentage of total losses from diseases represented by these 1,872,243 cases. The per year average of 55,066 deaths from disease during that 34-year period of analysis was exceeded several times by events of waterfowl disease since 1964 (Friend and Pearson 1973, Friend 1987a, Locke and Friend 1987, National Wildlife Health Research Center files). The National Wildlife Health Research Center data base contains records of numerous disease outbreaks that have killed between 25,000 and 100,000 waterfowl since 1975. Die-offs of 5,000 to 10,000 waterfowl are common.

Bellrose (1976) reported annual nonhunting mortality of 20 million waterfowl from 1955 to 1973 and concluded that disease directly or indirectly accounted for the largest proportion of nonhunting deaths. In the United States, annual losses from lead poisoning were estimated at between 1.6 and 2.4 million waterfowl prior to implementation of nontoxic shot for waterfowl hunting (U.S. Fish and Wildlife Service 1976). The National Wildlife Health Research Center data base contains 215 reports of bird die-offs, the majority involving waterfowl, for the period of July 1, 1990 through June 30, 1991. The largest die-off during this period was a 50,000 bird loss from avian botulism on the marshes of the Great Salt Lake. The 215 die-offs during that reporting period are comparable to an average of 206 during the past three years and slightly higher than the 180 average for the past six years. The frequency of disease outbreaks and the magnitude of waterfowl losses according to the National Wildlife Health Research Center data base and published literature seem to be substantially greater than that for 1930–1964 reported by Stout and Cornwell (1976).

Disease Patterns

Changes in disease patterns also occurred over time. The most significant change is the prominence of infectious disease as a cause of waterfowl mortality during the past quarter-century. Furthermore, the geographic distribution of historic diseases, such as avian botulism, greatly expanded, and traditional seasonal occurrences for specific disease were replaced by broader temporal occurrences.

Avian botulism is probably the best documented nonhunting waterfowl mortality (Stout and Cornwell 1976). Prior to 1970, avian botulism was generally considered a late summer event in alkaline areas of the western United States and Canada. Avian botulism outbreaks now occur from coast-to-coast and border-to-border in the United States, and caused large-scale losses of waterbirds in many other countries (Jensen and Price 1987, Locke and Friend 1987). Most initial outbreaks of type C avian botulism in countries other than the United States and Canada occurred since the mid-1960s (Azuma and Itoh 1987, Gimenez and Ciccarelli 1987, Haagsma 1987, Locke and Friend 1987, Skulberg and Holt 1987, Smart et al. 1987). Spring, fall and winter outbreaks of avian botulism were diagnosed frequently enough to suspect this disease at all times of the year, despite prominence as a late summer event. Outbreaks in urban environments and in association with wastewater discharges and sewage lagoons are common occurrences of recent years (National Wildlife Health Research Center files).

Avian cholera (fowl cholera) was unreported in migratory waterfowl in North America before 1944 (Friend 1987a). Citing others, Stout and Cornwell (1976) stated that avian cholera was limited to the Central and Pacific flyways; outbreaks in the Mississippi flyway were unusual; only two outbreaks were cited for the Atlantic flyway; and with the exception of a single instance during the breeding season, outbreaks were associated consistently with winter. The July 1979 to May 1980 series of avian cholera outbreaks among waterfowl from the Canadian breeding grounds to the Gulf Coast wintering areas in the Central and Mississippi flyways, attests to the current broad geographic range of this disease (Brand 1984). Avian cholera is now a major cause of waterfowl mortality throughout the United States and occurs regularly in Canada. This disease caused several major waterfowl die-offs on breeding grounds in the United States and Canada and has had frequent fall, winter and spring outbreaks (Friend 1987a, National Wildlife Health Research Center records).

In 1973, duck plague (duck virus enteritis) became another infectious disease of major concern as a result of the death of more than 40 percent of the 100,000 mallards (*Anas platyrhynchos*) wintering at the Lake Andes National Wildlife Refuge in South Dakota (Friend and Pearson 1973). This disease has greatly expanded its North American distribution since its introduction in the Long Island, New York, commercial duck industry in 1967 (Leibovitz and Hwang 1969, Friend 1987b). Nearly all occurrences of duck plague have been in captive waterfowl. Vigorous disease control efforts by the wildlife conservation community since the Lake Andes die-off successfully prevented establishment of duck plauge as a major mortality factor for wild waterfowl populations. However, the rising number of duck plague die-offs in captive waterfowl is of increasing concern (National Wildlife Health Research Center files).

The cited diseases and data suffice to illustrate that disease is annually causing the death of large numbers of waterfowl and that disease patterns are changing in geographic distribution, frequency of occurrence and type of diseases. Other examples also could be cited. These losses are increasingly important because of severely diminished numbers for some waterfowl species. Degradation of the waterfowl habitat base (quantity and quality) is a primary factor contributing to these changes. Understanding the relations is essential for reducing current and future losses from disease and is a contribution to be realized from enhanced disease investigations and management.

Habitat/Disease Relations

The occurrence of disease generally involves three common factors: a susceptible host, a disease agent, and suitable environmental conditions for contact between the host and agent in a manner that results in disease. These relations can be direct and simple, highly convoluted and complex, or anywhere along a continuum between these extremes. For example, poor visibility (environmental factor) of power transmission lines (disease agent) resulting in a bird (host) striking the wires can result in death from mechanical injuries (disease = trauma). Ingestion by waterfowl (host) of lead shot (disease agent) deposited within feeding reach in the substrate of a wetland (environmental factor) can result in death from lead poisoning (disease) depending on among of lead ingested and absorbed, nutritional state of the bird, and other factors that affect toxicity. Other relations may involve requirements for intermediate hosts needed for development of infective stages of parasites (e.g., sarcocystis), vectors for transmission of infectious diseases (e.g., avian malaria and avian pox) and multifactor relations that affect the susceptibility of the host to disease (e.g., lead-induced immunosuppression resulting in death from aspergillosis).

Habitat Quantity

Major reductions in the amount of habitat can alter host/agent relations that facilitate the occurrence of indigenous infectious diseases. Habitat loss results in a redistribution of waterfowl to the remaining habitat. A common consequence of this redistribution is greater number of birds per habitat unit and prolonged use of that habitat by the birds. When this occurs, enhanced exposure to threshold levels of disease agents, enhanced disease transmission and spread of infectious disease to other locations are common results. The key factors are the number of disease carriers in the population and number of organisms required to cause disease in individual birds (infection threshold). Disease carriers in a population irregularly shed infectious organisms into the environment. These organisms have finite survival times and for disease to occur they must survive long enough for host exposure to occur at infection thresholds. The probability for waterfowl exposure to infection thresholds of pathogens generally increases with high densities of waterfowl and with prolonged use of limited habitat.

Spread of infectious disease among waterfowl using a specific unit of habitat is often facilitated by bird density once disease erupts. However, multiple factors, including virulence of the disease agent and host immunity from previous exposure to the disease agent, affect spread of the disease. Maintenance of infectious disease in the population and spread to other populations is accomplished by disease carriers among infected survivors of the outbreak. These birds may be stimulated to shed disease organisms into new environments or among new susceptible hosts at later times and other locations as a result of natural stress, such as that associated with migration and molt, food deprivation, inclement weather and harassment.

The events identified above are undoubtedly involved in the spread of avian cholera in North American waterfowl populations. This disease was probably present in free-living waterfowl in the United States prior to the first documented epizootics in 1944. Avian cholera had been recognized as a disease of domestic poultry in the United States since at least 1867 (Rhoades and Rimler 1991). Earlier undetected outbreaks in wild waterfowl were probably of small size and self-limiting because the greater habitat base minimized waterfowl concentrations and provided more transient use of individual wetlands. Habitat quality that facilitated degradation of the causative bacterium also was more characteristic of earlier than current times.

Habitat Quality

Microorganisms, including those that cause diseases of waterfowl, have strict environmental needs for maintenance and growth. These needs control the abundance and composition of microbial populations in nature. Monospecies is strikingly atypical of nearly all habitats that are colonized by microorganisms and, in most instances, many different types of microorganisms are present (Bull and Slater 1982a). Changes in environmental conditions induce changes in these microbial populations (Bull and Slate 1982b). Habitat quality, as it affects the composition of microbial populations and survival of microbial pathogens, is of great importance in the potential for disease outbreaks.

Avian cholera and avian botulism are examples of the importance of wetland quality in the occurrence of disease in waterfowl. Large volumes of *Pasteurella multocida* are discharged into wetlands by birds dying from avian cholera. Price and Brand (1984) recovered virulent avian cholera organisms in water from a Nebraska wetland during a large waterfowl die-off, and Rosen (1969) found water from a California pond remained infective for mice for three weeks after removal of dead birds. Evaluations of differences in water chemistry between wetlands with major avian cholera problems and with minimal occurrence of this disease in Nebraska disclosed higher concentrations of calcium (Ca) and magnesium (Mg) ions in waters from the problem wetlands (Windingstad et al. 1985).

Laboratory studies by Price et al. (1992) disclosed that high concentrations of Ca and Mg ions in pond water, singly or in combination, significantly (P is greater than 0.001) increased survival of *P. multocida*. The synergism between Ca and Mg extended survival of *P. multocida* in pondwater by 15 days compared with 3 days for Mg alone and greater than 1 day for Ca alone under laboratory conditions. Associated study of a culture of *P. multocida* at 37° C in saline containing 2 ppm Mg has viable organisms after more than five years (J. Price personal communication: 1992). *Pasteurella multocida* may be sustained indefinitely in the environment, especially where Ca, Mg and their complex exist in high concentrations along with other unknown variables. An influx of susceptible birds into an area where high numbers of *P. multocida* organisms exist in the water could result in an avian cholera outbreak (Price et al. 1992).

Avian botulism is clearly an environmental disease. The natural habitats of *Clostridium botulinum* is soil and lake, river and estuary bottoms. Birds are known to excrete *C. botulinum* spores they pick up from the environment, thereby, serving as carriers of botulinal spores between widely separated geographical habitats (Lamanna 1987). Evidence for waterfowl carrying botulinal spores was found in studies by Rocke and Reed (National Wildlife Health Research center files) that disclosed 21 of 40 healthy sentinel mallards maintained on a California wetland for two months had detectable type C botulism spores in the livers or ceca.

Spores of *C. botulinum* type C most frequently occur in feshwater habitats and coastal sediments (Mitchell and Rosendal 1987). Specific conditions must be met for these spores to germinate, multiply and produce toxin. Recent data collected from marshes with and without botulism outbreaks in California and Montana suggest a positive correlation between specific wetland sediment factors, such as temperature, pH, conductivity, redox potential and the occurrence of botulism in birds (T. Rocke personal communication: 1992). Further field and laboratory studies are underway to verify these relations.

C. botulinum spores coexist with other microbes in a dynamic microbial community that may influence one or more steps in the progression from resting spore to toxin-secreting cell. Bacteria with inhibitory activity against *C. botulinum* type C were abundant and present in about half the marsh sediment samples studied from a California wetland. Sandler (1990) postulated that these bacteria may combine with redox potential, water temperature and other factors to regulate the timing, location and severity of avian botulism outbreaks.

Microbial ecology and habitat quality relative to survival of threshold levels of disease agents are poorly studied and have not previously been incorporated in wetland management for waterfowl. Failure to do so results in lost opportunity to manage against major disease problems.

Conclusion

There should be no debate that the annual loss of waterfowl from disease is millions of birds. The preceeding discussions linked habitat quantity and quality to disease patterns and the magnitude of losses of waterfowl from disease. Many other examples could have been cited to strengthen the identified linkages. These examples could have been drawn from scientific knowledge of diseases affecting humans and domestic animals, as well as wildlife. The concepts are well-recognized among disease investigators and are aggressively dealt with in combatting disease in non-wildlife species. Economic losses of disease has been instrumental in the development of major health industries for humans and domestic animals. Similar response has not occurred for free-ranging wildlife. This disparity defies logic.

Gilmour and Munro (1991) raised, a fundamental choice in considering wildlife disease in general: ". . . is wildlife disease a phenomenon warranting mans interference or should nature be allowed to take its course and achieve a balance?" They also noted, that, "However fine-sounding the concept of "nature's balance" may seem, the reality is that there are few situations in which man has not had at least an unwitting hand in the scheme of things." The preceding discussion illustrates harm from disease associated with anthropogenic environmental changes and supports the conclusion by Gilmour and Munro (1991) of need for positive involvement in dealing with disease. This involvement must be aggressive and well founded to provide positive benefits.

The potential and promise of the study, and control of diseases is as important for the well-being of migratory waterfowl as investigations and control of diseases are for humans, domestic animals and captive wildlife. Infectious diseases have been the dominant selective forces in human populations at least for the past 10,000 years (Haldane 1949) and, in combination with malnutrition, are still the main cause of the drastic differences between survivorship curves in developed and developing countries (Bradley 1974).

Infectious disease has become a major cause of waterfowl mortality during the past quarter-century and will continue to increase in importance unless more favorable host/agent/environment relations are created for waterfowl. Effects and economic costs are no less severe from wildlife diseases than from diseases in other species, nor are returns from major efforts to combat diseases likely to be less rewarding. Wildlife conservation is costly, fiscal resources to address species needs are limited and competition for funds demands viable returns from investments. About $270 million in federal aid in wildlife restoration funds will be distributed to state fish and wildlife agencies during fiscal year 1992 (U.S. Fish and Wildlife Service 1991a). The budget for the U.S. Fish and Wildlife Service during this same period exceeds $1 billion for the first time in history (U.S. Fish and Wildlife Service 1992). Also, a coalition of more than 200 conservation groups, businesses, individuals, states and the U.S. Government in 1990 spent a record $118 million for conserving wetlands in the United States. Eventual cost of the North American wetlands habitat conservation program is estimated at $1.5 billion (U.S. Fish and Wildlife Service 1991b). The magnitude of these investments challenges acceptance of current waterfowl losses from disease and continued failure to significantly improve population numbers of key waterfowl species.

High quality habitat is the key to healthy waterfowl populations. However, traditional definitions for habitat quality need to be expanded to rigorously address waterfowl disease considerations. Achievement of significant reductions in waterfowl losses from disease also requires that wetland management fully incorporate enhanced understanding of host/agent/environment relations. Investment in these aspects of wetland research and management are needed to guide wetland acquisition, restoration and enhancement on behalf of North American waterfowl populations.

References

Azuma, R. and T. Itoh. 1987. Botulism in waterfowl and distribution of *C. botulinum* type C in Japan. Pages 167–187 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Bellrose, F. C. 1976. Ducks, geese, and swans of North America. Stackpole Books, Harrisburg, PA. 543 pp.

Bradley, D. J. 1974. Stability in host parasite system.s Pages 71–87 *in* M. B. Usher and M. H. Williamson, eds., Ecological stability. Chapman and Hall, London.

Brand, C. J. 1984. Avian cholera in the Central and Mississippi flyways during 1979–80. J. Wildl. Manage. 48:399–406.

Bull, A. T. and J. H. Slater. 1982a. Historical perspectives on mixed cultures and microbial communities. Pages 1–12 *in* A. T. Bull and J. H. Slater, eds., Microbial interactions and communities. Vol. 1. Academic Press, NY. 567 pp.

Bull, A. T. and J. H. Slater. 1982b. Microbial interactions and community structure. Pages 13–44 *in* A. T. Bull and J. H. Slater, eds., Microbial interactions and communities. Vol. 1. Academic Press, NY. 567 pp.

Dahl, T. E. and C. E. Johnson. 1991. Status and trends of wetlands in the conterminous United States, mid-1970s to mid-1980s. U.S. Dept. Interior, U.S. Fish and Wildl. Serv., Washington, D.C. 22 pp.

Friend, M. 1987a. Avian cholera. Pages 69–82 *in* M. Friend and C. J. Laitman, eds., Field guide to wildlife diseases. Vol. 1. U.S. Fish and Wildl. Serv. Resour. Publ. 167, Washington, D.C. 225 pp.

———. 1987b. Duck plague. Pages 117–127 *in* M. Friend and C. J. Laitman, eds., Field guide to wildlife diseases. Vol. 1. U.S. Fish and Wildl. Serv. Resour. Publ. 167, Washington, D.C. 225 pp.

Friend, M. and G. L. Pearson. 1973. Duck plague: The present situation. Proc. West. Assoc. St. Game and Fish Commiss. 53:315–325.

Gilmour, J. S. and R. Munro. 1991. Wildlife disease: Management or masterly inactivity? J. Nat. Hist. 25:537–541.

Gimenez, D. E. and A. S. Ciccarelli. 1987. Botulism in South America. Pages 143–152 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Haagsma, J. 1987. Avian botulism in the Netherlands. Pages 153–166 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Haldane, J. B. S. 1949. Disease and evolution. La Ricerca Sci. Supp. 1. 19:68–76.

Jensen, W. I. and J. I. Price. 1987. The global importance of type C botulism in wild birds. Pages 33–54 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Lamanna, C. 1987. The scope of the avian botulism problem. Pages 5–11 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Leibovitz, L. and J. Hwang. 1968. Duck plague on the American continent. Avian Dis. 12:361–378.

Locke, L. N. and M. Friend. 1987. Avian botulism. Pages 83–93 *in* M. Friend and C. J. Laitman, eds., Field guide to wildlife diseases. Vol. 1. U.S. Fish and Wildl. Serv. Resour. Publ. 167, Washington, D.C. 225 pp.

May, R. M. 1988. Conservation and disease. Conserv. Biol. 2:28–30.

Mitchell, W. R. and S. Rosendal. 1987. Type C botulism: The agent, host susceptibility, and predisposing factors. pages 55–71 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Price, J. I. and C. J. Brand. 1984. Persistence of *Pasteurella multocida* in Nebraska wetlands under epizootic conditions. J. Wildl. Dis. 20:90–94.

Price, J. I., B. S. Yandell, and W. P. Porter. 1992. Chemical ions affect survival of avian cholera organisms in pondwater. J. Wildl. Manage. 56:274–278.

Rhoades, F. R. and R. B. Rimler. 1991. Pasteurellosis/fowl cholera. Pages 145–162 *in* B. W. Calnek, H. J. Barnes, C. W. Beard, W. M. Reid, and H. W. Yoder, Jr., eds., Diseases of poultry, 9th ed. Iowa St. Univ. Press, Ames. 929 pp.

Rosen, M. N. 1969. Species susceptibility to avian cholera. Bull. Wildl. Dis. Assoc. 5:195–200.

Sandler, R. J. 1990. Microbial interactions and population dynamics in relation to avian botulism. M.S. thesis, Univ. Wisconsin, Madison. 79 pp.

Skulberg, A. and G. Holt. 1987. Avian botulism in Scandinavia. pages 107–110 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Smart, J. L., T. A. Roberts, and L. Underwood. 1987. Avian botulism in the British Isles. Pages 111–122 *in* M. W. Eklund and V. R. Dowell, Jr., eds., Avian botulism: An international perspective. Charles C. Thomas, Springfield, IL. 405 pp.

Stout, I. J. and G. W. Cornwell. 1976. Nonhunting mortality of fledged North American waterfowl. J. Wildl. Manage. 40:681–693.

U.S. Fish and Wildlife Service. 1976. Final environmental statement on proposed use of steel shot for hunting waterfowl in the United States, U.S. Govt. Print. Off., Washington, D.C. 276 pp.

———. 1991a. Money earmarked for state fish and wildlife programs tops quarter billion dollars. Dept. Interior News Release, October 22, 1991. 2 pp.
———. 1991b. Record among spent on wetland under North American waterfowl plan. North Central Region News Release, December 9, 1991. 2 pp.
———. 1992. Administration proposes record budget for U.S. Fish and Wildlife Service, Dept. Interior News Release, Jan. 29, 1992. 2 pp.
Windingstad, R. M., J. J. Hurt, A. K. Trout, and J. Carey. 1985. Avian cholera in Nebraska's Rainwater Basin. Trans. N. Am. Wildl. and Nat. Resour. Conf. 49:576–583.

Toxicity of Bismuth Shot Compared with Lead and Steel Shot in Game-farm Mallards

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Introduction

Effective with the 1991–92 hunting season, only nontoxic shot may be used to hunt waterfowl in the United States. Steel (Fe) shot is the only shot currently approved by the U.S. Fish and Wildlife Service (FWS) as nontoxic, and hunters generally have adapted to its use. Presently, there are fewer complaints about Fe shot than when it was introduced, but there is ongoing interest in other types of nontoxic shot.

The FWS (1986) published detailed guidelines for evaluating candidate nontoxic shot. Before this agency will approve studies evaluating candidate shot, the applicant must provide information that demonstrates a basis for nontoxicity. The present study was thus designed to provide "The applicant's assessment of the potential toxicity of the candidate shot to migratory birds . . . as compared to lead shot and steel shot" (FWS 1986). The protocol for the present study was submitted to Keith Moorehouse, FWS, Office of Migratory Bird Management, for review prior to initiation of the study.

Bismuth (Bi) is a heavy metal with a specific gravity of 9.747 (20°C), compared with 7.874 for Fe and 11.35 for lead (Pb) (Lide 1990). Its hardness is 7 on the Brinell scale compared with 4–5 for Pb, 67–90 for Fe and 116–240 for steel. It occurs in the Earth's crust at approximately 0.2 ppm, is obtained as a byproduct in the processing of Pb, copper and tin ores, and contracts when melted (Windholz 1976).

The only previous study of Bi in birds was by Hanzlik and Presho (1923), who administered metallic Bi, Pb and other heavy metals to pigeons. The fatal dose of metallic Pb in their studies ranged from 0.6 to 2.28 g/kg. By contrast, there were no deaths among the four pigeons receiving Bi at an average dose of 1.39 g/kg. The researchers concluded that Pb is more toxic than other heavy metals, including Bi.

Abbracchio et al. (1985) administered tri-potassium-dicitrato bismuthate intraperitoneally and by gavage in laboratory rats. These authors believed that there was low absorption of orally administered Bi. Woods and Fowler (1987) reported that little information was available on the effects of Bi in mammals in general, but noted that toxic effects in the liver, kidneys and blood have been found in humans and laboratory animals after exposure to Bi compounds.

Ross et al. (1988) injected Bi subnitrate intraperitoneally in laboratory mice. Bi levels in both blood and brain of mice that showed signs of neurotoxicity were significantly higher than those in dosed mice that showed no signs. These authors concluded that Bi blood level did not predict neurologic signs, but that levels above 50 ppb are necessary to produce frank encephalopathy in humans.

Dipalma (1988) said that although exposure to Bi by humans is as common as exposure to mercury and Pb, Bi is not considered a serious industrial hazard. According to him, studies are rarely done of Bi levels in blood from either oral or topical applications because of the assumption that absorption of Bi is very low. He suggested that blood Bi should not exceed 20 μg/L.

Slikkerveer and de Wolff (1989) summarized current information on the effects of Bi in mammals. They reported a peak of Bi in blood 45 minutes after oral dosing with colloidal Bi in humans, but with continued dosing, three to four weeks were necessary to reach a steady state of Bi in plasma. Although the site of Bi absorption in the gastrointestinal tract is unknown, they suggested that colloidal Bi is absorbed in the small bowel and stomach. Meaningful reference values for Bi levels in tissues are not available because of large variations in experimental and analytical techniques. The highest levels of Bi were always in the kidney, and after 14 months of dosing colloidal Bi subcitrate in rats, Bi concentrations ranked from high to low in kidney, lung, spleen, liver, brain and muscle, respectively. When bone levels were measured, concentrations were usually 10–20 times lower than in the kidney. Slikkerveer and de Wolff (1989) reported, however, that following oral dosing of trimethyl Bi to dogs, the Bi concentration was higher in the liver than in the kidney, probably because of the organic character of the molecule. Bi is found in both urine and feces. The Bi in the feces comes from Bi excreted in bile, which concentrates plasma Bi by a factor of 10, and from intestinal secretion.

In the present study, metallic Bi in the gizzards of ducks eroded for 30 days in most Bi-dosed ducks. Thus, the conditions in our study were substantially different from those described in the literature.

Methods

One hundred and twenty male wild-type, game-farm mallards were purchased from Whistling Wings, Hanover, Illinois. The ducks were six to eight months old and were reared on a 60-acre (24.3-ha) lake. The ducks were weighed and randomly assigned to pens—one duck per pen—on August 14, 1991.

The pens were consecutively numbered, elevated, outdoor, 3.3-foot (1-m) squares of vinyl-coated, 1-inch (25.4-mm) mesh, 14-gauge wire (Valentine Equipment Company, Hinsdale, Illinois). Each pen had a metal feeder, and water was provided by a flow-through system constructed from 3-inch (7.6-cm) PVC pipe. A small rectangular opening, approximately 6 by 1.75 inches (15.2 by 4.4 cm), was cut in the top of the pipe near the middle of each pen. This system allowed the ducks access for drinking but prevented them from defecating in the water. frames for the pens were untreated cypress lumber. Shade was provided by a commercial shade cloth (A. H. Hummert Seed Company, St. Louis, Missouri), which screened 63 percent of the sun's rays.

Facilities for holding the ducks were inspected by the Laboratory Animal Care Committee, University of Illinois, prior to placing the ducks in the pens. The committee also conducted a scheduled, semi-annual inspection of the facilities during the study. Commercial duck pellets (Wayne Duck Grower, Wayne Feed Division, Continental Grain Company, Chicago, Illinois), which contained a minimum of 16.0 percent protein, were provided *ad Libitum* during the three-week acclimatization period. On the date of dosing, the pellets were removed and shelled corn was provided *ad libitum* for the duration of the study.

The ducks were divided into 12 groups of 10 ducks each and dosed as follows: control (sham dosed), two, four or eight Number two Fe, Pb or Bi shot; four Pb and four Bi shot; and four Bi shot and given access to soil. In an earlier study, Sanderson (1979, Sanderson and Bellrose 1986) found that access to soil reduced the effects of Pb shot in ducks. In the present report, ducks in each of the treatment groups are referred to as follows: control, Fe2, Fe4, Fe8, Pb2, Pb4, Pb8, Bi2, Bi4, Bi8, Bi4:Pb4 and Bi4:soil.

The study began on September 3, 1991 (Day 0). A small plastic funnel fitted with plastic tube (⅜-inch [9.5 mm] outside diameter, 9 inches [22.9 cm] long) was inserted into the proventriculus. The tube was kept in a pail of water until used. The shot were poured into the funnel and flushed into the proventriculus with approximately 5 ml of water. Controls were treated the same except that no shot was placed in the proventriculus.

Blood was collected from the wing vein in heparinized microhematocrit capillary tubes for hematocrit determination and in 3-ml Vacutainer whole blood collection tubes with liquid EDTA (k3) for determination of Bi, Pb and Fe. Twenty-gauge, 1-inch (25.4-mm) needles were used (Baxter Healthcare Corporation, Scientific Products Division, McGaw Park, Illinois). Blood was collected on Day 0, and from surviving ducks on Days 3, 9, 15 and 30. Ducks were weighed on Day 0, and then on Days 3, 15 and 30 or on the date of death.

All ducks that died during the study were necropsied by the third author (Foley). In addition, three controls, three Fe8 ducks and three Bi8 ducks were necropsied at the end of the study. The duck holding facility was checked at least twice daily for dead ducks. Animals that had died were weighed and refrigerated until necropsy. The necropsy procedure included a complete examination of all body cavities and organs. In addition, samples of liver, bone, muscle, gizzard and heart blood were collected for analysis. Representative samples of all major organs were collected and fixed in 10 percent neutral buffered formalin. All surviving ducks were euthanized by decapitation at the end of the study.

Liver, muscle and bone samples were analyzed for Fe, Pb and Bi. The second author (Wood) performed Bi analyses on fecal samples and all Fe and Pb analyses. Ms. Saada Hamdy, Illinois State Water Survey, performed Bi analyses on blood, liver, muscle and bone samples.

The Bi shot were provided by John Brown, St. Catharines, Ontario, Canada. Three shot were analyzed in our laboratory prior to dosing the ducks. All were 100 percent Bi.

Statistical Analyses

Variation in survival times among treatment groups over the 30-day trial was evaluated by estimating survival functions with the Kaplan-Meier production-limit.

Equality of survival functions among treatments was evaluated with generalized Wilcoxon test statistics (Tarone-Ware or Breslow).

Several variables of interest (e.g., hematocrit and body mass) involved repeated measures of individuals throughout the experiment. We tested for differences among treatments over time with repeated-measures ANOVA. Cell frequencies were balanced at the onset of the experiment, but—within treatment—differential numbers of birds died before Day 30. Therefore, repeated-measures ANOVA for unbalanced designs was used. Tests among treatments were made with single degree of freedom contrasts and Wald statistics. In several cases, we pooled across certain treatments (e.g., all Bi-dosed birds) when contrasts indicated no heterogeneity.

Tests for dose effects on variables measured post-mortem were done by one-way ANOVA. In cases where homogeneity of groups variances could not be assumed, Brown-Forsythe test statistics were used. Pairwise differences among treatments were tested by Tukey's studentized range method. Comparisons of various dose treatments to controls were made with Dunnett's procedure. All analyses were run with the BMDP statistical package (BMDP386, *see* BMDP 1990). The fourth author (J. D. Brawn) was responsible for all statistical analyses.

Results and Discussion

Survival

Thirty eight of 40 (95 percent) ducks dosed with Pb shot died during the study. They survived an average of 15.1 days after dosing (Table 1). The two Pb2 ducks that survived had no shot in their gizzards when they were euthanized.

The shortest survival time for a Pb-dosed bird was 4 days (one Pb8 duck), and the longest was 30 days (two Pb2 ducks). Cook and Trainer (1966) reported that

Table 1. Mean body weight (lb [kg]) and mean survival of game-farm mallards.

Dose[a]	September 3, 1991	October 3, 1991[b]	Mean survival (days)
Controls	2.64 [1.197]	2.52 [1.144]	30.0
Fe2	2.72 [1.235]	2.61 [1.184]	30.0
Fe4	2.81 [1.276]	2.60 [1.180]	30.0
Fe8	2.72 [1.233]	2.57 [1.166]	30.0
Pb2	2.68 [1.218]	1.42 [0.643] (8)[c]	19.1
		2.24 [1.018] (2)[d]	30.0
Pb4	2.69 [1.222]	1.48 [0.670]	15.0
Pb8	2.71 [1.230]	1.74 [0.789]	12.6
Bi2	2.70 [1.225]	2.54 [1.152]	30.0
Bi4	2.60 [1.178]	2.50 [1.132]	30.0
Bi8	2.78 [1.261]	2.61 [1.186]	30.0
Bi4:Pb4	2.46 [1.115]	1.47 [0.666]	14.4
Bi4:soil	2.63 [1.195]	2.65 [1.202]	30.0

[a]All shot were Number two, 10 ducks in each dose, and ducks placed in pens on August 14, dosed on September 3, and surviving ducks euthanized on October 3, 1991.
[b]Weight at death for ducks that died before Day 30.
[c]Sample size in ( ) when fewer than 10.
[d]These two ducks survived to the end of the study.

Canada geese (*Branta canadensis*), dosed with 25 or more Number four Pb pellets, died within 10 days, whereas those dosed with 10 or fewer Pb pellets survived as long as 72 days. All controls, all Fe-dosed ducks and all Bi-dosed ducks that received only Bi pellets, including Bi4:soil, survived to the end of the study. Bi-dosed ducks survived longer than Pb-dosed ducks ($P < 0.001$).

Several investigators (Heppel and Kornberg 1946, Six and Goyer 1972, Sanderson et al. 1981) previously reported that Fe deficiencies increased toxicity to ingested Pb, and that supplemental Fe decreased the toxicity of ingested Pb in birds and mammals. Bi, however, did not show a similar effect. In the present study, dosing with Bi in addition to Pb did not reduce Pb toxicity; average survival of Bi4:Pb4 ducks (14.4 days) was not significantly different ($P = 0.6116$) from survival of Pb4 ducks (15.0 days).

Hematocrit (hct)

Hematocrits were analyzed on the basis of percentage change from Day 0. There were no significant differences in mean changes of hct among the groups of Bi-dosed ducks, but there were significant differences among the groups of Fe-dosed ducks. The data for Bi-dosed ducks were pooled for these analyses. Changes in hct for Fe8 ducks versus controls, Fe8 ducks versus all Bi-dosed ducks, all Bi-dosed ducks versus controls and Bi4 ducks versus Bi4:soil ducks were similar. All Pb-dosed ducks had larger declines in hct than Bi-dosed ducks, and Pb2 and Pb8 ducks had larger declines in hct than Fe8 ducks (tables 2 and 3). The difference in hct for Fe8 versus Pb4 ducks was substantial, but not significant ($P = 0.06$), perhaps because of the samll sample size due to the death of Pb4 ducks. Differences in changes of hct were not significant in Bi4:Pb4 versus Pb4 ducks. Hct of Bi-dosed ducks increased from Day 0 to Day 30, whereas hct of all Pb-dosed ducks decreased ($P < 0.001$). Hct in controls declined less ($P < 0.007$) than in Bi4:Pb4 ducks.

Table 2. Mean hematocrit values and mean change from dosing to death of game-farm mallards.

Dose[a]	September 3, 1991	October 3, 1991[b]	Percentage change—from dosing to death[b]
Control	48.7	48.4	−0.5
Fe2	48.2	46.2	−3.8
Fe4	45.1	48.2	+6.9
Fe8	47.9	48.9	+2.2
Pb2	47.4	31.2 (8)[c]	−31.4 (8)
			−4.5 (2)[d]
Pb4	45.1	30.2 (5)	−32.0
Pb8	45.7	25.5 (6)	−42.9 (6)
Bi2	47.9	47.2	−1.3
Bi4	45.7	47.9	+5.1
Bi8	46.7	47.7	+2.6
Bi4:Pb4	46.1	26.3 (6)	−44.0 (6)
Bi4:soil	46.0	49.8	+8.8

[a]*See* Table 1.
[b]Last value for ducks that died before Day 30.
[c]Number of ducks in ( ) when fewer than 10.
[d]These two ducks were euthanized on Day 30.

Table 3. P values.

Comparison	Changes[ab] in hct	Changes in body weight[cd]	Changes in blood Pb
Bi vs controls	0.09	0.12	—
Bi vs Fe8	0.183	—	—
Bi vs Pb2	<0.001	<0.001	—
Bi vs Pb4	<0.001	<0.001	—
Bi vs Pb8	<0.001	<0.001	—
Bi4 vs Bi4:soil	0.83	0.067	—
Bi4:Pb4 vs control	0.007	<0.001	—
Bi4:Pb4 vs Pb2	—	—	0.675
Bi4:Pb4 vs Pb4	0.25	0.619	0.86
Bi4Pb4 vs Pb8	—	—	0.39
Fe8 vs control	0.76	—	—
Fe8 vs Pb2	<0.001	—	—
Fe8 vs Pb4	0.06	—	—
Fe8 vs Pb8	<0.001	—	—
Bi vs Fe	—	0.67	—
Fe vs control	—	0.31	—
Fe vs Pb2	—	<0.001	—
Fe vs Pb4	—	<0.001	—
Fe vs Pb8	—	<0.001	—

[a]Data from Table 2.
[b]Data from Bi-dosed ducks were combined.
[c]Data from Table 1.
[d]Data from Bi-dosed ducks were combined, as were data from Fe-dosed ducks.

Forbes and Sanderson (1978) summarized the symptoms of Pb poisoning, including anemia, in waterfowl. O'Halloran et al. (1988) reported that Pb poisoned mute swans (*Cygnus olor*) were anemic, but cautioned against using hct alone to indicate Pb toxicosis. In the present study, hct in Pb-dosed ducks that died prior to Day 30 declined 36.4 percent from dosing to the last time they were bled (Table 2). Hct of Pb2 ducks declined by Days 3 and 9, but then began in increase, and hct of the two Pb2 ducks that survived to Day 30 returned to normal (Table 2).

Slikkerveer and de Wolff (1989:310) stated, "This study showed that the early toxic effects of bismuth are possibly related to effects on enzymes of the haem synthesis. . . . Anaemia, however, has never been associated with bismuth synthesis." In the present study, changes in hct of Bi-dosed ducks versus controls, Bi-dosed ducks versus Fe8 ducks, and Bi4:Pb4 versus Pb4 ducks were not significantly different, and hct of Pb-dosed ducks decreased more than hct of Bi-dosed ducks. Thus, Bi appears to have no effect on hct in ducks and provides no protection from the adverse effects of Pb on hct.

Body Weight

All groups gained small amounts of weight during the three-week acclimatization, while on a diet of commercial duck pellets. Evaluation of body weights is based on the percent change from Day 0. Weights of Pb-dosed ducks that died between Days 0 and 15, and between Days 15 and 30 were analyzed as if the ducks died on Days

15 and 30, respectively. Mean changes in body weights were similar in all ducks dosed with only Bi and in all Fe-dosed birds. Weights for these groups were combined for analysis. There were no significant differences in mean weight changes in Bi-dosed versus Fe-dosed ducks, between either Bi-dosed or Fe-dosed versus control ducks, between Pb4 ducks versus Bi4:Pb4 ducks, or between Bi4 versus Bi4:soil birds (Table 3). Mean weight losses were greater in Bi4:Pb4 ducks and in all Pb-dosed ducks versus Bi- and Fe-dosed, and control ducks. Thus, four Bi pellets administered with four Pb pellets provided no protection from the adverse effects of Pb on body weight, and Bi had no effect on the body weights of ducks not dosed with Pb.

The average weight loss for ducks that died of Pb poisoning was 42.2 percent, with a range of 16 to 56 percent for individual ducks. Cook and Trainer (1966) reported captive Canada geese that died of acute Pb poisoning lost approximately 19 percent of their body weight, whereas chronic cases lost about 36 percent. Sanderson and Bellrose (1986) found that game-farm mallards on a diet of corn and dosed with five No. 4 lead pellets died of acute lead poisoning in an average of 7.6 days after dosing, when they had lost 20.5 percent of their body weight. Other ducks on the same study died of chronic lead poisoning in an average of 20.7 days after dosing, when they had lost 47.6 percent of their body weight.

Weight of Liver

Weights of livers of Pb-poisoned waterfowl are difficult to evaluate. Livers can be enlarged or atrophied. Adler (1944), for example, reported that livers of Canada geese suffering from Pb poisoning were about three times normal size. Beer and Stanley (1965), however, reported atrophied livers in 20 percent of Pb-poisoned waterfowl. Sanderson and Bellrose (1986) noted a reduction of liver size of Pb-poisoned ducks. They also reported that seasons, diet, postdosing survival time and anorexia resulting from Pb poisoning affect liver size.

There were no significant differences in liver weights among groups, except that livers of Pb2 ducks were significantly lighter ($P < 0.05$) than livers of Bi4:soil ducks (Table 4). Pb2 ducks survived longer ($P < 0.05$) than other Pb-dosed ducks.

Retention and Erosion of Shot

Lead. Ducks dosed with two, four or eight Pb pellets retained 60.0 percent (12 of 20), 71.2 percent (57 of 80) and 82.5 percent (66 of 80) pellets, respectively. All ducks dosed with Pb pellets retained 75.0 percent of them (135 of 180 pellets) (Table 5). Seventeen and one-half percent (7 of 40 ducks) dosed with Pb pellets voided all of them prior to death; however, all but 2 of the 40 ducks died of Pb toxicosis before Day 30. Two of 10 Bi4:Pb4 ducks voided all pellets prior to death and the other 8 birds voided a lower percentage of Bi pellets (22.5 percent) than of Pb pellets (32.5 percent) (Table 5). The higher rate of erosion and consequent smaller size of the Pb pellets probably contributed to their higher rate of expulsion.

We did not confirm the voiding of shot by examining feces from individual ducks. We are confident, however, that all dosed Pb shot not recovered in the gizzards were voided. None of the Pb pellets recovered from the gizzards had eroded more than 47.5 percent of the weight (in 18 days). All recovered Pb pellets remained round.

Table 4. Mean weight (oz [g]) of livers of game-farm mallards.

Dose[a]	Ducks that died prior to end of study	Ducks euthanized 30 days post-dosing
Controls	—	0.66 [18.7] (10)[b]
Fe2	—	0.57 [16.2] (10)
Fe4	—	0.61 [17.4] (10)
Fe8	—	0.66 [18.7] (10)
Pb2	0.54 [15.2] (8)[c]	0.56 [15.9] (2)
Pb4	0.58 [16.6] (10)	—
Pb8	0.85 [24.0] (10)	—
Bi2	—	0.66 [18.6] (10)
Bi4	—	0.66 [18.6] (10)
Bi8	—	0.68 [19.1] (10)
Bi4:Pb4	0.58 [16.4] (10)	—
Bi4:soil	—	0.71 [20.1] (10)

[a]*See* Table 1.
[b]Sample size in ( ).
[c]*See* Table 1 for mean number of days survived.

No thing, disc-shaped flakes, characteristic of some Pb pellets in the final stages of erosion in a duck's gizzard (McAtee 1917), were found in any of the gizzards.

The average daily erosion rates for Pb pellets ranged from 1.5 percent (in 19.1 days) in Pb2 ducks to 2.2 percent (in 14.4 days) in the Bi4:Pb4 birds (Table 5). Cook and Trainer (1966) found that the erosion rate of Pb pellets in Canada geese was not influenced by the number of pellets.

Table 5. Mean weight (mg) of metal eroded from shot in each gizzard, the percent of the weight eroded per day in the gizzard, and the number in the gizzard at death.

Dose[a]	Mean weight of shot eroded[b]	Percentage weight of shot eroded per day[c]	Number of shot in gizzard at death
Control			
Fe2	292 (10)[d]	2.2	20 of 20
Fe4	477 (10)	1.8	40 of 40
Fe8	816 (6)	1.6	74 of 80
Pb2	158 (5)	1.5	12 of 20
Pb4	363 (6)	2.1	30 of 40
Pb8	422 (6)	1.6	66 of 80
Bi2	538 (6)	2.8	12 of 20
Bi4	1,029 (9)	2.6	36 of 40
Bi8	1,864 (5)	2.3	52 of 80
Bi4:Pb8	126 (7)[e]	0.7	31 of 40
	336 (5)[f]	2.2	27 of 40
Bi4:soil	(0)		0 of 40

[a]*See* Table 1.
[b]Based on number of ducks that retained all dosed shot at death.
[c]Based on number of shot in gizzard at death.
[d]Sample size in ( ).
[e]Bi shot.
[f]Pb shot.

Pb pellets in the same gizzard with Bi pellets eroded about three times faster than Bi pellets. The average daily erosion rates for 7 of the 10 Bi4:Pb4 ducks was 0.7 percent for Bi and 2.2 percent for Pb. These same ducks eroded an average of 126 mg of Bi (range 45–250) and 336 mg of Pb (range 220–430) prior to death.

For determining the amount of Pb eroded in the gizzards of ducks prior to their death from Pb poisoning, only ducks that retained all dosed shot were included. The average amount of Pb eroded for each group ranged from 158 mg for five Pb2 ducks (average survival 17.0 days) to 422 mg for six Pb8 ducks (average survival 11.3 days). Ducks died after eroding 100–740 mg of Pb. One Pb8 duck died 4 days post-dosing after eroding 100 mg of Pb, whereas another Pb8 duck died 17 days after dosing, when he had eroded 740 mg of Pb.

Iron. Thirty ducks dosed with Fe shot retained 95.7 percent (134 of 140 pellets) until the end of the 30-day study (Table 5). Each group of Fe-dosed ducks eroded an average of 1.6 to 2.2 percent of the weight of the shot per day and an average of 292 to 816 mg of Fe by Day 30 (Table 5). The daily erosion rates for Pb and Fe shot were similar, but ducks dosed with Pb shot died while the shot in their gizzards were large. Thus, direct comparisons of both daily and total rate of erosion are misleading unless the same number of days are used for Pb and Fe shot. Such a comparison was not possible in the present study.

Bismuth. Forty ducks dosed with only Bi shot retained 55.6 percent (100 of 180 pellets) of them until the end of the study (Table 5). These 40 ducks included 10 Bi4:soil birds that retained no pellets. The 30 ducks dosed with only Bi shot and without access to soil retained a lower percentage (71.4 percent, 100 of 140) of the pellets on Day 30 than did Fe-dosed ducks (95.7 percent) (Table 5).

In ducks dosed with only Bi and without access to soil, shot eroded at an average rate of 2.6 percent of its weight per day for 30 days, compared with 1.9 percent for Fe shot. These ducks eroded an average of 1,151 mg of Bi in 30 days, compared with 531 mg of Fe in Fe-dosed ducks. Thus, even though the retention rate was high for Bi shot after 30 days in ducks without access to soil, most of the Bi had disappeared from their gizzards. All 30 ducks dosed with Fe retained one or more shot and eroded an average of 55.8 percent of the weight in 30 days. The 22 ducks dosed with only Bi shot and without access to soil that retained one or more shot for 30 days eroded 78.1 percent of the weight. All 25 ducks that were dosed with only Pb shot and that retained one or more shot at death eroded an average of 27.1 percent of the weight in an average of 14.8 days (time of death).

As indicated under the discussion of Pb shot, Pb eroded approximately three times as fast as Bi when in the same gizzard. Bi shot in ducks dosed with only Bi shot and with no access to soil eroded at a higher daily rate (2.6 percent) for 30 days than did Bi shot in those ducks dosed with Pb and Bi (0.7 percent for 14.4 days). These differences would be larger if assessed over the same length of time because the average rate of Bi shot dosed alone included smaller and smaller shot as erosion occurred. Most of the Bi shot fragmented into many flakes by 30 days; thus, the surface for chemical/physical action possibly increased with time.

Importantly, by 30 days after dosing, Bi had essentially disappeared from the gizzards of ducks with access to soil and was reduced to small amounts in most ducks without access to soil. An average of only 22 percent of the weight of the Bi shot remained in recognizable "pellets" (mostly in disc-shaped pieces) in the gizzards after 30 days; however, by Day 30 there were countless tiny flakes of Bi in the gizzards of most ducks dosed with Bi shot. There also were many tiny bits of Bi in the small indentations on the surface of the grit. These bits were only visible under a binocular microscope. The flakes and fragments would probably erode or be voided, or both, soon after 30 days; however, the bits on the surface of grit might remain in the gizzard longer than the flakes and fragments.

Metal Residues

Lead. Pb residues in blood, liver and muscle were below detection limits (0.750 ppm) in all ducks not dosed with pb, except that the liver of one Bi4 duck had 1.52 ppm Pb (tables 6 and 7). Pb in the blood of ducks dosed with Pb increased sharply by Day 3, decreased by Day 9 and continued to decrease as long as the ducks survived. By Day 30, Pb levels in blood of the two surviving Pb2 ducks again were below the detection limit (Table 6). The highest mean blood Pb concentrations we found (20.6 ppm) were on Day 3 in Pb2 ducks. There was a negative relationship between the number of pellets dosed and the amount of Pb in the blood on Day 3, but these differences had disappeared by Day 9. There were no significant differences in the changes of Pb in the blood of ducks dosed with only Pb versus Bi4:Pb4 ducks (Table 6).

Pb levels in livers of Pb-dosed ducks varied from 50.7 to 84.8 ppm, but the only significant differences were that Pb2 ducks had lower Pb concentrations versus Pb4 and Bi4:Pb4 ducks ($P < 0.05$) (Table 7).

Table 6. Concentrations of Fe and Pb (ppm wet weight) in blood of game-farm mallards at intervals after dosing with Fe, Pb or Bi shot.

	Fe in blood					Pb in blood[b]				
Dose[a]	Day 0	Day 3	Day 9	Day 15	Day 30	Day 0	Day 3	Day 9	Day 15	Day 30
Control	473	471	470	470	490	<0.750	<0.750	<0.750	<0.750	<0.750
Fe2	460	438	439	453	460	<0.750	<0.750	<0.750	<0.750	<0.750
Fe4	472	458	463	465	492	<0.750	<0.750	<0.750	<0.750	<0.750
Fe8	473	453	457	471	492	<0.750	<0.750	<0.750	<0.750	<0.750
Pb2	463	364	169	253	410	<0.750	20.6	6.69	6.52	<0.750
			(9)[c]	(8)	(2)			(9)	(8)	(2)
Pb4	450	366	185	235		<0.750	19.1	7.16	6.85	
			(9)	(5)				(9)	(5)	
Pb8	462	354	164	198		<0.750	15.8	9.37	6.53	
			(7)	(6)				(7)	(6)	
Bi2	467	458	439	460	478	<0.750	<0.750	<0.750	<0.750	<0.750
Bi4	458	443	432	460	455	<0.750	<0.750	<0.750	<0.750	<0.750
Bi8	464	458	422	454	455	<0.750	<0.750	<0.750	<0.750	<0.750
Bi4:Pb4	477	352	185	201		<0.750	18.0	9.69	7.86	
			(9)	(8)				(9)	(6)	
Bi4:soil	472	478	446	464	508	<0.750	<0.750	<0.750	<0.750	<0.750

[a]*See* Table 1.
[b]Detection limit was 0.750 ppm.
[c]Sample size (number of surviving ducks) when fewer than 10.

Table 7. Concentrations of Fe and Pb in liver, muscle and bone of game-farm mallards.

	Fe			Pb[b]		
Dose[a]	Liver[c]	Muscle[c]	Bone[d]	Liver[c]	Muscle[c]	Bone[d]
Controls	589	50.4	24.4	<0.750	<0.750	4.48
Fe2	986	49.4	20.2	<0.750	<0.750	5.08
Fe4	1,160	43.2	31.1	<0.750	<0.750	5.81
Fe8	1,220	50.9	25.8	<0.750	<0.750	7.73
Pb2	2,420	109.0	21.4	50.7	1.20	241.0
Pb4	2,580	113.0	25.1	65.8	1.10	214.0
Pb8	2,050	93.7	20.4	60.9	1.31	229.0
Bi2	518	44.3	15.5	<0.750	<0.750	5.59
Bi4	717	44.3	18.7 (9)[e]	<0.750	<0.750	6.03
Bi8	546	52.0	13.7	<0.750	<0.750	3.19
Bi4:Pb4	3,170	104.0	20.6	84.8	1.25	174.0
Bi4:soil	631	43.5	32.5	<0.750	<0.750	9.80

[a]*See* Table 1.
[b]Detection limit was 0.750 ppm.
[c]Ppm wet weight.
[d]Ppm dry weight.
[e]Sample size in ( ) when fewer than 10.

Pb in muscle of ducks dosed with only Pb ranged from 1.10 ppm in Pb4 ducks to 1.31 ppm in Pb8 ducks. There was little difference in Pb concentrations in muscle of Pb4 ducks (1.10 ppm) versus Bi4:Pb4 ducks (1.25 ppm).

Pb in bone ranged from 3.19 ppm dry weight in Bi8 ducks to 241 ppm in Pb2 ducks. Pb levels in the bones of ducks dosed with only Pb were similar ($P > 0.05$), and were lower ($P < 0.05$) in Bi4:Pb4 ducks versus Pb2 ducks. Pb in bone was higher ($P < 0.01$) in Pb-dosed ducks than in all other groups. Bi might be responsible for the higher accumulation of Pb in the liver of Bi4:Pb4 ducks than in ducks dosed with only Pb (Table 7) and, thus, for the lower ($P < 0.05$) amount of Pb in bones of Bi4:Pb4 ducks versus Pb2 ducks. There were no significant ($P > 0.05$) differences in levels of Pb in bone among the ducks not dosed with Pb, including Bi4:soil versus Bi4, or between Bi4:Pb4 versus Pb4 ducks. Thus, ingested Bi shot had no effect on the amount of Pb in the bones of ducks, other than perhaps reducing Pb concentration in bone when both Bi and Pb shot were ingested at the same time. Because Pb in bones of ducks dosed with only Pb were higher (but only significantly higher in Pb2 ducks) than in Bi4:Pb4 ducks, future research might be worthwhile to clarify this possible relationship.

Iron. Fe in the blood of ducks not dosed with Pb showed no relation with either time or dose even though an average of 292 to 816 mg of Fe was eroded in the gizzards of these ducks (Table 6). Fe in the livers, muscle and bone of Fe-dosed ducks was not significantly different ($P > 0.05$) (Table 7); however, Fe concentrations were higher in livers of Fe-dosed ducks versus controls ($P < 0.05$).

Fe concentrations in liver and muscle of Pb-dosed ducks were higher ($P < 0.01$) than those in ducks not dosed with Pb (Table 7). Fe in blood of Pb-dosed ducks declined by Day 3, continued to decline to Day 9, and remained low but increased slightly by Day 15, the last day blood was collected from all but two Pb-dosed birds

(Table 6). The only two ducks dosed with Pb that survived to Day 30 had near normal levels of Fe by then. Fe in the blood of Pb-poisoned ducks follows a similar pattern to that of the hct. It is well documented that Pb interferes with the synthesis of heme in blood. As a result, hct and Fe in blood decline, and Fe increases in the liver and muscle of Pb-poisoned ducks, but not in bone (tables 6 and 7).

Bismuth. Because of difficulty analyzing Bi in biological samples, we had only a few results in time to be included in this report. Bi in the blood of nine Bi8 ducks on Day 3 was below the detection limit (3.00 ppm) and was 6.86 ppm in one duck. Bi in the blood of 10 Bi4:Pb4 ducks on Day 3 was below the detection limit. Bi concentrations in the muscle of 10 Bi8 and 3 Bi4:Pb4 ducks were below detection limits. The Bi level in the livers of two Bi8 ducks was below the detection limit, averaged 5.00 ppm (wet weight) in seven, and was 42.3 ppm in one duck. Bi levels in bone averaged 5.30 ppm (dry weight) in eight Bi8 ducks and was below the detection limit in four control, three Fe4, one Fe8, two Bi8, one Bi2, six Bi4 and one Bi4:soil ducks. Considering these low Bi levels, and based on references to Bi in mammals, we suspected that little of the Bi eroded in the gizzards was absorbed. We returned to the pens in which the ducks were confined during the study. Although the pens had been cleaned, we were able to collect small samples of feces from the underside of the wire in some pens. These feces were analyzed for Bi with the following results: three control pens, below the detection limit (3.50 ppm); three Bi8 pens, 10,737 ppm; two Bi4 pens, 4,870 ppm; and two Bi2 pens, 3,365 ppm, dry weight.

These feces were probably passed near the end of the study. Although the data allow only crude estimates, if we assume that the feces that were analyzed from the seven ducks dosed with only Bi shot and no soil in the pens were typical of ducks dosed with the same number of Bi shot, we can estimate the Bi excreted in the feces during the study. Sanderson and Anderson (1981) reported that female, captive, game-farm mallards on a diet of corn excreted 8.0 g (dry weight) of feces per duck per day. If we make calculations based on these data, Bi8 ducks excreted 1.4 times as much Bi as they eroded from the shot in their gizzards; Bi4 ducks, 1.1 times as much; and Bi2 ducks, 1.5 times as much. We do not claim accuracy for these calculations, but these estimates, plus the finding of almost no Bi in the blood, none in muscle, and minute amounts in liver and bones of ducks dosed with Bi, provide strong support for the speculation that most of the Bi eroded from the pellets in the gizzard was excreted in the feces without being absorbed.

We believe our results indicate that metallic Bi is not readily absorbed in the gastrointestinal tract of ducks. This belief parallels the assumption, based on inconclusive evidence, that Bi is not easily abosrbed in the gastrointestinal tract of mammals. Thus, although ducks in the present study were exposed to Bi at rates of 332 to 1,847 mg/kg of body weight over a 30-day period, we detected no adverse effects of the Bi.

Necropsy

All animals that died during the study belonged to the Pb-dosed groups. These ducks demonstrated wasting of muscle and a decrease in adipose tissue. The amount of muscle wasting was least among animals that died shortly after the start of the study and greatest among those that died late in the study. Affected internal organs included the spleen and liver, which decreased in size. Testis size varied among the animals. No gross diseases other than Pb poisoning were found in the ducks, although one Pb4 duck and one Bi4:Pb4 duck had moderate amounts of fibrous adhesions of the intestinal tracts. Ducks that died shortly after the start of the study (acute Pb poisoning) tended to have more coelomic and pericardial fluid. Ducks dying late in the study (chronic Pb poisoning) tended to have enlarged gall bladders and little coelomic fluid. Several ducks examined late in the study had boluses of feathers in their intestinal tracts.

All nine ducks (three control, three Bi8 and three Fe8) examined at the end of the study had normal amounts of muscle and abundant fat depots. Internal organs were within normal limits. No significant differences were observed among the three groups of ducks.

Conclusions

1. All control, Fe-dosed and Bi-dosed ducks survived to the end of the study, whereas 95 percent of the Pb-dosed birds died in an average of 15.1 days after dosing.
2. Four Number two Bi pellets dosed with four Number two Pb pellets provided no detectable protection from the adverse effects of Pb on body weight.
3. When administered to the same bird, Pb pellets were voided more frequently than Bi pellets, perhaps because the Pb shot eroded about three times faster (and thus were smaller) than Bi shot.
4. When dosed separately, Bi and Pb shot were voided at about the same rate, which was much faster than the rate for Fe. Pb-dosed ducks died in an average of 15.1 days after dosing, whereas Fe-and Bi-dosed ducks were alive at the end of the study (Day 30).
5. When Bi was dosed alone, it eroded nearly four times as fast as when dosed with Pb.
6. When dosed separately, Bi eroded faster than Fe and Pb. Fe and Pb eroded at about the same rate, but the Pb-dosed ducks survived an average of 15.1 days, whereas erosion rates for Bi and Fe are based on 30 days in the gizzards.
7. By Day 30, Bi had essentially disappeared from gizzards of ducks with access to soil and was reduced to small amounts in ducks without access to soil.
8. Bi shot had no detectable effects on hct. Thus, Bi provided no protection from the adverse effects of Pb on hct.
9. The only significant difference ($P < 0.05$) in mean liver weights among treatment groups was that livers of ducks dosed with two Pb shot weighed less than livers of Bi-dosed ducks with access to soil. Ducks dosed with two Pb pellets survived longer than other Pb-dosed ducks. Thus, their livers had more time to be affected by Pb toxicosis.
10. Blood Pb levels were similar in Bi4 ducks versus Bi4:Pb4 ducks. Liver Pb levels were higher in the Bi4:Pb4 ducks versus other Pb-dosed ducks, suggesting that Bi might stimulate the removal of blood Pb by the liver.
11. Bi shot in a duck's gizzard erodes readily, but most of the eroded metal is directly excreted in the feces, with only minor amounts absorbed.
12. Two, four or eight Number two Bi shot, or four Number two Bi shot, when ducks had access to soil, had no adverse effects when administered to ducks.

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References

Abbracchio, M. P., W. Balduini, A. Cavallaro, P. Adamoli, M. Fittipaldi, F. Muzio, S. Malandrino, and F. Cattabeni. 1985. Brain and blood levels of bismuth after oral or parenteral administration of tripotassium-dicitrato bismuthate to rats. NeuroToxicology 6(3):139–144.

Adler, F. E. W. 1944. Chemical analyses of organs from lead-poisoned Canada geese. J. Wildl. Mgmt. 8(1):83–85.

BMDP. 1990. Statistical software manual: 1990 software release. W. J. Dixon, Chief Ed. Univ. California Press, Berkeley.

Beer, J. V. and P. Stanley. 1965. Lead poisoning in the Slimbridge wildfowl collection. The Wildfowl Trust, Ann. Rept. 16:30–34.

Cook, R. S. and D. O. Trainer. 1966. Experimental lead poisoning of Canada geese. J. Wildl. Mgmt. 30(1):1–8.

Dipalma, J. R. 1988. Bismuth toxicity. Amer. Family Physician 78(5):244–246.

Forbes, R. M. and G. C. Sanderson. 1978. Lead toxicity in domestic animals and wildlife. Pages 225–277, *in* J. L. Nriagu, ed., Biogeochemistry of lead. Part B. Biomedical effects. Elsevier/North Holland Biomedical Press B.V., Amsterdam. 397 pp.

Hanzlik, P. J. and E. Presho. 1923. Comparative toxicity of metallic lead and other heavy metals for pigeons. J. Pharmacol. Exp. Thera. 21(2):145–150.

Heppel, L. A. and A. Kornberg. 1946. Influence of iron salts on the toxicity of lead. Proc. Exp. Soc. Biol. and Med. 61(3):220–223.

Lide, D. R., ed. 1990. CRC handbook of chemistry and physics. CRC Press, Boca Raton, Ann Arbor, Boston. 2,325 pp.

McAtee, W. L. 1917. The shedding of the stomach lining by birds, particularly as exemplified by the Anatidae. Auk 34(4):415–421.

O'Halloran, J., P. F. Duggan, and A. A. Myers. 1988. Biochemical and haematological values for mute swans (*Cygnus olor*): Effects of acute lead poisoning. Avian Pathology 17:667–678.

Ross, J. F., Z. Sahenk, C. Hyser, J. P. Mendell, and C. L. Alden. 1988. Characterization of a murine model for human bismuth encephalopathy. NeuroToxicology 9(4):581–586.

Sanderson, G. C. 1979. Lead and soil. A saving combination? Ducks Unlimited 43(5):26–27, 74, 76, 78.

Sanderson, G. C. and W. L. Anderson. 1981. Waterfowl studies at Lake Sangchris, 1973–1977. Illinois Nat. Hist. Survey Bull. 32(4):656–690.

Sanderson, G. C. and F. C. Bellrose. 1986. A review of the problem of lead poisoning in waterfowl. Illinois Nat. Hist. Survey Special Publ. 4. 34 pp.

Sanderson, G. C., H. W. Norton, and S. S. Hurley. 1981. Effects of ingested lead—iron shot on mallards. Illinois Nat. Hist. Survey Biol. Notes 115. 15 pp.

Six, K. M. and R. A. Goyer. 1972. The influence of iron deficiency on tissue content and toxicity of ingested lead in the rat. J. Lab. Clin. Med. 79(1):128–136.

Slikkerveer, A. and F. A. de Wolff. 1989. Pharmacokinetics and toxicity of bismuth compounds. Med. Toxicol. Adverse Drug Exp. 4(5):303–323.

U.S. Fish and Wildlife Service. 1986. Migratory bird hunting: Nontoxic shot approval procedures. Federal Register / 51(225):42,098–42,102.

Windholz, M., ed. 1976. The Merck index. Merck & Co., Inc., Rahway, New Jersey.

Woods, J. S. and B. A. Fowler. 1987. Alteration of mitochondrial structure and heme biosynthetic parameters in liver and kidney cells by bismuth. Toxicol. Appl. Pharmacol. 90:274–283.

Special Session 8. *The Dilemma of the National Wildlife Refuge System*

Chair
WILLIAM C. REFFALT
The Wilderness Society
Washington, D.C.

Cochair
DON BARRY
World Wildlife Fund
Washington, D.C.

Opening Remarks

William C. Ashe
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Thanks for inviting me here today. I am always eager to talk about the compelling issues that face us in the '90s, and no issues are more compelling than those of the National Wildlife Refuge System and the dilemmas it faces.

I want to say, however, that before I create a dilemma for anybody else, these are my views, and they are empirical in their formulation—which is to say, they are largely based on observation, experience and the "school of hard knocks."

I find the word entitling this session, "dilemma," fascinating and appropriate. "Dilemma," Webster says, is "a situation involving choice between equally unsatisfactory alternatives."

Unfortunately, we have been confronted by too many unsatisfactory alternatives lately in our burgeoning Refuge System. It is the price, I suppose, of the fact that we have indeed come a long, long way from modest beginnings. . . .

The System began on March 14, 1903, with an Executive Order by President Theodore Roosevelt designating Pelican Island in Florida the nation's first federal wildlife refuge. A warden, Paul Korgel, was appointed to protect the island. That was the System in 1903—3 acres and one FTE—a humble beginning. However, Ira Gabrielson later wrote: "One might reasonably say that on this small beginning has been built present wildlife conservation policies and programs."

Other reservations from the public domain followed. Most were small islands set aside to protect colonial nesting birds, shore birds and sea birds. Several were refuges for big game to protect bison, longhorns, etc. Emphasis on waterfowl additions came later after passage of:

- the Migratory Bird Treaty Act of 1918;
- the Migratory Bird Conservation Act in 1929; and
- the Migratory Bird Hunting Stamp Act in 1934.

With this legislation, the System really started to grow.

(Parenthetically, let me repeat those dates—1918, 1929 and 1934. For the history buffs among you, those dates conjure up the "war to end all wars," and desperate economic hardship . . . a time when FDR said "the only thing we have to fear is fear itself." Yet I consistently marvel at our forefathers—and mothers—who had the foresight, the vision, to care for *our* future. Note that I didn't say for the future of wildlife, for I'm convinced we do this selfishly, for ourselves. As Aldo Leopold said "there are some who can live without wildlife—and some who cannot." We, who are in this profession, and the many who champion our cause, are those who cannot live without our wildlife. It is this clear desire to live with wildlife that moved us toward the Refuge System in the first place. But I digress.)

By 1941, we had 272 refuges containing over 17 million acres.

More legislation came in the 1950s and 1960s:

- the Fish and Wildlife Act in 1956;
- the Refuge Recreation Act in 1962;
- the National Wildlife Refuge Administration Act in 1966; and
- the Endangered Species Act in 1966.

Each of these Acts impacted the management policies and acquisition priorities of refuges.

Beginning in the late 1960s, Land and Water Conservation Fund dollars were available for acquisitions authorized by the Fish and Wildlife Act, Recreation Act and Endangered Species Act, so the focus of acquisition changed. More biologically diverse areas were acquired. More refuges were located near urban areas. Growth continued. By 1975, there were 367 refuges containing over 32 million acres.

The big growth in the Refuge System, of course, came in 1980 with the passage of the Alaska National Interest Conservation Act, affecting over 76 million acres. Huge refuges were established, some over 19 million acres in size, with entire ecosystems involved. At the end of the 1980s, the Emergency Wetlands Resources Act and North American Wetland Conservation Act were adopted. So, today, the Refuge System statistics are:

- 478 refuges through 1991–and more in the pipeline;
- at least one refuge in every state;
- more than 90 million acres;
- more than 20 million acres in wilderness;
- more than 3.5 million acres in national natural landmark areas; and
- almost 2.5 million acres in research natural areas.

The National Wildlife Refuge System is, without question, the world's largest, most diverse, most valuable collection of wildlife lands. And, equally important, as former Assistant Secretary of the Interior, Nat Reed, once said: "they are managed by men and women whose commitment in the face of adversity is unsurpassed. . . ."

That's the good news!

The other side of the coin is that the Refuge System has real problems (some of which you will discuss later), faces more problems and all will become much more serious in time if positive actions are not taken—and soon! What are the causes of the Refuge System's dilemma?

First, in my judgment, the dilemma reflects overall national problems. Rising population, increasing demands, and changing demographic patterns mean a dwindling habitat base that collectively increase pressures on refuge lands and staff.

Contaminant problems—buried septic systems, gasoline tanks, household refuse—are ubiquitous. Water, clean and in good supply, is no longer just a western issue.

Also, today, when people see a large open space, publicly owned and seemingly unused, they want a piece of it. The general public is largely uneducated about fish, wildlife, and their needs. Conflicting philosophical and ideological views affect virtually all issues—which tends to put lawmakers and decision makers into a political coma. Thus, good laws are not passed. Sound programs and actions are not undertaken and reason is lost.

Second, in my judgment, the dilemma of the System lies within the U.S. Fish and Wildlife Service (FWS) and the Department of Interior—an old problem of support, direction and leadership. For several decades now, we have been struggling to determine what the System is, what its role is and just what it should be doing. The struggle continues.

The Refuge System is the largest activity in the FWS—entertaining one-third of its budget, one-third of its employees—but many of its people complain that it is so layered down in the organization that the system has limited visibility, suffers from lack of recognition and has lost its direction. Resources, they say, have not kept up with responsibilities and, internally, it has lost its ability to compete with other units of the Service.

There have been two comprehensive studies of the National Wildlife Refuge System in the past 25 years: the Leopold Report, in the late 1960s, completed by five of the most respected and most experienced wildlife professionals of their day, and the Wildlife Refuge Study Task Force report, done in the late 1970s. Not surprisingly, the two reports covered the same ground, and came up with the same recommendations overall on acquisition, development, administration, planning, biodiversity, funding, compatibility, hunting, water rights, grazing, disease threats, pesticides, public use and education.

Both reports were excellent, containing sound recommendations. The Leopold Report included a "Philosophy for the Refuge System," which should be read and re-read by refuge managers and others interested in the System. The recommendations of these reports were never effectively implemented, nor, in my judgment, taken seriously at high levels.

Both reports emphasized the need for refuge planning. However, despite its great need, the FWS has not come to grips with developing a comprehensive, coordinated and consistent refuge planning effort. Planning, well done, prevents and solves problems. It also can be the vehicle to develop sound budgets and sound arguments for funding. Refuge 2003, which Rob Shallenberg will discuss shortly, is a good start—though the effort must be carried down to the individual refuge, as needed, and done in a consistent and planned manner. The System is unplanned.

Third, in my opinion, the dilemma of the National Wildlife Refuge System is that it has no unified, supportive constituent voice. Oh, it has many groups interested in what it does, or interested in utilizing its land, resources or recreational opportunities, but, more often than not, these groups are at cross purposes about what should be done. That is why I doubt any meaningful refuge legislation will be passed in the near future. (I hope I'm wrong.) On the other hand, when constituent groups do agree—say, for example, on habitat acquisition—things get done.

I do not observe a single, powerful, persuasive conservation voice whose primary purpose is support of the National Wildlife Refuge System. We need one.

But this brings me to my final dilemma—the unprecedented growth in the last half-dozen years (some 15 percent!). Growth, to be sure, but without a corresponding growth in operating dollars or staff. This is not only straining the System, but draining the energy of dedicated employees who are continually told to do more with less.

Finally, its problems notwithstanding, there is a large, functioning national Wildlife Refuge System. And, thanks to the work of its field staff, it is reasonably well managed.

The Refuge System needs more recognition—internally and externally. It needs more support in its activities—internally and externally. It needs better planning and clearer direction. The System should provide leadership in programs of natural diversity, non-game management, private lands assistance and endangered species activities, as well as steadfastness in its stewardship responsibilities.

Overall, I see the System as an underutilized resource in the Fish and Wildlife Service. It needs more imagination and a more pro-active posture. There are things than can be done on refuges, and with refuges, that cannot be done elsewhere. One example is environmental education. There is a fundamental lack of knowledge about wildlife in America, and nowhere is that problem more pronounced than in our urban areas. And nowhere in our cities is it more pronounced than with our minority and elderly groups—our fastest growing populations. We have refuges in or near many of our large cities. But how do we reach out to these important groups? Where should we locate our visitor centers and concentrate our educational programs to serve all of our constituencies? Thought and good planning will provide the answers.

Our job, therefore, to overcome the dilemma is to replace the choice of unsatisfactory alternatives with satisfactory alternatives, and to be more innovative and more imaginative in our problem-solving. As it always has been, the past is merely the prologue.

Refuges 2003—A Plan for the Future

Robert Shallenberger
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Introduction

As we rapidly approach the nineteenth anniversary of the National Wildlife Refuge System, it is appropriate that we pause to reflect on its origins and its future. The Refuge System is, without question, the most spectacular network of lands and waters devoted principally for the conservation of fish and wildlife. Nearly 500 refuges comprise this "string of pearls" that now reaches all states and five territories. If there was ever a priceless legacy to conserve for future generations, this is it.

The conveners of this session chose the title, "The Dilemma of the National Wildlife Refuge System." I prefer to substitute the word "challenge." First and foremost, our challenge is to be wise stewards of the land . . . to leave it at least as rich and productive as it was when we took responsibility for it. Our challenge is to maintain the integrity of each refuge and the Refuge System as a whole, when faced with the growing abuse of neighboring lands and waters and the dramatically increasing human population. Our challenge is to balance competing demands to use the land, and to reconcile short-term, local interests with long-term, national objectives. It is with these challenges in mind that the Fish and Wildlife Service has embarked on an ambitious planning process entitled "Refuges 2003—A Plan for the Future." This project will chart a course for the Refuge System into the next century.

Planning Considerations

Refuge System History

We begin this planning process with the need to look back at the rich history of the Refuge System, for its future will be intimately tied to its past. The Refuge System has its origins at the turn of this century. Mounting public concerns about the decline of once-abundant wildlife led a coalition of conservation organizations to promote the concept of protected lands, initially for migratory birds. In 1903, Pelican Island was set aside by executive order. Within a decade, more than 50 protected areas had been set aside from the public domain for wildlife. In 1924, the first purchase of private land for refuges was authorized.

In 1934, the Migratory Bird Conservation and Hunting Stamp Tax Act provided a source of funds to buy additional migratory bird habitat. Other refuges were established on former Resettlement Administration lands and as overlays of Bureau of Reclamation projects. Acquisition continued under new authorities, such as the Fish and Wildlife Act of 1956 and the Endangered Species Act of 1966. The Game Range Act of 1976 transferred large blocks of Bureau of Land Management lands. The largest addition to the Refuge System resulted from the Alaska National Interest Lands Conservation Act of 1980, creating 40 million acres of new refuges and expanding existing refuges by nearly 14 million acres.

Several legislative mandates also have affected both the administration and management of lands in the Refuge System. The Refuge Recreation Act of 1962 authorized compatible public recreation. The National Wildlife Refuge System Administration Act of 1966 consolidated lands with varied legislative history into the Refuge System and strengthened the "compatibility standard." The Endangered Species Act, the Clean Water Act, the Clean Air Act and the Wilderness Act are additional examples of statutes which have greatly influenced the way we do business.

Departmental and Service Policy

Over the nearly 90 years since the first refuge was established, the administrative policies that influence management of the Refuge System also have evolved. The primary source for current refuge management policy and practices is found in the two volume *Refuge Manual.* This manual defines the Refuge System *mission* as follows: "To provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity and location to meet society's needs for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available." The manual further defines four Refuge System *goals*:

1. to preserve, restore, and enhance in their natural ecosystems (when practicable) all species of animals and plants that are endangered or threatened with becoming endangered;
2. to perpetuate the migratory bird resource;
3. to preserve a natural diversity and abundance of fauna and flora on refuge lands; and
4. to provide an understanding and appreciation of fish and wildlife ecology and man's role in his environment and to provide refuge visitors with high quality, safe, wholesome, and enjoyable recreational experiences oriented toward wildlife to the extent these activities are compatible with the purposes for which the refuge was established.

Servicewide policy was most recently articulated in the 1991 document entitled "VISION for the Future." This document establishes a Service mission "to provide leadership to achieving a national net gain of fish and wildlife and the natural systems which support them." The Refuge System plays a critically important role in the achievement of this mission.

Public Input

From the first outcries that led to the Pelican Island executive order, the evolution of the Refuge System has been directly influenced by public interests. Indeed, the constituency that cares passionately about the Refuge System has evolved with it. In some cases, public and Congressional input has been quite formal.

In 1968, Secretary of the Interior Stewart Udall appointed the Advisory Committee on Wildlife Management, chaired by A. Starker Leopold. His report, "A Study of the National Wildlife Refuge System," included many recommendations for future management. In 1977, Assistant Secretary Robert Herbst established the Wildlife Refuge Study Task Force, with representation both within and outside government. Their report, published in 1978, also suggested actions to enhance Refuge System management. The most recent task force review of the Refuge System has been the Commission on New Directions for the National Wildlife Refuge System, appointed by Defenders of Wildlife in 1990. Their report was released in March, 1992. Several General Accounting Office (GAO) studies over the last decade also have influenced the Refuge System. Topics have included the management of fish and wildlife resources (1981), economic uses of refuges (1984), contaminants on refuges (1987) and the management of secondary uses (1989).

Origins of Refuges 2003

This planning process had its origins nearly 20 years ago, when the Service decided to develop an Environmental Impact Statement (EIS) on the Refuge System. The Final EIS on "Operation of the National Wildlife Refuge System" was published in 1976. It described the current program as projected through 1985 and compared it with several alternatives, ranging from "mothballing the System" to a major expansion of all activities. It also explored the concept of a separate National Wildlife Refuge Service and management of the Refuge System by other agencies. At the time this document was published, there were 367 refuges in the Refuge System.

The 1976 EIS identified the need for a 10-year update. That process began in February 1986, with publication of a notice of intent to prepare a second EIS. Eleven public meetings were held to gather input. Three issues topped the list of concerns raised by the public: hunting, natural diversity and contaminants. A draft EIS was published in November 1988. It contained four Management alternatives, each reflecting a different balance of activities: (1) current program; (2) increased recreational and economic uses; (3) restrictive, "hand off" management; and (4) the current management program without hunting, trapping and fishing.

The Service received over 33,000 comments on the 1988 Draft EIS most of which focused on single issues. Many of those who commented felt the EIS failed to address all the issues identified in scoping, and provided insufficient opportunities for public input. Commenters also felt that the Service did not consider a reasonable range of alternatives or fully evaluate the environmental consequences. After review of this input, the Service decided in December 1989 to withdraw the 1988 EIS and start the process again.

Refuges 2003—How Far Have We Come and Where Are We Headed?

One of the earliest decisions in the "Refuges 2003" planning process was to develop an "issue-driven" plan and EIS. Up to this point, public input had been overwhelmingly focused on significant issues of concern. Building the plan/EIS around these issues would permit the public to identify and compare how specific issues of interest would be addressed under various management alternatives. Using this approach, the planning team initially identified 17 key issues. With additional input along the way, three more issues were added to the list. The public has been drawn into the planning process through a series of newsletters, including one designed as a workbook to gather specific information. In October 1990, representatives of 41 major interest groups were invited to a workshop to identify a range of management options for each issue. In the spring of 1991, 31 public meetings were held around the country to gather additional public input. Collectively, the information received was used by the planning team to develop an array of nine management alternatives, including the current operation of the Refuge System, as projected to the year 2003. This alternative (the "no action" option) becomes the benchmark against which the characteristics and consequences of other alternatives can be compared.

The Draft "Refuges 2003 Plan/EIS" will be released for public review and comment in June 1992. It will identify the Service's "Preferred Alternative" and will compare the environmental consequences of all nine alternatives. Soon after release of the document, a second series of public meetings will be held at various locations around the country to gather public comment. Information received will be reviewed, and used, as appropriate, to modify the Service's Preferred Alternative and to prepare the Final Plan/EIS, to be released by the end of 1992.

Refuges 2003—What It Will Do and What It Will Not Do

Despite the comprehensive nature of this planning process, and the extensive public involvement which has occurred, "Refuges 2003" will *not* please everyone. The diversity of public opinion on several controversial issues is simply too great to expect this level of satisfaction. Also, this document will *not* be refuge-specific, either in the description of alternatives or in the evaluation of environmental consequences. It is a "programmatic" EIS, designed to establish focus and direction for the Refuge System, not to define specific management programs and activities on individual refuges. That is the role of plans and NEPA documents subsequently developed at the refuge level.

The Preferred Alternative in "Refuge 2003" will set the tone for future management of the Refuge System and will clarify Service policy and priorities as it applies to specific issues. Readers who are familiar with the history of the Refuge System will note a significant programmatic change in some areas, but it will be evolutionary rather than revolutionary. *Full* implementation of the Service's Preferred Alternative would require substantial increases in funding and staffing, but significant progress towards the objectives of this alternative can be accomplished if recent funding trends continue over the next decade.

What are the Issues

Twenty key issues were selected for detailed consideration in "Refuges 2003." I will briefly describe each issue and the approach to each issue that will be reflected in the Service's Preferred Alternative. As the Draft Plan/EIS is still undergoing internal review, the Preferred Alternative may change somewhat before it is printed for public release. The Draft Plan/EIS will include a more detailed description and evaluation of each issue.

1. *Administration of the Refuge System.* Widely disparate views have been expressed regarding the level of centralized direction for the Refuge System and the procedures for individual refuge planning. The Preferred Alternative would not involve substantive changes in Service organization, but it would include a greater role for the Division of Refuges in coordination of national policy development and implementation. It also would include improvements in data management and reporting. Policy for refuge planning would be improved,

including provisions for greater public involvement, and the rate of planning would increase.

2. *Biological diversity*. The role of the Refuge System in the conservation of the nation's biological diversity has emerged as a prominent issue in this planning process. Controversy has been fueled by perceptions, on the one hand, that refuge programs have been oriented too much towards single species. Equally strong opposing views reflect concerns that enhanced management for biological diversity would impact traditional uses, particularly hunting. The Service's Preferred Alternative would include measures to enhance the Refuge System's contribution to the conservation of biological diversity, both in the management of existing refuges and in the acquisition of new lands. Inventory, monitoring, research, education and management programs relating to biological diversity would be accelerated. Priority emphasis would be placed on those refuges (existing and potential) that include areas of high species diversity, imperiled biological communities or corridors which link important habitats. Programs at other refuges may be unaffected. System-wide adverse impact on single species programs is not envisioned, as a very clear mandate for waterfowl and endangered species management remains undiminished.
3. *Compatibility*. The recent flurry of attention relating to the compatibility of "secondary" uses stems largely from a 1989 General Accounting Office review of the Refuge System. Refuge managers are bound by law to ensure that allowed uses are compatible with purposes for which their refuge was established. Recent Service policy, once fully implemented, will extend the compatibility determination process to include the four Refuge System goals and individual refuge objectives. Other initiatives are underway to improve guidance on the setting of refuge objectives, to improve tracking of progress in resolving identified use problems and to enhance training for refuge managers. Under the Service's Preferred Alternative, these initiatives would continue and procedures would be implemented to minimize the problems associated with refuge uses. Greater attention also would be directed toward the systematic evaluation of allowed-use impacts on fish and wildlife resources.
4. *Environmental contaminants*. A 1987 General Accounting Office report on refuge contaminants attracted considerable public attention to a problem refuge managers have been trying to resolve for decades . . . the insidious contamination of refuge habitats from sources, both within and outside refuge boundaries. The Preferred Alternative would accelerate refuge contaminant investigations and remediation activities. Long-term monitoring methodology, currently under development and testing, would be implemented. Air quality monitoring would be initiated on the Service's Class 1 wilderness areas.
5. *Cultural resources*. The Refuge System is richly endowed with important archeological and historic resources. To date, most inventory work has been associated with projects that impact the soil or natural events that have exposed critically important sites at refuges such as Stillwater and Malheur. The Preferred Alternative would increase the systematic inventory and evaluation of cultural resources and the protection of identified sites on Service lands.
6. *Data collection, interpretation and management*. Refuge land management decisions are driven by biological data gathered through monitoring and research activities. These data also make possible the systematic review and management

of allowed uses. The Preferred Alternative would improve the processes used for data collection and management. In addition, Service research focused on refuge management issues would be accelerated.

7. *Economic uses*. A wide variety of economic activities (grazing, haying, farming, oil/gas production, concessions, etc.) are underway on national wildlife refuges. In many cases, these uses occur where the Service has acquired only surface rights or wetland easements on private lands. In other cases, these activities are managed to achieve specific wildlife habitat objectives. Some refuges have allowed previously occurring economic uses to continue where they do not adversely effect refuge wildlife. Unfortunately, there also are situations where economic uses are causing resource management problems. The Preferred Alternative would seek to phase out economic uses that do not contribute to refuge management objectives, beginning most aggressively with those believed to adversely impact habitat.
8. *Educational and interpretive opportunities*. National wildlife refuges are uniquely suited to provide a wide variety of educational and interpretive opportunities for the visiting public, both passively and in structured classroom type programs. The Preferred Alternative would enhance and accelerate refuge education activities, with emphasis on ecological principles, resource management, biological diversity and related subjects. ''Watchable Wildlife'' opportunities would be developed and enhanced at several refuges.
9. *Fisheries management*. Although only four refuges have been established specifically for fish, nearly 300 refuges support a wide variety of fishery resources and aquatic habitats. Fishery management plans have been developed for 93 of these refuges, typically in corporation with Fishery Assistance Offices. The Preferred Alternative would accelerate the development and implementation of fishery management plans.
10. *Habitat management*. Refuge managers employ a wide variety of methods of manage habitat, ranging from highly manipulative processes (e.g. grazing, burning, haying, forest cutting, periodic flooding) to ''hands off'' monitoring of natural processes. Management may be directed at single species, groups of species or natural communities. The Preferred Alternative would stress the importance of collecting the biological data necessary to drive intelligent habitat management decisions. Greater emphasis would be placed on the perpetuation or restoration of natural ecological processes, where they do not conflict with refuge-specific purposes. Biological diversity among habitat types in the Refuge System would be enhanced. Partnership activities with private landowners and other public land managers that support refuge objectives would be encouraged.
11. *Hunting, trapping and fishing*. Of all issues which have surfaced during public involvement for ''Refuge 2003,'' recreational hunting has been, by far, the most controversial. At this time, 267 refuges and Wetland Management Districts are open to recreational hunting. Refuge trapping also is hotly debated. A total of 195 refuges and Wetland Management Districts report trapping programs underway. Most refuge trapping programs are designed to achieve a population management objective, such as to limit predation or destruction of dikes. In contrast to hunting and trapping, recreational fishing on refuges has provoked comparatively little controversy. A total of 251 refuges and Wetland Management Districts are open to recreational fishing. Some increase in the number of

refuges open to recreational hunting, trapping and fishing would occur under the Service's Preferred Alternative, in large part, through the acquisition of new lands. The Service also would enhance the quality of existing programs while ensuring compatibility with refuge purposes and minimizing conflicts with other users.

12. *Refuge land protection.* The Refuge System has grown significantly in recent decades, both through the establishment of new refuges and the expansion of older units. In the 1987–1991 period alone, 33 new refuges were added to the Refuge System. This growth has broadened the diversity of units within the Refuge System and significantly increased public-use opportunities. Land acquisition would accelerate under the Service's Preferred Alternative, with expanding emphasis on the conservation of biological diversity, protection of important aquatic systems and the establishment of urban refuges with exceptional public-use potential. Efforts to acquire inholdings and complete ongoing refuge acquisition projects also would increase.
13. *Nongame species management.* Most of the earliest refuges were established principally for nongame migratory bird species, and many of the more recently established waterfowl refuges provide important habitat for diverse wetland species as well. Under the Service's Preferred Alternative, refuge nongame management programs would expand, with emphasis on species or species groups in jeopardy, such as neotropical migratory birds. Greater focus of land acquisition on imperiled biological communities and areas of high species diversity would result in a more significant role for the Refuge System in nongame species management. Inventory, monitoring and research activities relating to nongame species also would increase.
14. *Pesticide use.* Pesticide use on refuge lands is, for the most part, associated with cooperative farming programs that provide food resources for refuge wildlife. Current policy mandates an integrated pest management (IPM) approach, which combines biological controls, physical and cultural methods, and pesticides. The type and amount of pesticide used is controlled by law, as well as by the Service and Departmental policies and regulations. The Preferred Alternative would expand the use of IPM approaches in the Refuge System, with an ultimate goal to eliminate all unnecessary pesticide use.
15. *Predator management.* Predator management programs are underway on approximately 100 refuges and Wetland Management Districts. Lethal and/or nonlethal methods are employed. Techniques which separate potential predators from desired species (e.g., fencing, nest platforms, nesting islands) are preferred, but may be very costly and are effective only in limited situations. Predator removal also has been used in select locations (e.g., arctic foxes from islands in Alaska Maritime National Wildlife Refuge). Under the Service's Preferred Alternative, greater emphasis would be placed on non-lethal predator management. Priority would be given to protection of threatened and endangered species.
16. *Recreational activities.* Wildlife-oriented recreation is a legitimate goal of the Refuge System when it is compatible with the purposes for which a particular refuge has been established. With this in mind, potential uses must be evaluated on a case-by-case basis. Wildlife-oriented recreation visits to the Refuge System would be expected to increase significantly under the Preferred Alternative, as the quality and diversity of opportunities were enhanced. In contrast, non-

wildlife-oriented uses would be reduced or phased out, particularly where they conflict with more desirable uses or wildlife management objectives.

17. *Special management areas.* Much of the land within the Refuge System derives additional recognition and protection through the use of "special management" designations, such as Research Natural Areas, Wild and Scenic Rivers, National Historic Landmarks and National Natural Landmarks. The Refuge System alone has 75 designated wilderness areas, totalling 20.6 million acres. Under the Service's Preferred Alternative, wilderness area designation would increase, as would the use of other designations subject to nomination by the land-managing agency.
18. *Threatened and endangered species.* The Refuge System provides habitat for at least 162 species of animals or plants currently listed as threatened or endangered. In fact, 34 refuges have been established specifically for endangered species. Under the Preferred Alternative, the Refuge System role in endangered species conservation would grow appreciably, with the acquisition of new lands, expansion of existing refuges and accelerated implementation of recovery programs on refuge lands. Greater emphasis would be placed on the protection of listed plants and candidate species.
19. *Water rights.* Water is the lifeblood of most refuges in the System, yet, legal rights to and adequate supplies of water are not assured, particularly in the western states. Many refuges lack the water-use data needed to quantify their water rights and prove continued beneficial use. Under the Preferred Alternative, Service efforts to quantify, adjudicate, acquire and/or otherwise protect refuge water right would be accelerated.
20. *Waterfowl management.* The Refuge System plays a critically important role in the management of wetlands and associated uplands as breeding, migration and wintering habitat for waterfowl. Both natural and highly manipulated habitats contribute toward this objective. Waterfowl hunting did not become a significant recreational activity in the Refuge System until the "Duck Stamp Act" was amended in 1949, to open up to 25 percent of certain refuges to hunting. Later amendments increased the percentage to 40 percent and authorized the purchase of Waterfowl Production Areas that would not be subject to the "inviolate sanctuary" provisions of the Act. Under the Preferred Alternative, the acquisition and management of waterfowl refuges would continue to be an important Service objective. Waterfowl hunting opportunity would increase through the acquisition of new lands. Greater emphasis would be directed at hunt quality, hunter ethics and the resolution of conflicts between hunting and non-hunting visitors.

Conclusions

The Process to develop "Refuges 2003" has been underway for over a year, and several months of work lie ahead. So what more have we learned about the challenges that face us? We have learned that there is a very broad cross section of the public that cares passionately about the future of the Refuge System, but this cross section includes people who differ widely in their views. Fortunately, there appears to be far more about which we agree than issues that separate us. Our challenge is to build on this common ground and create partnerships to achieve the objectives we share.

We also have learned that there is a much larger group of people who do not even know the Refuge System exists. Our challenge here is to inform and educate this public who, like all of us, share "ownership" in the Refuge System and are stakeholders in its future.

Wise stewardship requires that we act in the present, while remaining aware of the future and sensitive to the past. Some have characterized the Refuge System as an ad hoc collection of lands and waters, brought together by a loose set of unrelated authorities, and set aside for many different purposes. Yet, the real strength of the Refuge System *is* this diversity . . . the wildlife it serves, the habitats it protects and the public use opportunities it provides. Our challenge is to cultivate that diversity and manage it with care.

Water Rights for Wildlife: The Challenge Facing Western Wildlife Refuges

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Introduction

The U.S. Fish and Wildlife Service (Service) is the principal federal agency responsible for protecting and managing the nation's fish and wildlife resources. However, the nonmanaged habitat for these resources is disappearing at an alarming rate, as illustrated by the following statistics:

- From the 1780s to the 1980s, the lower 48 states lost an estimated 53 percent of their original wetlands (Dahl 1990).
- The Central Valley of California is the most important waterfowl watering area in the Pacific Flyway, supporting 60 percent of the total duck and goose populations (Central Valley Joint Venture Implementation Board 1990). From 1939 to the mid-1980s, the Central Valley lost 250,000 acres (31.5 percent) of its wetlands. This represents an average annual loss for the 46-year period of 5.4 thousand acres, Frayer et al. (1989). This habitat loss has taken its toll on wildlife populations. The number of ducks using the Central Valley has declined 50 percent over the past 30 years.
- In the early 1800s, the Columbia River Basin had annual runs of over 14 million salmon. Today, only 2.5 million salmon and steelhead annually migrate up the Columbia River and its tributaries. This decrease is due to the loss or blockage of 56 percent of the spawning habitat (Western Region Fisheries Team 1991).
- Although wetland habitat losses appear to be slowing since the mid-1980s (Dahl and Johnson 1991), it is still occurring at a rate of hundreds of thousands of acres per year nationally (Central Valley Joint Venture Implementation Board 1990). Increased urbanization, conversion to agricultural uses, drought and development continue to take their toll on wetland wildlife habitat.

Federal wildlife refuges and fish hatcheries have been established to provide protected and managed facilities to supplement the remaining natural habitat. However, the effective operation of these facilities requires water. In the arid West, this is a scarce and valued commodity.

Western Water Resources and Water Rights

Most, if not all, of the Western states have streams that are over-appropriated, drainage systems that are fully appropriated, ground-water regions where annual withdrawal exceeds average annual recharge, and/or designated ground-water areas within which water rights are granted only for preferred uses. Physical factors govern the supply of water in the West, whereas water rights control the growing for the water.

There are two basic, though vastly different, state water rights doctrines in the United States. In the humid eastern half of the country, water is usually plentiful and the *riparian* water rights doctrine applies. The chief attributes of this system of water law are that:

- It exists by virtue of ownership of land that is contiguous to a body of water.
- Riparian water users are entitled to a reasonable use, or an equal share, of available water.
- The right is not lost by nonuse.
- Disputes are decided by the courts.

In the arid West, water is not distributed evenly, is not plentiful and, increasingly, is not sufficient for the demand. Because water is not available for all potential users, the *prior appropriation* system of water rights evolved. The chief attributes of this system of water law are that:

- It follows the philosophy of "first in time, first in right," thus protecting the water supplies of earlier appropriators from subsequent appropriation.
- The water is owned by the state which allows appropriators to *use* the water.
- The conditions of water use are enumerated in a state-issued permit. Users risk loss of the right due to nonuse or by failure to follow the terms of the permit.
- Water must be put to beneficial use and cannot be wasted.

In addition to these two state water rights doctrines, there also is the *federal reserved* water rights doctrine. The courts have held that when the federal government withdraws land from the public domain for specified purposes such as an Indian reservation, national forest, national park, national wildlife refuge or other federal reservation, it concurrently reserves sufficient unappropriated water to accomplish the purposes. The chief attributes of this system of water law are that:

- The priority date is the date of the reservation regardless of when the water is actually put to use.
- The amount of water reserved is the amount necessary to satisfy existing and future needs of the primary purposes of reservation.

Federal agencies may have all three of the aforementioned types of water rights. They, like all other water users in the West, must have a permit to appropriate state water.

Western Water Rights Coordination Group

The Service's water rights policy is to acquire, manage and protect sufficient water rights for its facilities in the arid West such that its resource management objectives, statutory responsibilities and international treaty obligations are accomplished. In March 1990, the Western Regions of the Service formed a Western Water Rights Coordination Group (Group). The Group is comprised of the water rights managers of the Service's Region 1 (California, Hawaii, Idaho, Nevada, Oregon and Washington), Region 2 (Arizona, New Mexico, Oklahoma and Texas), Region 6 (Colorado, Kansas, Montana, Nebraska, North and South Dakota, Utah, and Wyoming), Region 7 (Alaska) and the Washington, D.C. Office's Division of Refuges and Division of Hatcheries staffs. The Group's objective is to develop and recommend to management, a comprehensive and regionally-consistent water rights management program that will enable the Service to effect its water rights policy. The activities of the organization to date have been varied and are described below.

Water Rights Strategy Plan

A water rights management responsibility of the Western Regions of the Service is to develop region-specific action plans to acquire, manage and protect the Service's water rights. The Group has recommended that the strategies outlined below be included in regional plans.

Acquisition of water rights.

- Before property is acquired by the Service, the appurtenant water rights should be examined to determine if the right is consistent with resource management objectives or if the right can be changed to be made consistent. The priority dates and prospective utility of the rights should be a factor in determining which lands to acquire.
- If a water right without land is proposed for acquisition, and subsequent transfer to a Service facility, the acquisition should be contingent upon the state's approval of the transfer application.
- If a permittee acquires a new water right for use on Service lands, the new right shall be in the Service's name, and this requirement should be specified in the permit.

Management of water rights.

- All organizational levels of the Service have water rights management responsibilities.
- All water rights (appropriative, riparian and federal reserved) appurtenant to newly acquired Service lands should be identified and quantified.
- All water rights must be managed in a manner consistent with applicable laws and regulations.
- Water rights training will be provided to all personnel responsible for managing Service facilities and resources.
- A Western Water Rights Coordination Group comprised of representatives from Regions 1, 2, 6, 7, and the Washington, D.C. Office's refuges and fisheries programs will coordinate water rights activities in the Service. Where legal issues are implicated, this group will consult with the solicitor's office.
- The Regions will maintain a *Water Rights, Water Uses and Water Needs* database to help identify problems and track progress in addressing these problems. The regional databases will be integrated and provided to the Washington Office for their use in assisting in the solution of Service-wide water rights issues.
- Engineering and hydrological assessments of water delivery and distribution systems at Service facilities should be performed to determine what improvements may be necessary to ensure an effective and efficient water delivery infrastructure.
- Water-use management plans that are consistent with each facility's water rights should be prepared.

Protection of water rights.

- All primary water diversions should have water measuring and recording systems to document water use.

- Management staff at all refuges and hatcheries should keep records documenting water use. This information is necessary to defend the Service's water rights in general stream adjudications and administrative hearings.
- Technically valid and legally defensible standardized methodologies should be developed, where practical, for engineering and hydrological studies, monitoring systems, and data analyses.
- Water rights filings of non-Service entities which propose diversions in the area of Service facilities should be reviewed to determine if the new rights could potentially injure the Service's senior water rights.
- Facility-specific models should be developed to predict and describe the spatial and temporal impacts of events of a facility's water supply.

Identification of Water Rights Priorities and Budget Needs

The Group annually prepares water rights budget justifications to address the Service's most urgent water rights program needs.

Water Rights, Water Use and Water Needs Database

During the autumn of 1990, the Group developed a seven-page questionnaire which was subsequently completed by all Service refuge and fish hatchery managers. These data are periodically updated. The purpose of the questionnaire is to identify water rights' problems and needs in order to help guide the Service's water rights management program and to provide information that can be used to respond to Congressional inquiries in a timely and regionally consistent manner. The data reveal that of the 224 refuges in Regions 1, 2 and 6 that require water:

- 84 refuge managers report that their most serious water issue is insufficient quantity.
- 99 refuge managers report that the water supply in an average water year is insufficient for full refuge operation.
- 96 refuge managers report that the water supply in an average water year is only sufficient for facility operation at the existing level of refuge development (i.e., no additional wetlands can be developed).
- 218 refuge managers report that there is no existing site-specific computer model that can be used to predict the effect of specific events such as upstream diversions, ground-water pumping, changing climatological conditions, changes in off-refuge irrigation practices, etc., on a refuge's short- and long-term water supply.
- 116 refuge managers report that new water control structures are required in order to effectively use the available water supply; 112 managers report that extensive repairs to existing water control structures are required.
- 38 refuge managers report that vested water rights for their facility have been researched.
- Federal reserved water rights have been quantified for 11 of 75 refuges that have these rights.
- 143 refuge managers report a current or potential conflict with other water users.
- 79 refuge managers report a current need for water-rights related legal services.
- 54 refuges have had recent engineering evaluations to specifically address the sufficiency and needed improvements of existing water delivery and control systems.

- 128 refuge managers report that they have limited or no water-use measuring devices to monitor water use.
- 142 refuge managers report that discharge and reservoir capacity curves are either inaccurate or nonexistent.

Water Rights Training

The Group has developed a recommended curriculum for water rights training at the Fish and Wildlife Service Academy (Academy). The objectives of the water rights training proposed by the Group are:

- To introduce water rights terminology.
- To describe the history and differences of the various water rights doctrines.
- To enable the Service's resource managers to understand basic water law.
- To provide the knowledge required to acquire, manage and protect the Service's water rights.

The recommended curriculum for the Academy includes the following topics:

- *Appropriative and riparian water rights doctrines.* This session will provide a general overview of the appropriative and riparian doctrines, including their evolution, relevant case and statutory law, application to natural resource managers, and geographical scope.
- *Federal reserved water rights doctrine.* This session will provide a general overview of the doctrine, important case decisions, and implications of federal reserved water rights to the federal resource manager.
- *Public trust doctrine.* This session will provide an overview of the public trust doctrine, including its definition, development, meaning to resource managers, and important historic and ongoing case law.
- *Functions of a state water rights office.* This session will provide an overview of a typical Western state's water rights processes and include a discussion of the application, permitting, perfection, certification and water use documentation processes, the kinds of beneficial uses recognized by the Western states, storage versus nonstorage rights, the determining of forfeiture, and the conduct of administrative hearings.
- *Testifying at a water right hearing.* This session will cover the need for preparation time with an attorney, the importance of technically valid and legally defensible data, factual versus expert witness testimony, direct and cross-examination, and other topics that refuge managers who may be required to provide testimony must know.

In addition to recommending curriculum for the Academy, the regional water rights managers are conducting training for regional staffs. This training includes the above topics as well as instruction on state-specific water law and water measurement and recording methodologies.

Information Exchange

The Group also provides the opportunity for the regions to exchange information on monitoring systems, model development, database development and analytical techniques. This will ensure that Regional development efforts are nonduplicative and that the Service's water rights management program is administered cost-effectively.

Conclusion

In many geographical areas of the West, the demand for water exceeds the supply. Competition for the remaining supplies is extremely keen and frequently results in judicial and administrative proceedings. As an example, the Service is involved in four adjudications in Region 1, three in Region 2 and three in Region 6, as well as being involved in over 300 administrative water rights protests in the three Regions. The Service has recognized that a comprehensive water rights management program is essential to protect its water rights and, thus, to help ensure the effective operation of Western refuges. Although progress has been made, much remains to be accomplished including:

- Developing facility-specific water supply models to predict the impact of spatial and temporal events on a refuge's short- and long-term water supply.
- Developing facility-specific water-use models to enable managers to make informed decisions concerning the most effective utilization of dynamic water supplies.
- Conducting engineering and hydrological assessment studies to determine the sufficiency of existing water distribution systems and to determine the appropriate water-use measuring systems to document water use for each Service water right.
- Acquiring and installing water-use measuring systems.
- Inventorying and quantifying federal reserved water rights. This is an enormous undertaking. For example, the refuge system in Region 7 (Alaska) comprises 77 million acres, most of which is only accessible by air or water.
- Developing water rights maps for each refuge for integration with the Service's Geographic Information System.
- Acquiring and perfecting additional water rights for Service facilities.
- Continuing participation in water rights adjudications and in administrative protest actions.
- Providing water rights and water law training to all Service personnel responsible for managing or protecting water rights and water resources.

The accomplishment of these programs in a timely fashion will help ensure a reliable supply of water and, consequently, the operational integrity of national wildlife refuges in the Western United States.

References cited

Central Valley Joint Venture Implementation Board, 1990. Central Valley Joint Venture Implementation Plan. Sacramento, CA. 102 pp.

Dahl, T. E. 1990. Wetland Losses in the United States 1780s to 1980s. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C. 13 pp.

Dahl, T. .E. and C. E. Johnson. 1991. Status and Trends of Wetlands in the Conterminous United States, mid-1970s to mid-1980s. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C. 28 pp.

Frayer, W. E., D. D. Peters, and H. R. Pywell. 1989. Wetlands of the California Central Valley, Status and Trends, 1939 to mid-1980s. U.S. Dept. Interior, Fish and Wildl. Serv., Portland, OR. 30 pp.

Western Region Fisheries Team. 1991. Pacific Salmon Management. U.S. Dept. Interior, Fish and Wildl. Serv., Portland, OR. 10 pp.

The Water Crisis in the Western Refuge System: An Environmental Response

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Water is for fightin'; whiskey is for drinkin' (Mark Twain).

Introduction

Throughout the continental western United States, natural supplies are scarce, variable, unpredictable and non-uniformly distributed. Where water does occur, natural biological activity is concentrated. The most important ecological systems tend to be water dependent. Naturally, the components of the National Refuge System are concentrated around wet places. And few refuges embrace entire watersheds on which their water supplies depend; most of the hydrological processes necessary for their survival occur outside the refuge. They are, therefore, at risk in the ongoing western water wears.

The U.S. Fish and Wildlife Service (Service) has formed a water rights coordination group, surveyed water problems in the refuges and proposed strategies for management of the water resources of the system. In addition to the general management issues involved, numerous hot spot refuges have been identified. These areas will require specific and extraordinary strategies in order to be protected. While there are no "standard formula" approaches to these highly variable problems, there are certain general principles that bear discussion. it is clear that the traditional single-issue environmental battle is an approach unlikely to bring a solution in these complex settings.

A Review of Some Hot Spots

Region 2; Arizona, New Mexico, Texas and Oklahoma

Pecos River Basin—Las Vegas National Wildlife Refuge and Bitter Lake. The State of New Mexico is proceeding with a water adjudication on the Pecos River and its tributaries. Currently, the Gallinas River subbasin is actively involved in the proceeding and the Service is having to respond to show cause orders concerning the specific factual bases of its water rights claims.

In the meantime, the refuges are caught in the squeeze resulting from the *Texas versus New Mexico* interstate lawsuit on the Pecos. Texas had successfully charged New Mexico with underdelivering its compact obligation on the Pecos for many years, and now that water debt is to be paid back. The state engineer is requiring across-the-board water conservation and the Service is involved in developing its internal conservation plan to comply with these targets. It is hoped that these targets can be attained with reduced application rates and without acreage reductions.

Bill Williams Unit of the Havasu N.W.R.—Bill Williams River, Arizona. The riparian corridor along the Bill Williams, below Alamo dam, has been severely threatened by ground water diversions at the Planet Ranch. The Planet, formerly acquired by the City of Scottsdale as a water farm for future diversions for municipal supply, has been heavily pumped for irrigation purposes in order to maximize water rights quantifications. The impact on water levels in the alluvium has caused some riparian community damage at the Bill Williams Refuge. It now appears that the acquisition of the Planet Ranch by the Service, and retirement of ground water diversions and irrigation should restore base ground water levels.

In addition to stable ground water levels in the alluvial aquifer, southwestern riparian communities are generally dependent upon other hydrologic functions for their survival and propagation. Periodic flooding is necessary to allow for community succession in the Cottonwood-Willow dominated communities. Channel overtopping, by clearing and wetting adjacent areas, allows new seedlings to start. Channel scouring and migration are key functions in providing for long-term community dynamics—for example, old communities are cut away; new sand bars are deposited; new seed generation occurs. The removal of a flood regime may preclude long-term riparian community protection. At the Bill Williams, negotiations have started concerning operations of the Alamo Dam to try to provide for a flow release regime that might provide necessary riparian community protection.

Region 6; North Dakota, South Dakota, Nebraska, Kansas, Montana, Wyoming, Colorado and Utah

Alamosa National Wildlife Refuge and Monte Vista National Wildlife Refuge, San Luis Valley, Colorado. These managed wetland areas are both highly dependent on valley-wide water resources, and both recently came under great threat by the proposed private water development known as American Water Development, Inc. (AWDI). The proposal was to pump up to 200,000 acre-feet of water per year and pipe it to the Colorado metropolitan front range. The recently concluded water court trail was the scene of a very active defense on the part of San Luis Valley farmers, the state wildlife agency and the federal government, principally on behalf of the Great Sand Dunes National Monument and the two wildlife refuges. The Service personnel and their attorneys from the Justice Department worked closely with the other protestants in the development of valley-wide computer modeling to demonstrate the impact that this proposed pumping would have on water levels and, therefore, wetland communities and streamflows. The water court's ruling was quite favorable to the San Luis Valley protestants, although all parties are waiting to see what further moves the developer, AWDI, may make.

In addition to this epic water fight, the Service is continuing with legal housekeeping to convert the state law water rights decrees, on which these two refuges depend, from their historical use for irrigation to wetland, pond and general refuge usage.

Souris River, North Dakota. (Des Lacs, Upper Souris and J. Clark Salyer). These refuges are worth special mention because of their dependence upon the hydrologic regime in an international river system. Operations of recently-constructed Canadian flood control facilities may have a severe impact upon this regime. The Service will be required to work within the framework of the boundary waters treaty and international law generally to try to protect the hydrologically based resources.

Quivira National Wildlife Refuge, Kansas. Quivira, a federal refuge with approximately 20,000 acres, has a number of threatened and endangered species using the site as a stopover in the central flyway, including whooping crane, piping plover and least tern. The refuge has a water right permit which is in the process of being perfected by a certificate from the Department of Water Resources. Extensive ground water pumping in the basin above the refuge along Rattlesnake Creek is causing some concern. If these withdrawals are too extensive, several impacts might occur, including stream depletions to the flow of Rattlesnake Creek, lowering of local ground water table levels and inducing the intrusion of salt water into the current fresh water regime.

The Service has been carefully monitoring a very similar controversy in nearby Cheyenne Bottoms which has state wildlife and Nature Conservancy refuge areas. Upstream pumping on the Walnut creek area had been causing significant overdraft situations with damage to the wildlife areas. After extensive and controversial hearings, the Chief Engineer, David Pope, declared the area an ''intensive ground water use conservation area'' (IGUCA). Furthermore, irrigators have been ordered to cut back pumping and usage to one-half of the previous rates, junior irrigators get 44 percent of half of the water use at previous rates, and cities are required to cut back by 10 percent. All recreation users, including refuges, must make a conservation plan to demonstrate to the chief engineer that water is being used in the most efficient way.

The prospect of this kind of controversy has prompted representatives of the Service to take affirmative steps on the Quivira to develop a hydrologic database and model and to define a long-term strategic plan. They are beginning talks with the local ground water district to pool efforts in developing this database and to try to reach a voluntary solution where all parties can continue to function within the hydrologic limits inherent in the system.

Region 1; Washington, Oregon, California, Nevada and Idaho

Central Valley California Refuges, Sacramento River and San Joaquin River—Kesterson, Grasslands, etc. The entire Central Valley of California is a system under siege. Amplified by the current drought sequence, the question of basin-wide water management has come to the fore and, as of this writing, is under intense negotiation in Congress as part of the Central Valley Project Improvement Act legislation. Historically, the Valley represented a massive system of interconnected wetlands and riverine ecosystems. Today, only a few of those remnants remain because of the intensive agricultural development. That agricultural development represents one of the richest, if not *the* richest, agribusiness resources in the world. It also represents one of the most complex plumbing systems ever devised in connection with irrigated agriculture.

Some of the particular problems in the Central Valley have become infamous. The water quantity, as a result of agricultural runoff in Kesterson Lake, has resulted in severe wildlife impacts. The general shortage of water and change of flow regimes have imperiled the wild salmon runs that historically existed on the Sacramento and has perhaps extirpated runs on the San Joaquin.

There is an integrated series of problems involving the quantity of water available of ecosystem uses, in light of the commitment of water to agricultural, municipal and industrial uses; the timing of water flows in this intensely regulated system; and the quality of water, particularly as results from agricultural runoff. In the recently concluded multi-agency San Joaquin drainage study (Natural Heritage Institute 1990), it was generally recommended that the long-term solution would require some mix of water conservation and reduced irrigation application rates through best management practices and the reallocation of some of the unused fresh water to environmental maintenance purposes. It has been common to look to BMP's to control the impact of agricultural runoff; generally reduced application rates will reduce the amount of soil toxins and other runoffs that contribute to the non-point water quality problem. In the San Joaquin Valley, however, it is apparent that overall scale of agriculture compared with the remaining hydrological resources is such that management practices alone are not likely to be sufficient to recover the resource. A significant reallocation of fresh water seems to be necessary. The drainage report proceeds to suggest that it is the local water user districts that may hold the key to requiring BMP's on one hand and reallocating fresh water on the other pursuant to some mandated performance targets. This approach, while perhaps counter-intuitive, dramatizes the need to integrate environmental planning with water resource planning generally. That task is the one currently confronting congress in the first instance and the one which the Service will have to deal with in order to preserve these critical Central Valley resources.

Stillwater Wildlife Refuge; Truckee River and Pyramid Lake, Nevada. The Truckee and Carson Rivers in western Nevada are one of the very interesting hot spots as to which integrated basin-wide strategic approaches are far advanced. This hot spot will be discussed in more detail later in the paper.

Some Common Problems and Common Themes

Out of This Sample of Hot Spot Refuges Some Common Problems Are Apparent

1. The significant threats, in most cases, are from off-site water development or use. The land owned by the refuge is not sufficient for complete protection. The water rights owned by the refuge—whether state appropriative rights or federal reserved rights—are not, in most cases, by themselves sufficient protection.
2. Much of the threat is in the form of ground water pumping, which may affect streamflows and on-site ground water levels.
3. In some cases, upstream reservoir development on the stream system has affected the timing of flows, as well as the rates. Many of these systems require both an overall average volume of water, as well as seasonal or other pulses, generally in the form of flood flows for flushing, geomorphologic functions or plant community succession.
4. While not clearly evident from the cases mentioned, some situations also require multi-year wet and dry period cycles. These natural hydrologic ebbs and flows

may also be necessary for plant community succession or for maintaining long-term water quality relationships, such as salinity balance.

5. Commonly occurring throughout the refuge systems is a concern for water quality, particularly as it is affected by non-point sources, such as agricultural return flow. Nutrient loads, soil-based toxic chemicals, and pesticide and herbicide residuals cause very serious threats in most locations where irrigated agriculture is a roommate in the watershed.

Common Themes in Moving Toward Protection

1. To remedy situations where the total volume of water is insufficient for the ecological requirements of the refuges and where present water rights are insufficient to protect those requirements, water rights are having to be purchased and transferred or changed from their historic use to refuge use. Throughout the west, the right to use water is considered a property right and it can usually be bought or sold separate from the land on which it has been historically used. Usually, such transfers of rights are complex legal or administrative proceedings and sometimes they are controversial.
2. Upstream reservoir operations often are necessary to be reviewed and amended, particularly where seasonality and rate of flow requirements are critical for flushing, channel maintenance or plant community succession. Where critical endangered species habitat is involved, §7 of the Endangered Species Act is invoked to precipitate theses operations reviews. With FERC licensed facilities, the reviews came up at least at the time of license renewal, although considerable attention is focused on the possibility of more frequent review. Other situations require site-specific legal strategies. In general, the parlance refers to "reoperating" existing reservoirs.
3. In nearly all of these hot spots, some effort is ongoing to develop models. The hydrology of these systems is universally complex. Ground water/surface water models are needed to identify pumping impacts. Reservoir operation models are necessary to identify characteristics of the natural and altered hydrographs. The most common theme seems to be the emergence of "water budgets," detailed hydrologic accounting of all inflows and precipitation, all outflows and losses, and all uses of water—whether for human activity or natural system uses (Table 1, Figure 1.) Only through such a water budget can one really determine the adequacy of the hydrologic processes to support the refuge's ecosystem requirements. And in general, the budgets need to be multi-year dynamic analyses in order to look at seasonal and multi-year fluctuations.
4. In almost all cases there is a political and socio-economic context within which the refuge hydrological situation exists and solutions must be fitted. Proposed solutions which are so simple-minded as the elimination of other competing uses in the basin are usually unrealistic. The politics of getting congressional funding for water rights acquisitions or the legality of transferring water rights where state water administrators believe it is not consistent with the public interest are real-life limitations on available solutions. It is common on the hot spot refuges to have to resort to a kind of basin-wide planning, where such uses, including human uses, are provided for in the solution set.
5. Basin-wide (or subbasin) dispute resolution and conflict avoidance are increasingly the subject of Service activities as the alternative legal and political strat-

Table 1. Water budget analysis of the San Pedro River Watershed 1990 development conditions (acre-feet per year)[a].

	Mexico	Sierra Vista	Benson	Redington	Winkelman	Aravaipa	Total[b]
Supply (+)							
SW inflow		23,420	39,200	25,500	32,100	0	23,420[c]
GW inflow		3,000	0	120	150	0	3,000[d]
Tributary SW	35,900	17,300	11,800	15,710	34,070[e]	1,500	78,880[f]
GW recharge	[g]	13,860	11,760	20,350	9,650		55,620[h]
Imports		200[j]	0	350[j]	0	0	510
Exports		960[k]	0	0	−1,860[l]	0	−2,820
Total	35,900	56,820	62,760	61,990	74,110	1,500	158,610[m]
Water use (−)							
Cultural							
Irrigation	5,000	4,590	14,230	8,480	3,360	1,810	30,660
Domestic	300	460	260	130	170	30	1,020
Municipal	2,300	4,530	750	1,220[n]	10	0	6,510
Stockpond	1,000	1,460	870	780	160	600	3,270
Reservoirs		160	270	80	110	100	620
Mining	3,000		0	19,560	0	0	19,560
Industrial	100	50	380	30	0	0	460
Total	11,700	11,250	16,760	30,280	3,810	2,540	62,100
Natural							
Channel Evap		950	770	2,220	1,680	970	5,620
Phreatophytes		14,450	17,690	13,400	7,060	1,500	52,600
Total	11,700	15,400	18,460	15,620	8,740	2,470	58,220
Total use		26,650	35,220	45,900	12,550	5,010	120,320[o]

Table 1. Continued.

	Mexico	Sierra Vista	Benson	Redington	Winkelman	Aravaipa	Total[b]
Surplus (=)							
GW Outflow	900	0	120	150	1,570	800	1,570[p]
SW Outflow	23,420	39,200	25,500	32,100	56,540[q]	27,559[r]	56,540[s]
Change in storage	−120	−9,030	1,920	−16,160	3,450		−19,820[t]

[a]Taken from Arizona Department of Natural Resources San Pedro River Basin Hydrographic Survey Report 1992. All values are rounded to the nearest tens, however, this should not be constructed to mean that the computed values are accurate to this degree.
[b]Totals include inflow from Mexico but do not include supplies or uses.
[c]Includes only surface water outflow from Mexico accounted for at the Palominas gage, 09470500 San Pedro River at Palominas, Arizona.
[d]Includes only groundwave entering the watershed from Mexico.
[e]Tributary surface water includes Aravaipa subwatershed tributary surface water.
[f]Total includes tributary surface water from Sierra Vista, Benson, Redington and Winkelman.
[g]– means no data available or not estimated.
[h]Total includes groundwater recharge from Sierra Vista, Benson, Redington and Winkelman subwatersheds.
[i]Groundwater pumped from Cienega Creek groundwater basin and used for irrigation within the San Pedro River watershed.
[j]Groundwater imported to Oracle.
[k]Groundwater exported to Bisbee.
[l]Groundwater exported to ASARCO.
[m]Summation of all above values of supplies including imports and exports.
[n]Includes municipal use of imported water to Oracle.
[o]Total includes all cultural and natural uses for the Sierra Vista, BEnson, Redington and Winkelman subwatersheds.
[p]Total groundwater outflow is the outflow at Winkelman.
[q]Surface water flows from the Aravaipa subwatershed are accounted for with surface water outflow from the Winkelman subwatershed.
[r]Aravaipa uses and tributary SW are accounted for at the Aravaipa gage, 0947300 Aravaipa Creek near Mammoth, Arizona, not included in total water use because it is accounted for at the Winkelman gage.
[s]Total surface water outflow is the outflow at Winkelman.
[t]Total change in storage = supply − total uses − groundwater out − surface water out. Negative values are assumed to indicate groundwater overdraft.

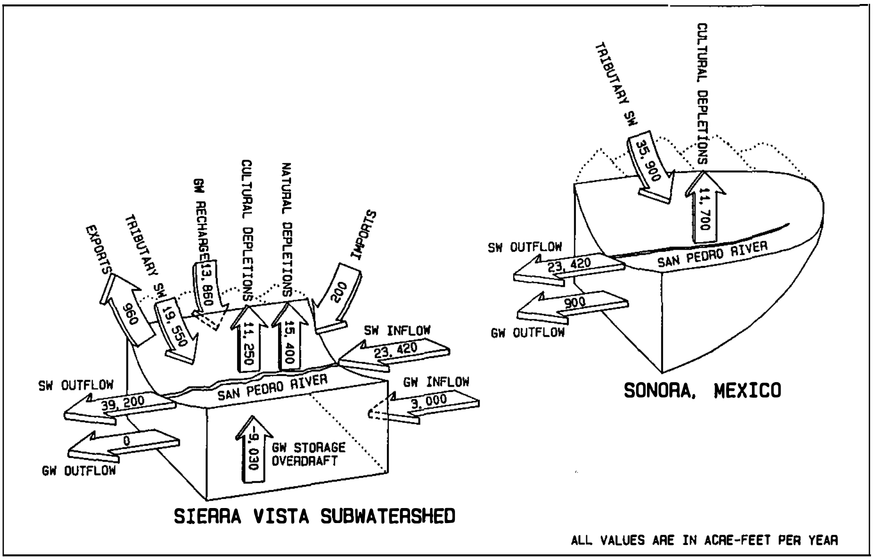


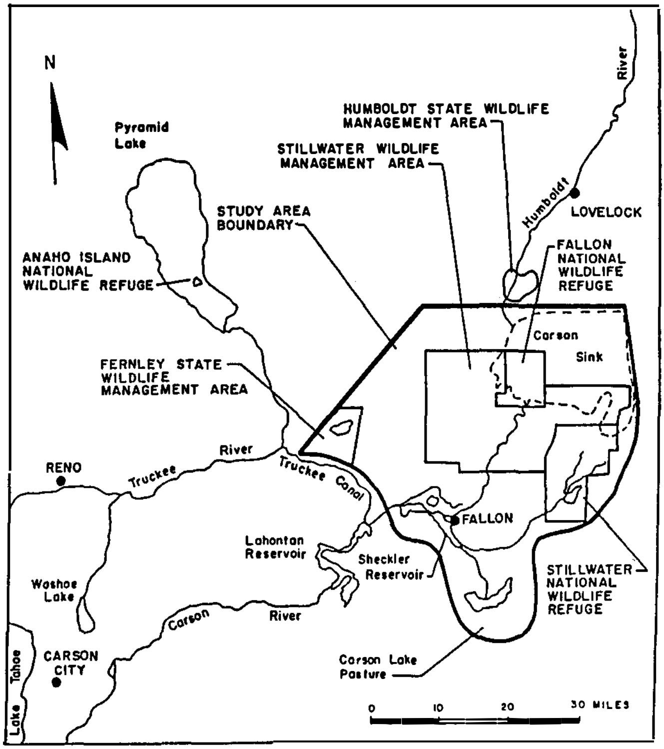
Figure 1. Schematic of the water budget components as they relate to the Mexico and Sierra Vista subwatershed portions of the San Pedro River watershed (*see* Table 1).

egies are realistically evaluated. A refuge plan that is compatible with other socio-economic interests in a basin is not only more feasible to implement in the first instance, but also is much more susceptible to long-term maintenance and protection.

A Closer Look at a Key Example: The Pyramid Lake/Stillwater Wetlands Complex in Nevada

In one of the most important ecological sites along the inland portion of the Pacific Flyway, the Truckee and Carson Rivers flow out of the High Sierras onto the Great Basin Desert, evaporating in historically great wetland complexes. (Figure 2.) The Truckee River ends up in Pyramid Lake, a unique aquatic ecosystem, home of the endangered Cui-ui and Lahanton Cutthroat Trout, and Anaho Island, one of the largest white pelican rookeries in North American. The Carson River ends up in the Lahanton valley wetland which include the Stillwater wetlands, one of the critical stepping stones in the Inland Pacific Flyway and a Western Hemispheric Shore Bird Reserve. Anaho Island in Pyramid Lake and Stillwater are both National Wildlife Refuges.

The Newlands Irrigation Project, one of the oldest reclamation projects in the country, diverts water from the Truckee River to the Lahanton Reservoir on the Carson and supplies irrigation water for the Lahanton Valley. The total use of water on the rivers have added to the cumulative depletion and now, dramatized by the extended drought, the wetlands have shrunk to a dangerously low area. Toxic buildup of agricultural runoff in the wetlands has caused wildlife kills in the last few years.



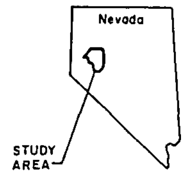


Figure 2. Study area and major river systems of Pyramid Lake and Stillwater Wildlife Refuge..

At the same time, the Pyramid Lake Paiute Indian tribe has vigorously fought to protect its cultural heritage in the ecosystem at Pyramid Lake. The maintenance of Truckee flows into the lake is critically important to maintain spawning habitat for the endangered fish and to maintain the lake itself in a stable, healthy posture. The future of the lake is still far from certain. To protect both the Stillwater wetlands and Pyramid Lake, a reduction in irrigation use and careful balancing of water supplies will have to be achieved.

The U.S. Fish and Wildlife Service, assisted by the Nature Conservancy, has been successful in completing several water rights acquisitions and transfers to date. These transfers, carried out on an emergency, interim basis, have helped avert an ecological disaster in the wetlands.

The irrigation project supports an agricultural community of about 60,000 acres. These farmers generally have come to recognize the need to go along with some habitat restoration programs, although historical animosity toward tribal interests in Pyramid Lake is still strong. The Truckee Carson Irrigation District and the tribe have gone along with initial water rights acquisitions from voluntary sellers of irrigation project water rights and conversion from irrigation use to the wetlands. There is significant controversy, however, about the ultimate magnitude of the conversion of water from agriculture to environmental uses because of related socioeconomic impacts. The spectre of an Owens Valley-like dry up of the local economic community looms large throughout the west wherever large agricultural transfers are considered.

The Nature Conservancy has been quite involved in a cooperative project with the Service in developing additional computer models needed to adequately design the ultimate project. First, the basin-wide surface water network account model developed by the Bureau of Reclamation has been extended to provide a detailed accounting capability in the Stillwater area below Lahanton Reservoir. This is necessary in order to define the effects of transfers of water from irrigation in the Fallon area to wetlands in the Refuge. In addition, the overall model allows the assessment of the balance between the Truckee-Pyramid Lake system on one hand and the Carson River Stillwater system on the other. In addition, the Conservancy is experimenting with a network model, normally used for reservoir operations, extending it to the wetland complex in order to get a handle on the flows and salinity gradient through the wetland, and the dynamics of the wetland hydrologic requirements.

The work to date, however, has led to the realization that further progress is unlikely to occur unless there is a basin-wide settlement defining the amounts of the overall water budget allocated to Pyramid Lake, to the Stillwater wetlands and to continued agricultural use. Uncertainty has resulted in resistance by each of the parties to the efforts of the others to the point that gridlock appears imminent. Using the comprehensive modeling database, and working with the other parties in the area, the parties must now reach an overall conflict resolution providing for the different ecological uses and the continued human economic activity.

Summary and Recommendation

The Stillwater/Pyramid Lake analysis shows a large complex landscape which must be dealt with in order to achieve any security of long-term viability for either of the two wildlife refuges. A site-specific focus is simply inadequate and a basin-wide approach, as being adopted by the Service, is inevitable. This probably is true in general for all the hot spots in the refuge system. Stillwater/Pyramid also seems to demonstrate all the general elements that are typically involved in basin-wide planing for refuge protection.

1. There must be an *overall ecological analysis* to determine and clarify the management objectives and reach an understanding of the biological processes in the basin. A conceptual model of those processes must be developed in the early stages and continuously refined.
2. A *hydrological analysis*, referred to as a "water budget," must be developed. This analysis is an accounting of all the water that flows in and out of the system, and all of the uses—both human and ecological—of that water. Before we can presume to suggest any reallocation of water to environmental purposes or any preservation of existing hydrologic conditions, we have to know the budget. What other uses, human or environmental, would be displaced by any change?
3. Concurrently with the scientific and technical work, in all cases we have to do important *work with the people and interest groups* in each basin, defining the interests at risk and establishing communication with all the stakeholders. Understanding the objectives and problems of each group leads to exploration of alternative solutions for those interests, a key process in developing components of basin-wide solutions.

4. In most cases, *computer simulated operating models* of the key parts of the hydrologic system are required. It usually is necessary to look at the water budget over long time periods to see how it works over seasonal and multi-year dry and wet periods. Any proposed allocations of water to environmental or human purposes must be examined to be sure there is an overall understanding of impacts. Well-intended but uniformed protection efforts are likely to fail, or worse, cause other adverse impacts at some other point in the basin.
5. A *basin-side strategy* must be worked out, within the constraints of the water budget, which provides for adequate and reasonably certain water supplies for the *essential ecological requirements* and for *compatible, sustainable human uses*. In general, the strategy is worked out through negotiations with all the key parties, so that it can form the basis of long-term partnerships for the protection of the resource. In effect, these water management tools are being used to drive basin-wide conflict resolution and avoidance. Typically, the strategy will quantitatively identify reallocation of water through *water rights purchases, agreements for the modification of reservoir operations, water conservation* or other techniques.

Refuge Management and Biological Diversity: A Refuge Manager's Perspective

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Introduction

During the early years of the nation's conservation movement, little thought was given to habitat fragmentation, endangered species, wildlife corridors and intrusion of exotic species. At that time, many of these problems did not exist, could not be recognized or were of lower priority (Harris and Gallagher 1989). But times have changed and many of out public lands are now surrounded by urban sprawl, isolated and fragmented from other natural sites, and increasingly threatened by outside influences. Management emphasis to protect public lands from these threats also are undergoing dramatic shifts as well.

Wildlife conservation has expanded its scope since the turn of the century, when the only management concerns were focused on wildlife populations in obvious decline and on species with a commodity value (Pletscher and Hutto 1991). However, an evolution has taken place, from game management in the 1930s, to endangered species and nongame management in the 1970s, to an increasing direction in protection of biological diversity in the 1980s and '90s. These shifts in management emphasis also have occurred within the National Wildlife Refuge System.

Historical Perspective

The perception that maintaining and protecting natural diversity equates to a "hands off" approach is just as prevalent today as in the early years of the system. The discussion of no management versus intensive land manipulation to conserve wildlife and their habitats on refuge lands has been around since establishment of the first refuge. Gabrielson (1943) discussed this at great length, concluding both approaches, active and passive, were needed in restoring and preserving the nation's wildlife resources.

In 1968, Secretary of Interior Udall appointed an advisory committee on wildlife management to appraise the significance of national wildlife refuges in migratory bird conservation. The committee's report recommended that individual refuges should include preservation or restoration of natural ecosystems, along with the primary management objective: "All native animals and plants should benefit by the presence of a refuge unit. . . . Naturalism in management is to be considered a virtue" (Leopold et al. 1968).

The National Wildlife Refuge System is the only network of federal lands devoted primarily to long-term management of fish, wildlife and their habitats. The system is extensive and varied, encompassing over 90 million acres in 50 states, Puerto Rico and American Samoa. From postage-stamp sized tracts to areas encompassing an entire ecosystem, management of these units varies from intensive land management actions to simple protection from disturbance. The refuge system harbors just about every kind of wild animal and plant native to the North American continent: over 220 species of mammals, 600 species of birds, 250 reptiles and amphibians, 200 fish species, and uncounted numbers of invertebrates and plants. Over 135 threatened and endangered species occur on refuge lands with over 400 refuges reporting the occurrence of one or more of these species. Most refuges also report the occurrence of at least one candidate or state-listed species as well. From these statistics, the refuge system's role in protecting biological diversity becomes very apparent. Several mechanisms are presently in place mandating or providing refuge managers the opportunity to incorporate a systems approach in managing the refuge.

Mechanisms for Providing Biological Diversity

Refuge Purposes

In 1903, the first refuge, Pelican Island, was established under an executive order by President Theodore Roosevelt. The purpose, to protect nesting birds from human disturbance, set the stage for the system's primary purpose. National Wildlife Refuges have as their overall purpose, in the words of the official *Refuge Manual*, "to provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's need for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available" (U.S. Fish and Wildlife Service 1982). This is further divided into four discrete management goals, three which relate to protection of biological diversity: "To preserve, restore, and enhance in their natural ecosystems (when practicable) all species of animals and plants that are endangered or threatened with becoming endangered"; "to preserve a natural diversity and abundance of fauna and flora on refuge lands"; and "to perpetuate the migratory bird resource."

The Refuge Manual further outlines policies for managing individual habitat types within refuges. However, the extent that management strategies for an individual refuge address ecosystem versus species management depends largely upon the purposes establishing the refuge. Since establishment of Pelican Island, refuges have been acquired under a variety of acquisition authorities, including legislative acts and administrative orders.

The acquisition authorities used to obtain refuge lands usually have one or more purposes for which the land can be acquired. Over a period of time, an individual refuge may contain lands acquired under a variety of acquisition authorities with different purposes. Thus, a single refuge may be comprised of a number of units, each with a different purpose. The purposes establishing each unit of the system dictates, to a large degree, how refuges incorporate protection of biological diversity into their program. In some situations these purposes may impede, or seem to impede, refuges from protecting biological diversity. More often than not, this may be a result of subjective interpretation of the purposes.

Since formation of the system, the perception within and outside the Service has been that most refuges were established for protection of migratory waterfowl. From the system's establishment in the early 1900s, the prime management objective has been directed at migratory birds. In the early years of the system, emphasis was on protecting habitat for colonial nesting birds. A management shift to waterfowl management occurred during the refuge's growth during the dust bowl era, and, hence, the perception began and has remained until today. Though many refuges may be managed primarily for waterfowl, most have a primary purpose decreeing protection for all migratory birds, even though money used to acquire these lands came from the sale of duck stamps.

As of 1991, over 370 refuges had a purpose related directly to migratory birds, over 135 refuges had a purpose for protecting endangered species and 25 refuges had a purpose for protecting natural diversity (U.S. Fish and Wildlife Service 1991). Even those refuges established for a specific purpose still provide for many other species and, in many situations, complete biological communities or ecosystems.

In the past, because of emphasis on wetland and waterfowl management, the "back forty" or upland areas of refuges often received little attention. In some respects, these "back forty" sites imply required protection from disturbance. However, for proper and successful management, knowledge of the site's ecological components and processes are needed before such an assumption can be made. Some of these sites also may require restoration or management efforts, or they may harbor a unique, declining or vulnerable biological community. Without such information, protection of these sites may be at risk.

Other Mechanisms Related to Biological Diversity

Refuge purposes are not the only mechanism directing refuge management programs. Refuge size, location, degree of isolation and influences from adjacent land management activities may determine the level of protection and subsequent management actions taken to provide for biological diversity. Legislative mandates or special area designations also provide for protection of biological diversity.

Legislative mandates such at the Migratory Bird Treaty Act, Wilderness Act, Endangered Species Act and Alaska National Interest Lands Conservation Act provide for some degree of protection and management for biological diversity. For example, whether or not a refuge has a purpose related to protection of endangered species, each unit of the system still has responsibility under mandates of the Endangered Species Act to provide for endangered species and the ecosystems upon which these species depend. If an endangered species occurs on the refuge, that particular refuge should, if at all possible, approach protection of this species on an ecosystem scale. Even refuges with specific programs to protect and manage endangered species may have to use intensive management techniques to successfully provide for these species. These refuges may be too small or too isolated to protect biological diversity at the ecosystem level.

The refuge or portions of the refuge may be further protected by supplementary designations that provide for protection of biological diversity. Such designations include wilderness, research natural areas, wild and scenic rivers, and Western Hemisphere Shorebird Reserve Network designations. Each one of these designations incorporates a community or ecosystem approach and, under most of these designations, use of the minimal tool concept for managing habitats is employed.

Constraints to Protection of Biological Diversity

Some refuges acquired were initially degraded or badly eroded from previous land-management activities. Aggressive and intensive habitat management programs brought these areas back to some sort of ecological semblance. However, many of these refuges are now surrounded by a "sea of humanity," or are fragmented and isolated from other natural communities without a possibility of connecting such sites via wildlife corridors. Again, protection of biological diversity at the highest level (Landscape/ecosystem) may be unattainable. Continued intensive habitat management may be the only viable avenue available to ensure that wildlife objectives are met.

Only a small part of the refuge system is specifically manipulated to maintain early successional stages. Within the National Wildlife Refuge System, approximately 5 million acres of the system's 90 million acres are managed by using land management techniques, such as silviculture, prescribed burning, grazing, water level manipulation, etc. The degree of management actions taken varies from intense to very light.

Older refuges established during the "dust bowl days" are managed rather intensively with impoundments, dikes, levees, water control structures and pumps. Management was directed primarily toward enhancing waterfowl habitat, though other wetland-associated species benefitted as well. However, some of these past management actions may be non-beneficial or even detrimental to other native species.

Wetland habitats may be intensively managed to maximize production or increase food availability for wintering waterfowl, which may actually arrest natural successional processes and limit wetland biological diversity. This is especially true where tidal marshes are impounded, which in turn impedes movement of marine life in reaching their spawning and nursery grounds. Water drawdowns occurring late in the season for the benefit of migrating waterfowl may deprive earlier migrating shorebirds of an opportunity to replenish depleted fat reserves by not having exposed mudflats available. In both cases, biological diversity is lost. In some situations, this disparity can be corrected by timing management actions on a temporal and spatial scale. For example, on water impoundments, gradual drawdowns in late summer will provide staging and feeding sites for migrating shorebirds. Reflooding these impoundments later in autumn will continue to attract waterfowl. Through managing impoundments for both nongame species and waterfowl, refuges can provide important staging and feeding habitats for more wildlife species.

Because many of these older refuges now are surrounded by residential, commercial and/or agricultural development, intense management programs may be the only means to provide and maintain wildlife and their habitats. Additionally, the species migrating to or living on the refuge may become dependent upon these managed lands and waters. Removal of impoundments that have been in place for 30 or more years may cause more harm than good, especially where wetlands on adjacent lands have been altered or destroyed. In these situations, protection of biological diversity may occur only at the species, population or, at most, the community level.

Future Direction for the National Wildlife Refuge System

Current concern over endangered species, nongame wildlife and biological diversity points to the need for the refuge system to aggressively protect the full spectrum of native wildlife species and habitats. The future direction in refuge management will require more than just increasing species diversity. To protect biological diversity at the highest level, refuges must be able to ascertain historical composition, abundance and distribution of native fauna and flora, determine the degree that native communities and ecosystems are threatened, and implement management actions to prevent these systems from becoming degraded and their ecological components from becoming extinct. Providing and maintaining more ''edge'' or enhancing species richness is not the answer.

Enhancing species richness does not necessarily equate to conservation of biological diversity. Some ecosystems, such as coastal barrier islands, experience high vertebrate species richness on a temporal and spatial scale. This usually occurs during peak migration periods and along bayside tidal marshes. At other times of the year, these systems may appear to be ''biological deserts'' because of the seemingly lack of high species diversity. From a landscape perspective, this view is entirely misconstrued. Implementing management actions to increase an artificial species diversity scenario on such a delicate and unique system compromises and threatens the integrity of such a system.

Another focus for refuge management will be to determine how and if isolated tracts of habitat can again become part of a functioning ecosystem. Refuges will need to increase use of native plant restoration techniques, establish viable wildlife corridors to connect fragmented tracts, use techniques emulating natural processes, such as fire, and implement cooperative management strategies with adjacent landowners. Very few new tools or techniques have been developed to assist land managers in applying the principles of biological conservation. To protect and maintain biodiversity at this time will require two approaches: judicious use of land management techniques that resource managers have used for years; and continual development, testing and refining of new and innovative techniques to protect biological diversity.

Critical to protection of biological diversity within the refuge system is a comprehensive inventory of the resources occurring on each refuge. Such an inventory is a component of the refuge management plan, though the quality and extent of the inventory varies from refuge to refuge, and, of course, dependent upon the availability of money, staff, and the significance of the resource (Lee 1986). However, an inventory of flora and fauna gives the manager the baseline information needed to measure future change, to develop management, restoration and protection strategies, and to identify those species and communities in jeopardy.

Conclusion

Since the early days of wildlife management, the charge was to get out on the land and do something with it, usually without considering what was there or what natural forces were prevalent in shaping the system—make the land ''produce useful wildlife.'' Useful wildlife at that time usually meant game species. Today, we know much more is needed and much more is at stake.

Management within the context of the entire system of protected areas helps ensure the viability of the species populations and the ecological communities they contain (Reid and Miller 1989). Integrating preservation and restoration of rare habitats and their associated ecological components with existing successful land-management programs becomes our best bet to protect and maximize regional and global diversity. As such, the National Wildlife Refuge System becomes an important participant in the growing international effort to protect biological diversity.

References

Gabrielson, I. N. 1943. Wildlife refuges. Macmillan Company, NY. 257 pp.

Harris, L. D. and P. B. Gallagher. 1989. New initiatives for wildlife conservation: The need for movement corridors. Pages 11–34 *in* G. Mackintosh, ed., In defense of wildlife: Preserving communities and corridors, 1989. Defenders of Wildlife, Washington, D.C. 96 pp.

Lee, W. S. 1986. The National Wildlife Refuge System. Pages 413–460 *in* R. L. Di Silvestro, ed., Audubon wildlife report, 1986. National Audubon Society, New York, NY. 1,094 pp.

Leopold, A. S., C. Cottam, I. McT. Cowan, I. N. Gabrielson, and T. L. Kimball. 1968. The National Wildlife Refuge System: Report of the Advisory Committee on Wildlife Management, appointed by Interior Secretary Stewart L. Udall. Trans. N. Am. Wildl. and Nat. Resour. Conf. 33:30–54.

Pletscher, D. H. and R. L. Hutto. 1991. Wildlife management and the maintenance of biological diversity. Western Wildlands 17(3):8–12.

Reid, W. V. and K. R. Miller. 1989. Keeping options alive: The scientific basis for conserving biodiversity. World Resources Institute, Washington, D.C. 128 pp.

U.S. Fish and Wildlife Service. 1991. Purposes of national wildlife refuges. Updated June 21, 1991. Service document. 49 pp.

———. 1982. Refuge manual. 2 RM 1.3.

Biological Diversity and the Refuge System: Beyond the Endangered Species Act in Fish and Wildlife Management

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Imagine, for a moment, a national wildlife refuge, a substantial part of which is devoted to a huge planted flower garden designed to attract and show off a great diversity and profusion of butterflies. Well-stocked with ornamental flowers selected for their ability to entice lepidopterous visitors, such a "garden-refuge" would surely attract many human visitors as well. Properly planned, it could offer genuine education and conservation benefits, particularly inasmuch as many of our native butterflies are declining in range or numbers. Somehow, nevertheless, such a "garden-refuge" goes against deeply embedded notions of what a national wildlife refuge should be.

Why is that? Is it because such a garden-refuge is so patently an artificial environment, a construct not of nature, but of man? Is it because such a refuge, to meet its wildlife (i.e., butterfly) objectives, must rely heavily upon cultivated, non-native plants? Is it because such a refuge fails to preserve a natural diversity and abundance of flora and fauna upon it, but instead must be intensively manipulated and managed through human endeavor to produce an unnatural abundance of a narrow range of animal species? Is it because butterflies aren't important enough to devote a national wildlife refuge to them? Or is simply because no one ever thought about having a refuge of this character before?

Rather than try to answer these questions now, I simply want to use them to explore the broader issue of what we should want from our National Wildlife Refuge System and, in particular, how the growing concern with the conservation of biological diversity—broadly conceived—might be more effectively integrated into refuge objectives and management. To being that inquiry, I want to focus for a while on the Fish and Wildlife Service's "Refuge Manual," the compilation of official policies that guide management of our refuges.

The Refuge Manual suffers at times from a pronounced case of schizophrenia. It tries to have its cake and eat it too on a whole lot of issues. Start with the very goals for the Refuge System. Four broad goals are set out in the Manual to guide Refuge management. They include preserving and restoring threatened and endangered species, perpetuating the migratory bird resource, providing an understanding and appreciation of fish and wildlife ecology, and "preserv[ing] a natural diversity and abundance of fauna and flora on refuge lands" (2 RM 1.4[1]).

The last goal, preserving a natural diversity and abundance of flora and fauna, might well rule out our hypothetical butterfly refuge, since its very object is to

[1]References to the U.S. Fish and Wildlife Service's Refuge Manual (1982) appear in text by chapter number, followed by "RM" and then the relevant section number. Thus, 2 RM 1.4 is section 1.4 of chapter 2 of the Refuge Manual.

achieve an unnatural abundance of a particular type of fauna. It might, but it doesn't because the Refuge Manual has more to say on this subject. Although set forth as one of the basic goals of the Refuge System, preserving a natural diversity and abundance of flora and fauna turns out not to be an absolute goal after all. It is immediately qualified in a general policy statement regarding ''population management.'' There the Manual declares that ''[t]he attainment of natural diversity is not an over-riding objective of refuge management, but it should be an underlying consideration for all habitat and populations management activities'' (7 RM 1.4.A). Put differently, our hypothetical butterfly refuge is back in the game, since achieving natural diversity and abundance turns out to be only an ''underlying consideration'' in carrying out other management objectives (which might be maximizing butterfly viewing opportunities), and not a prescription for what those objectives should be.

This fundamental tension between the goal of preserving natural diversity and the fact that most refuges are actively managed and manipulated to achieve other pre-established objectives shows up repeatedly in the Refuge Manual, including in the section devoted to ''exotic species introductions and management.'' There, a clear policy that ''[t]he National Wildlife Refuge System exists for the protection and management of plants and animals native to the United States'' is set forth (7 RM 8.1). Consistent with that policy, the introduction of exotic species is to be permitted only for biological control reasons. These policies are harmonious with the 1977 Presidential Executive Order directing the Fish and Wildlife and other federal agencies to restrict the introduction of exotic species into natural ecosystems under their jurisdiction (*see* Executive Order 11987 [1977]). They also would seem to spell the end for any plans for a butterfly refuge that relies upon ornamental flowers and other exotics to increase butterfly production.

But wait, there is more. Like the goal of achieving a natural diversity and abundance of flora and fauna, the Manual's stated commitment to native species and antipathy to exotic species weakens when one moves from the general to the particular. In particular, the Manual's more specific guidance on the subject of waterfowl management encourages the planting of native grasses whenever possible, but expressly permits the use of non-native grasses ''when native grassland management will not achieve the refuge waterfowl production objective'' (7 RM 3.5B). In other words, when refuge waterfowl production objectives exceed what would result from the natural diversity and abundance of fauna and flora on a refuge, the natural diversity of the fauna can be altered so as to achieve an unnatural abundance of waterfowl. Indeed, the Manual's recommended ''standard mixture'' of planted grasses consists of wheatgrass, alfalfa and sweet clover, all exotic species, which, under the Manual's exotic species policy, are not to be introduced on refuge lands except for biological control purposes. Compare 7 RM 3.5(B)(2)(a) with 7 RM 8.1. In short, one part of the manual authorizes the use of exotics for a purpose that another part prohibits.

The point of this discussion is not to suggest that our refuge management policies pertaining to waterfowl are misguided. Rather, it is simply to suggest that the Refuge Manual itself, the basic guiding document for the management of the National Wildlife Refuge System, is so riddled with exceptions and contradictory policies that almost anything—even a refuge for butterflies—can be squared with it. And that fact, coupled with the further fact that the very concept of biodiversity conservation is itself rather open-ended and imprecise, means that almost any set of refuge management actions can be justified, post hoc, on the basis of their contribution to biological diversity.

That result is not particularly satisfactory. My purpose in the remainder of this paper, therefore, is to suggest a direction in which the Fish and Wildlife Service should try to move in order to make biological diversity less an "underlying consideration" and more an affirmative objective of refuge management.

In the history of the development of the National Wildlife Refuge System, two themes has been paramount. The original, and still very vital, role that the System was to play was in the conservation of migratory waterfowl. A more recent emphasis stems from the Endangered Species Act. In the past decade or so, most of the expenditures for refuge acquisition have been for endangered species purposes. These two objectives, waterfowl conservation and endangered species preservation, have been the driving forces behind the expansion of the Refuge System (outside Alaska, at least). But between waterfowl conservation and endangered species preservation lies a huge universe of potential conservation concern, from nongame conservation, generally, to watchable wildlife, declining songbirds, disappearing amphibians, centers of species richness, centers of endemism and the like. Does the Refuge System try to address these new concerns merely as peripheral considerations in the pursuit of its very limited primary goals, or does it expand those primary goals to encompass these concerns as genuine objectives in their own right?

Although it may seem elementary, it is important to acknowledge at the outset that scale is extremely important in assessing actions to benefit the conservation of biological diversity. To illustrate, consider a tract of land on which a long-leaf pine and wiregrass community exists. This tract of land may well offer less diversity, in terms of number of species supported, than a similarly sized tract of hardwood forest. The diversity of the first tract could be increased by managing it so as to bring about its conversion to hardwood forest. But if that first tract is the only pine-wiregrass tract remaining in a region dominated by hardwood forest, the conversion of that tract to hardwood, enhancing diversity at the local scale, will diminish diversity at the larger, regional scale.

This recognition of the critical importance of scale is quite important for the National Wildlife Refuge System. That system is intended to serve national purposes. Its potential contribution to enhancing the conservation of biological diversity necessitates, therefore, that the scale of reference informing decisions about actions to advance biodiversity be regional or national, and not parochial.

Another, perhaps elementary, point is that the first step in assessing the potential for the Refuge System to contribute more effectively to the conservation of biological diversity is through a systematic inventory of the living resources, and potential resources, of the System. Without a comprehensive baseline of what we already have within our System, in terms of both species and natural communities, it will not be possible to offer a meaningful evaluation of whether we are progressing toward, or slipping from, the goal of enhanced conservation of biological diversity.

Knowing what is on our National Wildlife Refuges, however, is only part of what is needed. It is also critically important to know what is gong on outside of those refuges. If natural community types that are or could be represented within the Refuge System are disappearing outside the System, that fact is a very persuasive reason to try to keep them represented within the System. Here again, it may be much more important for refuge managers to manage for relatively low diversity community types that are under heavy pressure outside the System than for higher diversity community types already abundant elsewhere.

To serve the goal of conserving biological diversity, our National Wildlife Refuges ought to function as sentinels, capable of detecting trends in species abundance or distribution that portend potentially grave consequences for the future well being of wildlife. When two years ago, the news broke that many different species of amphibians appeared to be declining precipitously, and for unknown reasons, across much of North America, it ought to have concerned all of us that the source of this news was not the Fish and Wildlife Service. Although it has millions of acres of refuge lands scattered across all regions of the country, the Service didn't have the data collecting capability to detect (or refute) this alarming conservation development. Perhaps more disturbing, however, is the fact that since the news broke, the Refuge System has not been catalyzed into action to follow up those initial reports with some serious, long-range studies to monitor amphibian populations for the purpose of determining whether the apparent decline is real and, if so, what its causes are. The long-term declines of migratory songbirds, amphibians, saturnid moths and other wildlife are all examples of declining biological diversity that has not yet reached the point of triggering the Endangered Species Act. A National Wildlife Refuge System that was attentive to these trends could contribute enormously to the timely identification of conservation solutions that avoid the controversy and disruption that accompanies last-ditch efforts to avert imminent extinction.

Climate change is another example of how our Refuge System could function as a sentinel. Species at the periphery of their historic range are likely to be among the most sensitive indicators of subtle climatic changes. A Refuge System that sought to monitor such populations closely could serve as a bellwether of impending threats to biological diversity beyond those to which we have been long accustomed.

These are all new roles for our National Wildlife System. They are roles, however, that are suited to the dramatically changing circumstances in which we live. Biological diversity, a catchword, perhaps for the simple proposition that our attention must be focused on more than just the ducks and whooping cranes that have occupied it for so long, needs to be not just an underlying consideration in managing our refuges. It needs to be in the forefront of our thinking about what the National Wildlife Refuge System can and should do for our future.

Managing Refuges for Waterfowl Purposes and Biological Diversity: Can Both Be Achieved?

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National Wildlife Refuges and Biological Diversity

The National Wildlife Refuge System (NWRS) consists of lands and waters set aside for the management of fish and wildlife resources. The refuge system is a principal mechanism through which the Fish and Wildlife Service (FWS) fulfills its mission of conserving migratory birds and other public trust resources in which the federal government has an interest.

The FWS's Refuge Manual identifies the mission of the NWRS "to provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's needs for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available." Within the mission for the NWRS, a primary goal is "to perpetuate the migratory bird resource."

Under that individual goal of the NWRS, migratory bird refuges are managed as part of a complex national/international system of lands owned by agencies and private groups or individuals to provide habitat for migratory birds. Many individual refuges were explicitly established for waterfowl and, under the National Wildlife Refuge System Administration Act, the FWS is obligated to manage these areas for waterfowl or even individual species as a primary purpose. Other management goals are secondary to the primary purpose and other uses of the refuge must meet a test of compatibility with the purpose for which the refuge was established.

In 1924, the U.S. Congress authorized purchase of bottomlands along the Upper Mississippi River to establish a refuge for migratory waterfowl and to begin fulfilling international obligations under the Migratory Bird Treaty Act of 1918. By 1941, 3.9 million ha of NWRS lands existed in the U.S. Acquisition emphasis shifted to waterfowl breeding areas in the 1950s and 1960s, and management practices on migration and wintering areas shifted to growing and flooding row crops. Today, National Wildlife Refuges in southern latitudes are important in providing sanctuaries and food resources that enable migratory birds to replenish depleted energy reserves and gain important nutritional reserves for molt and breeding the following spring (Reid et al. 1989, Reinecke et al. 1989).

FWS strategy for acquisition of areas of importance to migratory birds is to protect networks of habitat across broad geographic ranges. Refuges have been secured throughout the breeding, migration and wintering areas of many species. Although waterfowl have been the driving force for most of this acquisition, many other migratory species have benefited. When viewed from a broad perspective, this network of migratory bird areas within the NWRS is designed to protect the biological diversity of the continent by accomplishing the mission of perpetuating the migratory bird resource.

The dynamic processes of natural systems are difficult to improve on, and protection, rather than manipulation, usually should be the management goal for pristine habitats. However, for most of the lower 48 states, modification of the landscape, and especially wetlands, has been extensive. Restoration and active management, including manipulation of water, soil and vegetation, are essential where hydrologic alterations have degraded habitats. Flooding row crops on National Wildlife Refuges that are surrounded by private agricultural fields does not meet all the nutritional or behavioral requirements of waterfowl in migration or wintering, nor does it provide habitat for other wetland dependent species. In recent years, management of refuges has begun to focus on more natural management schemes.

One example of intensive habitat manipulation that results in the production of natural cover and foods for wetland wildlife is moist-soil management (Fredrickson and Taylor 1982, Fredrickson and Reid 1990). This management practice emulates natural drying conditions through seasonal water drawdown of wetlands. Exposure of moist soils allows germination of wetland plants, and produces abundant seeds, tubers, rootlets and browse for wildlife. Substrate for aquatic invertebrates also is provided, and these organisms are important prey for waterbirds. More than 80 percent of 153 bird species that use moist-soil management units in eastern Missouri consume invertebrates (Fredrickson and Reid 1986).

Intensive management of moist-soil units or other practices on waterfowl refuges may negatively impact the local biological diversity as compared to what might result from attempts to manage the area for a diversity of natural communities. But these actions also provide for the life requirements of many other species, and they directly and greatly benefit numerous migratory bird species that may use the area for only a few days or weeks. In addition, most refuges are managed to provide a diversity of habitat types for migratory and resident species well beyond waterfowl.

Management for a habitat mosaic that mimics natural hydrological cycles is common on National Wildlife Refuges. Obviously, some conditions attractive to one group of birds might not be compatible with the needs of another. Nevertheless, when a refuge is managed as a mosaic of wetland types, denser, robust cover for rails may be provided on one site, while open mudflats with sparse cover can be provided for shorebirds on another site (Fredrickson and Reid 1986, Reid 1989). The mosaic of habitat types also will attract a diversity of waterfowl, such as mallards and green-winged teal on sites managed for rails, and northern pintail and blue-winged teal in the more open habitat required by many shorebirds (Rundle and Fredrickson 1981). Certainly, there are many areas that are intensively managed for a few species, but overall, current management provides for waterfowl *and* a diversity of other organisms.

Mandating Biological Diversity

It is impossible to predict the results of a legal mandate to manage all of the units of the NWRS for maximum biological diversity without knowing the language of such a mandate. However, if we assume that such a mandate was a simple directive to examine biological diversity in the normal planning processes for units of the NWRS, it is doubtful that refuges would be managed much differently than they are now. The principle of meeting the goals for which a refuge was established would presumably continue, the compatibility test would remain in effect, and for those rare instances where a direct conflict between a primary purpose and biological diversity could be shown, the primary purpose would still predominate. An examination of almost any unit of our NWRS where waterfowl are the target group will show that the area contains a diversity of habitats and a much greater overall biological diversity than the surrounding landscape. When this is coupled with the knowledge that intensive management of the refuge is contributing to the overall biological diversity of the continent by providing habitat needed not only by waterfowl, but by a broad array of other migratory birds, it should be obvious that these areas are already contributing greatly to biological diversity.

Unfortunately, many of our national wildlife refuges and waterfowl production areas are little more than small islands in a sea of agricultural lands. Many of these areas were restored from agricultural uses and this restoration has contributed significantly to the biological diversity of the landscape. The intensive management of these refuge lands results in increased biological diversity, especially when compared to previous uses that were agricultural and heavily manipulated with very low species diversity.

Waterfowl and many other waterbirds have adapted to the dynamic prairie landscape where breeding habitat is greatly dependent on precipitation patterns. Whereas many of the mobile waterfowl species may be able to exploit small and isolated wetlands, other wetland and grassland species are not as nomadic and they face great risks in isolated conditions. Fragmentation of habitat complexes may result in the extirpation of certain species (Diamond 1975). Brown and Dinsmore (1986) suggested that species richness often was greater in wetland complexes (20–30 ha size class) than in larger isolated marshes (up to 180 ha). Effective management may require wetland/grassland complexes large enough to include different types of marsh habitat (Weller and Fredrickson 1974). Different stages of prairie grassland habitat also are necessary to meet the requirements of species adapted to short, sparse vegetation, such as willets or snowy plovers (Ryan and Renken 1987), or taller, denser vegetation, such as mallards or northern harriers.

Waterfowl Production Areas—A Good Example

Lands acquired under the FWS Small Wetlands Acquisition Program, and known as Waterfowl Production Areas (WPA) in the northcentral midwest provide an excellent example of the contribution of the NWRS to biological diversity. WPAs are usually small land units designed to provide for waterfowl production. They typically consist of a small wetland complex with various wetland types and associated uplands. They were usually purchased from private landowners, who used them for intensive cropping or grazing. A purchase normally would include one or more central tracts where existing wetlands are protected or drained wetlands are restored. As much of the surrounding upland as possible is purchased with the wetland basin(s). These uplands will be restored to native vegetation, usually a complex of native grasses, and this will be maintained by management with fire, livestock and other means. Within a reasonable distance, the FWS will purchase perpetual easements on private land to protect existing wetlands. While this complex is designed to provide everything needed to produce waterfowl, it also creates the habitat required by a broad array of wading birds, shorebirds, neotropical migrants, and hundreds of resident species of plants and animals that find it difficult to survive on the otherwise intensively used agricultural land.

Conclusion

The answer to our question of "can refuges be managed for both waterfowl purposes and biological diversity?" is easily answered. Yes, they can be, and for the most part, they already are. Assuming the mandate of primary use stays in place and the legal mandate for biological diversity is not structured to somehow override the uses for which an area is established, these two purposes are very compatible.

We believe the concern that is being expressed about a lack of biological diversity on units of the NWRS actually results from the failure to recognize that management, and often intensive management, is required if one is to maintain or enhance biological diversity. Some proponents of biological diversity are actually arguing against nearly all forms of management. This, of course, has nothing to do with protecting biological diversity, but is simply a projection of ignorance of how natural communities work and what is necessary to protect our environment.

We need to move beyond these debates and arguments over individual units of land. We should support continued expansion of the protected and managed land base, and we also must see that those charged with the management of wildlife resources have the capacity, support and fiscal resources necessary to properly manage these landscape units.

In a recent presentation on meeting the biodiversity challenge, Rupert Cutler expressed this sentiment very well, "Rather than forcing wildlife biologists to be constantly one step ahead of the bulldozers and chain saws, the process must allow planning well into the next century and on a much larger geographic scale than we have used in the past" (Cutler 1991).

Our arguments within the conservation/environmental community over the management of these small units of the landscape are the biological equivalent of fiddling while Rome burns if we are not arguing with the rest of the world over the need to increase our financial commitment to the conservation of all resources.

References

Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. J. Wildl. Manage. 50:392–397.

Cutler, M. R. 1991. Meeting the biodiversity challenge through coordinated land-use planning. Renewable Resour. 9(4):14–16.

Diamond, J. M. 1975. The island dilemma: Lessons of modern biogeographic studies for the design of natural reserves. Biol. Conserv. 7:129–146.

Fredrickson, L. H. and F. A. Reid. 1986. Wetland and riparian habitats: A nongame management overview. Pages 59–96 *in* J. B. Hale, L. B. Best, and R. L. Clawson, eds., Management of nongame wildlife in the Midwest: A developing art. North Cent. Sect. Wildl. Soc., Chelsea, MI.

Fredrickson, L. H. and F. A. Reid. 1990. Impacts of hydrologic alteration on management of freshwater wetlands. Pages 71–90 *in* J. M. Sweeney, ed., Management of dynamic ecosystems. North Cent. Sect. Wildl. Soc., West Lafayette, IN.

Fredrickson, LH. and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Dept. Interior, Fish and Wildl. Serv. Resour. Publ. 148, Washington, D.C. 29 pp.

Reid, F. A. 1989. Differential habitat use by waterbirds in a managed wetland complex. Ph.D. thesis, Univ. Missouri, Columbia. 243 pp.

Reid, F. A., J. R. Kelley, T. S. Taylor, and L. H. Fredrickson. 1989. Upper Mississippi Valley wetlands—Refuges and moist-soil impoundments. Pages 181–202 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, eds., Habitat management for migrating and wintering waterfowl in North America. Texas Tech. Univ. Press, Lubbock.

Reinecke, K. J., R. M. Kaminski, D. J. Moorhead, J. D. Hodges, and J. R. Nasser. 1989. Mississippi Alluvial Valley. Pages 203–247 *in* L. M. Smith, R. L. Pederson, and R. M. Kaminski, eds., Habitat management for migrating and wintering waterfowl in North America. Texas Tech. Univ. Press, Lubbock.

Rundle, W. D. and L. H. Fredrickson. 1981. Managing seasonally flooded impoundments for migrant rails and shorebirds. Wildl. Soc. Bull. 9:80–87.

Ryan, M. R. and R. B. Renken. 1987. Habitat use by breeding willets in the northern Great Plains. Wilson Bull. 99:175–189.

Weller, M. W. and L. H. Fredrickson. 1974. Avian ecology of a managed glacial marsh. Living Bird 12:269–291.

Alternatives to Hunting in Wildlife Management Programs on National Wildlife Refuges

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The National Wildlife Refuge System was created in the mind of President Theodore Roosevelt as he learned of the indiscriminate slaughter of pelicans on Pelican Island, Florida. In 1903, the first National Wildlife Refuge—Pelican Island—was set aside by presidential proclamation. A lifelong hunter, Roosevelt also recognized the need for lands where wildlife is protected.

When Congress passed the Migratory Bird Conservation Act in 1929, it provided that all lands acquired pursuant to the Act's authority be operated as "inviolate sanctuaries." In 1949 and 1958, Congress amended the Act to allow first 25 and then 40 percent of the total acreage of a refuge to be opened for public hunting. In response to the growing public use of refuges, Congress in 1962 declared that such use must be "compatible with the major purposes for which such areas were established" (16 U.S.C. 460k *et seq.*). The notion of refuges as "inviolate sanctuaries" was battered but intact, but only if compatibility determinations were rigorously conducted.

Since the 1950s, increasing numbers of refuges have been opened to hunting, trapping and a number of economic uses. By even the most conservative standards the terms "inviolate" and "sanctuary" have lost their meanings. In fact, numerous observers acknowledge that, as the law is now administered by the U.S. Fish and Wildlife Service (FWS), legally sanctioned compatibility determinations have become so permissive that they are more protective of refuge exploitation than wildlife (*see* e.g., U.S. General Accounting Office 1989).

Today, hunting is allowed on 56 percent of refuges and trapping on 20 percent, and even refuge managers note that the majority of refuges are subject to incompatible secondary uses (General Accounting Office 1989). Hunting on refuges is increasingly accepted as the status quo by the FWS. Indeed, when criticized for opening new waterfowl hunting programs on refuges, the FWS responded that hunting, even of declining species, is justified as a way of maintaining the interest and participation of hunters (U.S. Fish and Wildlife Service 1990a).

Ninety-three percent of the public does not hunt (U.S. Fish and Wildlife Service 1988). Ninety-seven percent of the public does not hunt on national wildlife refuges (Humane Society of the United States 1988). A maximum of 3.2 percent of refuge lands was purchased with funds contributed by hunters through duck stamp sales (U.S. Fish and Wildlife Service 1990b). In 1979, Kellert found, in his now classic study of public attitudes toward wildlife, that most Americans oppose recreational killing of wildlife and the killing of wild animals for use in fur garments, arguably the primary purpose to which furbearers trapped on refuges are put. Given these findings, we conclude that the public would oppose, to an even greater degree, destructive uses of wildlife on national wildlife refuges for recreation and/or profit.

We believe that national wildlife refuges—lands belonging to the people of this nation—should be managed, at least in broad policy, in accordance with the views of the majority of Americans. That they are not is a matter of politics and tradition, not biological need. Indeed, of the more than 70 species that are currently hunted or trapped on refuges (U.S. Fish and Wildlife Service 1987), no one seriously suggests that more than about a dozen species are killed for true "wildlife management" purposes. Muskrat (*Ondatra zibethicus*), nutria (*Myocastor coypus*), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*) and white-tailed deer (*Odocoileus virginianus*) are sometimes killed on refuges in the name of wildlife and habitat management. But where, we ask, is the wildlife management justification for killing canvasbacks (*Aythya valisineria*), black ducks (*Anas rubripes*), sandhill cranes (*Grus canadensis*), sharp-tailed grouse (*Tympanuchus phasianellus*), hooded mergansers (*Mergus cucullatus*), buffleheads (*Bucephala albeola*), woodcock (*Scolopax minor*), fox squirrels (*Sciurus niger*), wild turkey (*Meleagris gallopavo*) and armadillo (*Dasypus novemcinctus*)?

In more than 20 years of observation and study of the management of national wildlife refuges, including as a member of the Department of the Interior's National Wildlife Refuge Study Task Force, author Grandy concluded that, even considering vagaries in the law, recreational and commercial killing of animals is permitted on refuges largely due to the synergistic action of tradition, political pressure and agency impotence. In these situations, the alternative to hunting is simply not to allow it. In short, let refuges be refuges.

Having said that, however, we recognize that there are times and places where managers, under the rubric of wildlife management, have asserted a serious need for population reduction or other means of limiting the effects of particular species on a refuge environment. In these situations, there continues to be a need for means of coping with alleged overabundance other than hunting or killing the wildlife that refuges were established, at least in a general sense, to protect.

To meet that need, let us set out a logical framework for examining alleged instances of overabundance. We do this because, in our experience, utilizing a focused analytical framework to examine alleged overpopulation problems increases the likelihood of achieving an effective, publicly acceptable solution.

1. A refuge should have and utilize a comprehensive plan that clearly defines goals and objectives for the refuge, its habitats, and the animals and plants involved, for the short term and long term. Such a plan provides a critical framework for evaluating solutions to alleged overabundance problems.
2. Refuge monitoring programs (as described by Porter 1991) should define ecological relationships on the refuge and surrounding lands. Variables monitored should include species abundance, recruitment, and related habitat variables. Such data are important to analyzing incidences of suspected overabundance or wildlife damage, and to predict refuge changes or the results of management programs.
3. For each specific incidence of presumed overabundance, there should be a clear definition of the problem or problems caused by the overabundance. This is particularly true because of the subjective nature of the term "overabundance,"

and the fact that a clear definition of the problem should aid in defining an acceptable solution.

4. Any proposed control program should examine alternative control strategies and the costs and benefits of each, in terms of economics, animals killed and public support for refuge programs, among others. All management plans should aim toward reducing perceived problems associated with so-called overabundance to acceptable levels. For each species for which overabundance is asserted and corrective action is proposed, there must be a clear definition of the results desired that relate directly to the proposed control.
5. The management program developed to solve the "overabundance" problem should be the most selective and least disruptive or destructive, and most humane in terms of its effects on target and other animals.
6. There should be complete compliance with policy and legal requirements, and full consideration of public attitudes and desires.

In legitimate cases of wildlife overabundance, game alternatives to killing have been developed which we believe to be relatively inexpensive and possible long-term solutions to damage.

Since most instances in which overabundance is claimed to occur concern white-tailed deer, muskrat, nutria, Canada geese (*Branta canadensis*), and several predators, the discussion of alternatives to hunting will center around these animals. Most refuge and wildlife managers are already familiar with many of these alternatives; they have been used in various forms for years. None of them is perfect, none is appropriate to every or even a majority of wildlife damage situations. However, if refuges are to receive broad public support, the challenge to managers is, in our view, to accomplish legitimate refuge objectives with the minimum killing, injuring and disruption of wildlife.

White-tailed Deer

Problems associated with alleged deer overabundance include vegetative changes, agricultural damage, deer/vehicle collisions and suburban yard damage. Again, the goal of any program initiated in response to a perceived overabundance problem should be to reduce the problem to levels that are acceptable, because complete elimination of all effects of deer or other wildlife are not achievable without eliminating the wildlife completely.

That said, however, the solutions to problems of deer/vehicle collisions may begin with reduced speed limits, improved signage and careful fencing that directs deer movements. Damage in yards adjacent to refuge lands may be mitigated with fencing, netting and a change in shrub composition and by encouraging tolerance among yard owners and by prohibiting artificial feeding. For small refuges or relatively isolated cases of deer damage, electric fences can be effective deterrents, but again the adequacy of solutions such as these depends on the nature of the problems managers are trying to solve or the desired result.

Where long-term reduction and stabilization of deer or other wildlife populations are appropriate, the rapidly expanding science of wildlife contraception may allow managers to stabilize deer numbers in certain situations. Immunocontraception represents a promising means of fertility control. It has the benefit of being completely reversible and is free from potential health and behavioral side effects of hormone-induced contraception.

In this technique, does are inoculated with a vaccine derived from porcine zonae pellucida (PZP), the sperm-attachment protein from pig ovaries. The protein stimulates the doe to produce antibodies that bind to the doe's sperm-attachment sites, preventing the attachment of sperm and thus blocking fertilization. The PZP vaccine is deliverable with a barbless dart. Field tests have demonstrated the efficacy of a vaccine administered in two injections, two weeks apart. Tests are underway to evaluate the effectiveness of a one-shot, one-year microencapsulated vaccine which, relative to the two-shot technique, would be a far more practical means of wildlife immunocontraception for most refuge situations.

Immunocontraception has been successfully tested on a variety of wild and domestic, free-ranging animals. It is clear, however, that this technique is at present suitable only for relatively confined deer populations in small areas. A thorough discussion of this technique is available in Kirkpatrick and Turner (1991).

Muskrat and Nutria

Muskrat and nutria may alter habitat, including vegetative composition and form, in wetland areas, and their burrowing often damages dikes and drainage systems. The problems caused by these animals can be distinguished from the animals themselves. Once refuges implement management plans that incorporate acceptable levels of damage, refuge resources can be protected to ensure that any "damage" caused by the activities of refuge wildlife does not exceed these levels.

Dikes and drainage systems can be protected from muskrat and nutria tunneling by the use of wire netting on the sides of dikes extending approximately three feet below the water level and two feet above. Riprapping is more expensive than netting yet is a nearly permanent solution to a tunneling problem. When possible, levees and dams should be constructed with gentle slopes that reduce their suitability as den sites.

Canada Geese

Although Canada goose populations have fluctuated widely over many areas in recent years for a variety of reasons (Williamson 1990, Hindman and Ferrigno 1990), it is clear that, in some areas, the number of geese is causing demonstrable problems. In large numbers, Canada geese may damage refuge vegetation and adjacent agricultural fields through their grazing activities.

Where refuges permit farming in part to attract geese with leftover grain, and resulting goose concentrations threaten productivity of adjacent agricultural lands, agricultural activities on refuges may have to be altered, and long-term habitat changes may need to be considered so as to reduce goose concentrations. When high goose numbers are desired on a long-term basis, the FWS should work with adjacent landowners to structure agreements, which will probably differ in each case, but which will contain elements such as compensation to farmers, physical harassment of geese and the assumption by farmers that some damage is a cost of doing business.

Over the short term, the use of hazing and automated scarecrows has achieved success in reducing Canada goose numbers and preventing habituation in specific areas. In addition, geese generally prefer tender grasses; use by geese will decrease in areas where grasses have been allowed to mature or mowing cycles are lengthened. A system of suspended notched flags, colored black or orange and placed in offset parallel rows in fields has been successful in repelling unwanted geese (Hodge 1991).

Predators

The last situation involving a typical management reaction to alleged overabundance involves the effects of predators on wildlife populations. Here again, there is a demonstrated need to define ecological relationships (including examing cause-and-effect relationships), cost/benefit relationships and program objectives before seriously contemplating a predator-control program using lethal techniques to benefit other wildlife. It should be remembered that predator populations virtually never overpopulate in the classic sense of herbivores because predators and their reproduction are controlled by prey availability, thus normally precluding major irruptions. Accordingly, most conflicts regarding predation on refuges occur when the ultimate predator, man, desires an animal, in this case a duck, which another predator needs. This generates proposals for reduction of predator populations so that hunters are provided with more ducks to shoot (*see* U.S. Fish and Wildlife Service 1990c).

A few other conflicts regarding predators on refuges occur with endangered species, where predators are identified as putting serious pressure on critically endangered species such as clapper rails (*Rallus longirostris*) and least terns (*Sterna albifrons*). We strongly oppose killing predators to provide more ducks for duck hunters, while we accept the idea of highly selective and tightly controlled predator control to protect critically endangered species in specific populations. However, there are numerous nonlethal controls to aid in reducing the effects of abundant predators on prey populations. These include habitat management or enhancement, construction of nesting platforms, predator exclosure or diversion systems, scare devices, island construction (for nesting waterfowl), and others.

Conclusion

The HSUS published a "Pocket Guide to the Humane Control of Wildlife in Cities and Towns" (Hodge 1991). The thrust of this guide is that conflicts with wildlife can and should be handled so as to reduce wildlife-related problems without killing wildlife. The response of the public to this handbook has been both overwhelming and positive.

In our view, this response is reflective of the evolving and increasing concern and compassion demonstrated in public attitudes toward wildlife and wild places, and the public's growing belief that wildlife should not be killed unnecessarily. Though refuge managers surely face a different set of wildlife damage problems than do the suburban homeowners for whom HSUS published this guide, the basic approach to refuge wildlife management should be the same: to accomplish legitimate refuge objectives with the minimum necessary killing and injuring of wildlife, and to treat all refuge animals as humanely and compassionately as possible within the context of accomplishing these objectives.

References

Hindman, L. J. and F. Ferrigno. 1990. Atlantic flyway goose populations: Status and management. Trans. N. Amer. Wildl. Natur. Resour. Conf. 55:293–311.

Hodge, G. R. 1991. Pocket guide to the humane control of wildlife in cities and towns. The Humane Society of the U.S., Washington, D.C. 116 pp.

Humane Society of the United States. 1988. State hunting, trapping and national wildlife refuges fact sheets. HSUS, Washington, D.C. Unpublished. 50 pp.

Kellert, S. R. 1979. Public attitudes toward critical wildlife and natural habitat issues: Phase I. Report no. PB80–138332. U.S. Fish and Wildlife Service, Washington, D.C. 138 pp.

Kirkpatrick, J. F. and J. W. Turner, Jr. 1991. Reversible contraception in nondomestic animals. J. Zoo. and Wildl. Medicine. 22(4):392–408.

Porter, W. F. 1991. White-tailed deer in eastern ecosystems: Implications for management and research in national parks. U.S. National Park Service, Washington, D.C. 57 pp.

U.S. Fish and Wildlife Service. 1987. Refuge-specific hunting regulations. Fed. Reg. 52(196):37789–37799.

———. 1988. 1985 national survey of fishing, hunting, and wildlife associated recreation. U.S. Dept. of Interior, Washington, D.C. 167 pp.

———. 1990a. Addition of five national wildlife refuges to the lists of open areas for hunting. Fed. Reg. 55(173):36647–36651.

———. 1990b. Annual report of lands under control of the U.S. Fish and Wildlife Service. Div. of Realty, Washington, D.C. 39 pp.

———. 1990c. Symposium on managing predation to increase production of wetland birds. 1990. Northern Prairie Wildlife Research Center, Jamestown, North Dakota. Abstracts only. 70 pp.

U.S. General Accounting Office. 1989. National wildlife refuges: Continuing problems with incompatible uses call for bold action. GAO/RCED–89–196. Washington, D.C. 84 pp.

Williamson, L. L. 1990. Hunting—an American tradition. American Hunter 18(2):26–27.

The Manager's Tool Kit: Alternatives for Reducing Unhealthy Wildlife Concentrations on National Wildlife Refuges

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Introduction

The National Wildlife Refuge System's primary purpose to restore and protect fish, wildlife and their habitats is unique among Federal land management agencies. Refuge managers are tasked with the responsibility to manage lands and waters on their respective refuges to fulfill national and international responsibilities for protection of wildlife resources. At their disposal are a variety of tools, techniques and methods. Refuge management efforts to restore wildlife populations may at times be too successful. Large concentrations of wildlife may destroy habitat for themselves and other species as well. Influences outside the refuge also may contribute to unhealthy concentrations. In these situations, the refuge manager must decide which management tool will be the most effective, efficient and safe to control, disperse or decrease the population.

Management Alternatives

Decisions to institute management actions are based upon a broad, systematic approach using available information on the ecology of the species, the factors that increase or decrease the species' capacity for damage, the nature and extent of damage, and the effects of management options upon the refuge's other wildlife resources. Population reduction methods are based upon effectiveness, cost and minimal ecological disruption. This includes minimum hazard to nontarget organisms and the refuge environment.

Refuge managers have an assortment of tools and techniques to consider when attempting to manage a population. However, what may work for one refuge may not be applicable to another. A refuge's size, location, outside influences, and its goals and objectives will help determine which techniques apply. The refuge manager may use habitat manipulation, population control, or a combination of both.

Following are a few examples of some alternative management techniques that are used to control or prevent unhealthy wildlife populations on refuges:

Bosque del Apache: Using a Mixed Bag of Techniques

Management of agricultural grain fields on refuges can help control and disperse undesirable concentrations of waterfowl. These techniques, along with controlled hunting, have been used to discourage large concentrations of snow geese on the Bosque del Apache National Wildlife Refuge in New Mexico.

At Bosque del Apache and adjacent areas within the Middle Rio Grande Valley, snow goose populations exploded during the late 1970s and early 1980s. This led to concern about the potential for massive disease epidemics, crop depredation to neighboring agricultural lands and disease transmission to other species. Through cooperative efforts of the refuge and state wildlife personnel, several actions were initiated to disperse snow goose concentrations on and around the refuge.

The refuge's farming program was altered to delay harvest of certain crops, which helped better distribute geese throughout the season. Within the Middle Rio Grande Valley, the possession limit and maximum season length for goose hunting also were increased and contributed to improved distribution of the population. As a result of these efforts, major disease problems have been averted and crop depredations on private lands have been minimized.

Petit Manan National Wildlife Refuge: Controlling External Influences

In other situations, large concentrations of wildlife may result from factors external to the refuge. The increasing numbers of herring and greater black-backed gulls in the northeast have been attributed in part to the increasing numbe of landfills, waste products from fish cleaning and processing, and farming operations. Such large populations of gulls stymied efforts to restore and protect populations of island-nesting species such as terns, puffins and eiders.

Petit Manan National Wildlife Refuge in Maine has the largest nesting colony of the endangered roseate tern of any refuge. The large concentrations of gulls in the area caused concern not only for the welfare of this species, but to other inland nesting species, such as the Arctic and common terns, black guillemot, Atlantic puffin, and the common eider. In 1984, the refuge initiated a gull control program using the toxicant 1399, selective shooting and human presence.

The primary control technique, toxicant 1399, was prepared as bait and placed directly into the gull's nests. This kept other bird species from coming into contact with the toxicant, which is selectively lethal to gulls, blackbirds and starlings. Selective shooting and the presence of volunteers who stayed on the islands during the entire nesting season provided an additional deterrent to gull predation.

Dramatic results were experienced within four years: The first recorded nesting of Atlantic puffins; an increase from 50 pairs to over 800 nesting pairs of common eiders; from no nesting roseate terns to 45 nesting pairs; from 15 to over 100 nesting pairs of black guillemots; and up to 1,800 nesting pairs of common and Arctic terns. Even laughing gulls increased from 150 pairs to 600 pairs. This particular control program's success was a result of the combined effects of three different methods.

National Elk Refuge: Supplementary Feeding and Hunting

The National Elk Refuge in Wyoming must resort to some unusual management approaches to help manage one of the largest migrating elk herds in North America. Supplemental feeding, controlled hunting and enhancement of the existing wintering range are used to manage the population's size, prevent depredation of hay supplies on private lands and control movement of the elk within their wintering range.

Surrounded by ranches with their fenced boundaries, and ever increasing residential and commercial development, the refuge's 25,000 acres comprise only 25 percent of the elk's historical wintering range. The refuge serves as the *last* remaining winter habitat available to elk in Jackson Hole and supports over 60 percent of the elk in the area.

During an average winter, about 60 percent of the food requirements of the wintering elk herd are met by standing forage and 40 percent by supplemental feed. Highly nutritious pelleted feed minimizes the elk's dependence on supplemental feed, and natural foraging conditions have been improved through the planting of more productive grasses.

With little natural mortality (less than 1 percent annually), the desired population level is successfully maintained through a cooperative, controlled public hunting program involving the refuge, Grand Teton National Park and the Wyoming Game and Fish Department.

The National Elk Refuge exemplifies the situation of many refuges in the lower 48 states: small enclaves of historical wildlife habitats, now surrounded and threatened by agricultural, commercial, recreational and residential development. Unlike other public lands, many national wildlife refuges in the lower 48 states do not represent complete, functioning ecosystems. To provide for the wildlife resource often requires a combination of traditional and innovative land management to maintain what habitat remains.

Minnesota Valley: Urban Environment and Cooperative Efforts

The Minnesota Valley National Wildlife Refuge is located in the Minneapolis-St. Paul area, and is surrounded by residential and commercial development. Following a deer die-off at the National Cemetery near the refuge in 1982, the refuge determined that deer were too numerous for the available habitat.

Local city councils granted waivers from city ordinances prohibiting hunting, and the refuge was authorized to proceed with a controlled public deer hunt and the use of sharpshooters. In 1984, the refuge had its first hunt in cooperation with the Minnesota Department of Natural Resources.

Though many safety precautions and restrictions were employed to ensure a safe and efficient controlled hunt, some groups continued to protest the control program. A Deer Management Task Force was formed in 1989 to make recommendations to control the population. The task force is comprised of members of the refuge, the Minnesota Department of Natural Resources, city and county offices, and conservation groups (both pro- and anti-hunting).

Management options reviewed included birth control, transplanting, reintroduction of predators, habitat manipulation and hunting.The group agreed to a three-year controlled hunt program to maintain the population at desired levels. In January 1991, the deer population was determined to be over the objective level again and a controlled public hunt was authorized along with use of sharpshooters. The harvest objective of 160 deer was met, with 99 taken during the public hunt.

A deer population control problem in an urban environment, such as that surrounding the Minnesota Valley National Wildlife Refuge, is obviously a bio-political issue. The Deer Management Task Force is an example of an innovative, creative approach to addressing this kind of a situation.

Conclusion

As we look to the future of the National Wildlife Refuge System, we can anticipate that the vast majority of our refuges will be increasingly affected by human development and other outside influences. As they become even more fragmented and isolated from other natural sites, the need for more intensive management will only increase. If managers in those situations are to maintain healthy wildlife populations and habitats, they must have the flexibility to select from a broad range of alternative management strategies. However, given the growing complexity of the management issues they face, they will have to become increasingly adept in the application of innovative wildlife population and habitat manipulation techniques that are not only effective, but that also are consistent with natural ecological processes and socially acceptable. The latter will require that we become much more effective at informing and involving the public in the management of refuge system wildlife and their associated habitats.

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The Efficiency of Public Hunting in Maintaining Balanced Wildlife Populations on Refuges

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Introduction

In recent years, substantial debate has evolved concerning the compatibility of various activities on national wildlife refuges. While there is broad recognition by the general public that units of the National Wildlife Refuge System have been established to protect, enhance and restore fish and wildlife habitats and the species which are dependent upon those habitats, there is some controversy about the compatibility of various uses, such as hunting, fishing and trapping, with the purpose of perpetuation and enhancement of fish and wildlife. It is well-established that some species of wildlife, particularly big game, are capable of overusing and damaging some habitat components and thereby diminishing habitat carrying capacity and even the land base. Consumptive uses, like hunting and trapping, have long been utilized as a means of keeping certain wildlife populations in balance with habitat carrying capacity. Yet, there are those who argue that not only is consumptive use unnecessary, it is incompatible and harmful to the wildlife resources for which wildlife refuge habitats are set aside to maintain. This paper asserts that wise consumptive use of wildlife resources on wildlife refuges is necessary to maintain balance between wildlife populations and habitat capability, and that such use does not diminish or harm the wildlife populations in the short-or long-term but, in fact, benefits them.

While there are over 400 refuges in the National Wildlife Refuge System, I am going to use, as an example, two national wildlife refuges in Nevada. Although I believe it would be difficult to choose any one, or even a few refuges to represent the very broad diversity of the system as a whole, I will use the two Nevada refuges as basically representative of the refuge system. Certainly, Nevada refuges, compared with those in areas of greater human population density, differ in degree of human use, however, hunting and trapping activities are regulated and managed on most wildlife refuges so that the impacts of these activities are similar in terms of their affects on wildlife population abundance. Refuges that support highly dynamic populations of such species as white-tailed deer (*Odocoileus Virginianus*) may better exemplify the efficiency of hunting in maintaining balance between wildlife populations and habitat, but the same basic principles apply, regardless of the geographical area and species of concern. Therefore, I believe the information and data from the Nevada wildlife refuges used here are illustrative of the refuge system and wildlife harvest management as a whole.

Wildlife Population Response to Hunting

The Charles Sheldon National Wildlife Refuge

The Charles Sheldon National Wildlife Refuge is located in northwestern Nevada, with its northern border coinciding with the Oregon/Nevada state line. The refuge lands were purchased by the Boone and Crockett Club and the refuge was established in 1936 by Executive Order. The refuge constitutes more than 500,000 acres of classic high desert country, dominated by rolling hills, low mountains and extensive flat basaltic tables. Elevations range from 4,500–8,000 feet, with a mean elevation of about 6,000 feet. The vegetative community is dominated by sagebrush, primarily basin big sagebrush (*Artemisia tridentata*) in the areas of deeper soils, and short sagebrush (*Artemisia arbuscula*) on the tables and areas of shallow soil. Other primary plant components include bitterbrush (*Purshia tridentata*), mountain mahogany (*Cercocarpus ledifolius*), and a broad array of perennial grasses and forbs.

Except for livestock grazing, which is currently being phased out, one short section of paved highway, some all-weather gravel roads and a small mining area on the eastern edge of the refuge, the area has escaped any substantial human-caused environmental changes. Over time, the greatest environmental changes have resulted from livestock grazing.

The area is occupied by a substantial diversity of mammals and birds typical of high desert ecosystems with a somewhat lesser diversity of reptiles, amphibians and fishes. The primary game animals which are utilized by hunters include pronghorn antelope (*Antilocapra americanas*), mule deer (*Odocoileus hemionus*) and sage grouse (*Centrocercus urophasianus*). A portion of the area is occupied by California bighorn sheep (*Ovis canadensis californiana*) which were reintroduced in 1968.

The area was initially acquired to provide a place for the perpetuation and propagation of pronghorn. Except for mule deer, the pronghorn is the most dominate ungulate on the area, and it is the pronghorn that will be the focus here. While the refuge was established in 1936, the hunting of pronghorn was first allowed in 1967. Examination of data collected from aerial surveys by the U.S. Fish and Wildlife Service and the Nevada Department of Wildlife shows average annual summer populations of about 1,200 pronghorn during the 1957–1966 period, prior to the initiation of the hunting program. In 1967, the first pronghorn hunt was held with only 10 tags available. In 1969, the number of available tags increased to 20 and remained there until 1976 when 24 pronghorn tags were available. During 1967–1976, the first decade of the hunting program, some 183 pronghorn tags were issued with 174 pronghorn taken. During this same period, the summer census revealed an average annual count of 700 animals, down from the average annual count of 1,200 animals during the preceding decade when hunting was not allowed. Initially, one might interpret from these figures that the population decline resulted from hunting. However, careful review of all the data shows this not to be the case. The ratio of pronghorn bucks per 100 does in the population averaged 45 during the pre-hunt decade, while during the first decade of hunting, the ratio of bucks per 100 does averaged 44 or an average drop of one buck for every 100 does. Annual fluctuations in buck ratios varied much more, with common differences of five bucks or more per 100 does during both the pre-hunt and hunting decades. Table 1 displays the population survey and harvest data averaged by 10 year increments except for the last increment of five years.

That hunting has not negatively impacted pronghorn populations is evidenced by population response throughout the 1980s when the hunting program continued with substantial increases in tag numbers to an average of 39 tags per year. A parallel rise occurred in the pronghorn population to an annual average of about 1,400 animals, with the highest count of 1,939 animals occurring in 1988 which substantially ex-

Table 1. Pronghorn population parameters and harvest averaged for various periods on the Charles Sheldon National Wildlife Refuge.

Period	Ave. annual summer population	Ratio of bucks per 100 does	Tags issued		Harvest	
			Total no.	Ave./year	Total no.	Ave./year
1957–66	1,200	45	0		0	
1967–76	700	44	183	18.3	174	17.4
1977–86	1,200	41	324	32.4	305	30.5
1987–91	1,400	47	368	73.6	307	61.4

ceeded the pre-hunt period high count of 1,485 in 1958. In fact, the pre-hunt population high was exceeded during the 1980s in five different years.

It is a matter of record that pronghorn populations have done very well, having increased to the highest densities of the past 50 years during the late 1980s. To the present time, habitat impact from pronghorn numbers has not been a problem and continued reduction in numbers of cattle and wild horses should enhance habitat carrying capacity for even greater increases in pronghorn populations.

The harvest management philosophy for pronghorn on the Charles Sheldon National Wildlife Refuge has historically been very conservative, with an emphasis on quality. During the first 10 years of the hunting program, the number of tags averaged about 18 per year. Over time, because of the expanding pronghorn herd, tag quotas have been somewhat liberalized, but considerably less than the resource would accommodate without impacting its growth potential. While the harvest management program has been conservative, allowing only for the take of buck pronghorn with emphasis on trophy quality, the efficiency of harvest is noteworthy. Over the 25-year period (1967–1991) during which hunting has occurred, some 875 tags have been issued with 786 pronghorn harvested for a harvest rate of 90 percent. As tag quotas have been liberalized, the efficiency of harvest (Harvest rate) has declined slightly. During the first 10 years of hunting, the most conservative period, the harvest rate was 95 percent; while during the last five years (1987–1991), the most liberal period, the harvest rate dropped to 83 percent. The average number of tags issued per year increased from 18.3 to 73.6 for the respective conservative and liberal periods, so that while the harvest rate has declined by 12 percentage points, the tag quotas have increased by over 300 percent. During the entire 35-year period under discussion (1957–1991), including the 10-year pre-hunt period, the buck ratio has changed little, averaging 45 bucks per 100 does during the pre-hunt decade and 47 bucks per 100 does during the 1987–91 most liberal hunt period.

One potential problem in using a hunting harvest program to keep the pronghorn population in balance with habitat capability is public acceptance of the harvest of female pronghorn. If the population continues to expand, the harvest of female pronghorn will likely become necessary to keep the population in balance with habitat capability. Such a harvest regime will necessitate a public education program to enhance public acceptance for female pronghorn harvest. I believe that this is possible, as many other western states currently provide for the harvest of female pronghorn with fairly strong public acceptance.

The Desert National Wildlife Refuge

The Desert National Wildlife Refuge is located about 20 miles north of the city of Las Vegas in southern Nevada. The refuge was established by Executive Order in 1936 to provide primary habitat for the perpetuation and propagation of desert bighorn sheep (*Ovis canadensis nelsoni*). The refuge encompasses five major mountain ranges and several valleys lying at the southern end of the basin and range country and falling generally within the Mohave Desert region. Because of substantial elevation differences, ranging from valley-floor elevations of about 2,500 feet to mountain peaks and ridges exceeding 9,000 feet, there is dramatic vegetational diversity ranging from Mohave desert plant communities in the valleys and foothills, to a pinion-juniper tree zone and a sagebrush-perennial grass zone, and even a limited subalpine tree zone at the highest elevations. Due to the refuge's elevation differences and multiple vegetative zones, it also contains a wide variety of wildlife including a diverse assortment of birds, mammals and reptiles. The only species which has traditionally been hunted on the refuge is the desert bighorn sheep although recently the area was opened to mule deer hunting.

The area contrasts significantly with the Sheldon National Wildlife Refuge by being more xeric, containing greater elevational differences, and in spite of high biological diversity, having generally lower wildlife density and lower overall biological productivity due to the dry climate. Additionally, bighorn hunting has existed there over a longer period of time than has pronghorn hunting on the Sheldon National Wildlife Refuge.

Hunting and Bighorn Sheep Population Response

Hunting of bighorn sheep has been allowed on the area since 1954, always under a conservative harvest program. Bighorn sheep population survey data is more limited than that for pronghorn on the Sheldon National Wildlife Refuge, because aerial surveys have not been consistently conducted over the long-term, although aerial surveys have been conducted for the past 20 years. During 7 of these 20 years only some of the five mountain ranges which support desert bighorn sheep were surveyed. In the 13 years when all five ranges were surveyed, the actual number of bighorn observed ranged from 260 to 717 with an average of 483. Populations have generally been stable to increasing from the early 1970s through 1987. From 1987 through 1991 the population has been declining as the result of poor lamb recruitment due to an extended and continuing drought.

The bighorn sheep hunting program has been designed and managed in a conservative fashion, with tag quotas established to allow the harvest of no more than 8 percent of the mature (7+ years of age) ram population. While harvest rates have been variable depending on tag quotas, hunting conditions and availability of mature rams, the average rate over the 20 year period of 1971 through 1990 has been about 65 percent with a high of 84 percent and a low of 25 percent. Again, as with pronghorn harvest on the Sheldon National Wildlife Refuge, harvest has had little impact on overall population levels. In order to effect noticeable population changes, the harvest of female bighorn would be necessary. Such a harvest program has not been initiated because there has not been a demonstrated need for such action. With desert bighorn sheep, disease and competition for scarce water are important factors which could necessitate the need for population reduction. These factors are more apt to cause consideration for the reduction of bighorn densities than is direct habitat degredation. High population densities are suspected of being a cause in the outbreak and spread of various diseases, especially pneumonia, which can be particularly devastating to bighorn populations. Even with such a difficult species to hunt, achieving long-term harvest rates of 65 percent is illustrative of the capability of hunting to effectively reduce population size if necessary for the long-term perpetuation of the species.

Discussion

While the examples examined here are not as demonstrative of the efficiency of hunting in maintaining wildlife population balance as might be some examples of white-tailed deer in the eastern and southern United States or possibly muskrats in other parts of the country, they do demonstrate the potential efficiency of hunting harvest even under conservative harvest management strategies. Maybe more importantly, they serve as excellent examples of hunting harvest in balance with other inimical factors and the environment, with no detrimental impact to population expansion capability. They also demonstrate that hunting strategies can be consistently applied which, given environmental conditions conducive to population expansion, will allow such expansion to take place readily.

The challenge for the wildlife manager is to be able to monitor habitat conditions and wildlife population density, and be in a position of making sound predictive judgements to implement appropriate harvest strategies before habitat degradation or disease can cause significant population declines. The consideration of public acceptance of any given harvest strategy, especially one that employs the harvest of female animals, may be an important factor in the process of designing and employing effective hunting programs. In my experience as a biologist and an agency administrator, hunting provides a substantial array of positive benefits, not the least of which is a healthy and diverse wildlife resource.

Bold Actions in Refuge System Law to Maintain Compatibility

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For more than 60 years, cattle have grazed a huge tract of public land in northwestern Nevada. Overgrazing has devastated native grasses, allowing sagebrush to invade, and eroded creek banks, drying up and silting-in streams that are the only home to a rare desert fish, *Gila bicolor eurysoma*. The chub—a candidate for the endangered species list—now inhabits only a few miles of two degraded streams. Species declining across their ranges, including songbirds and sage grouse, are faring no better here. The federal land manager who oversees the area recently lamented that it was being run "like a commercial cattle ranch" (Meier 1991).

This vast expanse of public land is not a multiple-use area managed by the Bureau of Land Management or the U.S. Forest Service. This forsaken area is the Sheldon National Wildlife Refuge, managed, at least in theory, "as a refuge and breeding ground for wild animals and birds" (U.S. Fish and Wildlife Service [USFWS] 1990b).

What accounts for a wildlife refuge where native species are being eliminated to grow beef? Numerous times over the past quarter century, critics of the National Wildlife Refuge System have identified three fundamental short-comings in refuge law—lacks of purpose, control and direction. We are endorsing legislation now in Congress designed specifically to overcome these problems. It will supply purposes for the system, provide clear standards and a formal process for determining what uses should be allowed on refuges, and require planning—for the system and individual refuges—so that refuges may fulfill their potential to meet the needs of our nation's wildlife diversity.

A Lack of Purpose

Twenty-four years ago, at the 33rd North American Wildlife and Natural Resources Conference, the esteemed Leopold Commission reported that the National Wildlife Refuge System lacked a "clear statement of policy or philosophy as to what the System should be and what are the logical tenets of its future development" (Leopold et al. 1969:32). The Commission recognized that without such an underlying philosophy, the refuge system would be unable to resist pressures "for larger picnic grounds, camping facilities, improved swimming beaches, motorboat marinas, water skiing, baseball fields, bridle paths, target ranges, and other assorted forms of play which are only obliquely related to refuge purposes" (Leopold et al. 1969: 44).

Yet, despite attempts by the Fish and Wildlife Service to develop a mission and goals, the Refuge System continues to host a wide array of inappropriate activities. The agency has identified more than 88 different uses occurring on National Wildlife Refuges, 82 of which the Service has some authority to control (USFWS 1990a). These activities range from mining to waterskiing, oil and gas operations to off-road vehicle traffic. By our count, no more than 30 of these appear more than "obliquely related" to achieving the mission of the National Wildlife Refuge System.

But who is to say what activities and uses are related to achieving the mission of the Refuge System? Today, through its new system plan, the Fish and Wildlife Service is moving toward a policy that would allow compatible economic uses only if such activities contribute to refuge management goals and objectives (USFWS 1991), a direction that would have been welcomed by the Leopold Commission. But for how long? Just 10 years ago, it was the policy of Secretary of Interior James Watt to promote "appropriate multiple use" of refuge lands, and refuge managers were directed to look for opportunities to *expand* public and economic uses on refuges (General Accounting Office 1984).

Only a clear statement from Congress articulating the purposes of the National Wildlife Refuge System will ensure that the needs of wildlife—not cattle ranchers and jetskiers—are met first in the management of the system.

A Lack of Control

Philosophy alone will not eliminate incompatible uses on national wildlife refuges, however. As the Leopold Commission recognized, "[o]nce any of these forms of . . . use becomes established, it is difficult to terminate" (Leopold et al. 1969:44). The truth of that statement is demonstrated in a 1990 report by the Fish and Wildlife Service on secondary uses of National Wildlife Refuges. Through a face-to-face survey of 185 refuge managers, the Service found 836 harmful activities—at least one on 63 percent of all refuges.[1] Of these, at least 326 (39 percent) were within the Service's authority to control (Figure 1). Personal communications with refuge managers indicate that this latter number is probably low.

Again, a recommendation of the Leopold Commission is apropos: The Commission urged that "patterns of public use *must* be rigorously controlled to protect the primary purpose of refuges, to emphasize natural values, and to minimize inappropriate uses" (Leopold et al. 1969: 52, emphasis added). Still, almost twenty-five years later, the Fish and Wildlife Service reports confusion among refuge managers about the criteria and process they should use to evaluate the compatibility of secondary refuge uses. The magnitude of this problem is evidenced by the fact that the refuge managers at Sheldon National Wildlife Refuge did not consider the grazing program incompatible (USFWS 1990a). Grazing at Sheldon is just one of 194 activities *within the Service's control* deemed harmful to achieving refuge objectives, but which were not found incompatible (Figure 2).

The task group conducting the secondary use study concluded that "the Fish and Wildlife Service has not provided refuge managers, as a group, with a good under-

[1] Fish and Wildlife Service defined "harmful" use to mean "the net result of the activity is that it adversely affects the ability of the refuge managers to conserve or manage in accordance with the refuge/wetland management district goals and objectives" (USFWS 1990a:17).

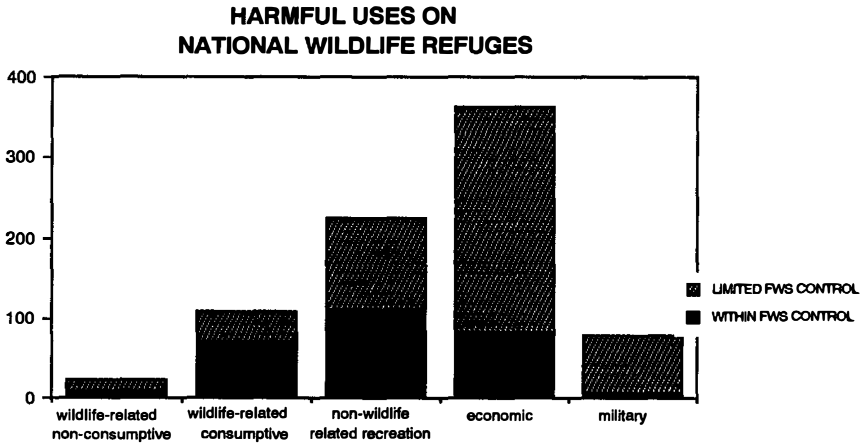

Figure 1. Numbers of harmful activities occurring on national wildlife refuges within the control of the U.S. Fish and Wildlife Service and over which the Service has limited control, for five use types: wildlife-oriented non-consumptive, wildlife-oriented consumptive, non-wildlife oriented recreational, economic and military. Data from USFWS (1990a).

standing of the legal requirements of the compatibility standard, nor of how it should be applied'' and recommended that the Service develop more effective guidance for refuge managers in deciding when uses should be allowed to occur on national wildlife refuges (USFWS 1990:215).

We agree, but past experience has shown that guidance must come from Congress if it is to be effective. The National Wildlife Refuge System has suffered long enough

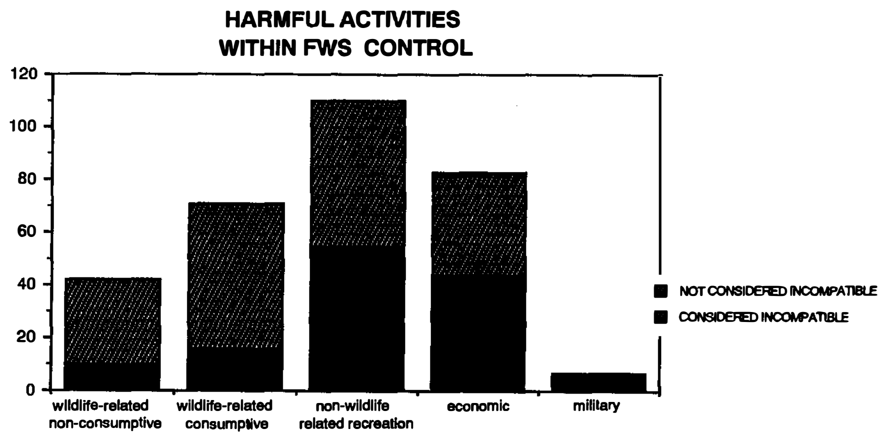

Figure 2. Numbers of harmful activities occurring on national wildlife refuges within the control of the U.S. Fish and Wildlife Service that were reported as incompatible and not incompatible, for five use types: wildlife-oriented, non-consumptive, wildlife-oriented consumptive, non-wildlife oriented recreational, economic and military. Data from USFWS (1990a).

under the vagaries of the current law that allows any use so long as ". . . such uses are compatible with the major purposes for which such areas were established" (16 U.S.C. 668dd(d)). A formal, Congressionally-mandated process for a scientifically-based, periodic review of the compatibility of refuge activities—such as grazing at Sheldon National Wildlife Refuge—is long overdue.

Even with a clear articulation of why the Refuge System exists and a formal process for governing compatibility determinations, the Fish and Wildlife Service still faces a large number of situations in which its own best intentions to conserve wildlife are undermined by the activities of other federal agencies. As the Leopold Commission recognized: "However carefully refuge sites may be selected, the lands are forever subject to invasion by government agencies with higher rights of eminent domain, such as military services, Atomic Energy Commission, Corps of Engineers, Bureau of Reclamation, and Bureau of Public Roads. After a refuge is acquired and developed, it often has to be defended" (Leopold et al. 1969:47).

The Fish and Wildlife Service has identified 78 instances where the military conducts harmful activities on a national wildlife refuge. At Sea Lion Rock, an island within the Copalis National Wildlife Refuge on the Pacific coast of Washington, the U.S. Navy drops 25-pound training bombs in obvious conflict with the needs of the area's marine mammals and other wildlife. The Navy was granted permission for this training operation during World War II, 37 years after the refuge was established. The practice continues today, despite opposition from the Fish and Wildlife Service.

At Cabeza Prieta National Wildlife Refuge in southwestern Arizona, U.S. Air Force and Navy pilots fly at low levels and super-sonic speed, occasionally jettisoning debris onto the refuge. The military operates under a Memorandum of Understanding with the Fish and Wildlife Service that authorizes flights over the refuge above a 1,500-foot ceiling. However, the military periodically requests, and is granted, permission to abandon the flight ceiling agreement despite fears that the activity may be harassing several endangered species, including the Sonoran pronghorn antelope (*Antilocapra americana sonoriensis*).

The Fish and Wildlife Service's Compatibility Task Group recommended in its 1990 report that the Service "seek legislative assurances that would require each federal agency, in consultation with the Secretary of the Interior, to ensure that any actions authorized, funded, or carried out wholly or in part by such agency will not impair the resources of any national wildlife refuge unless such action and resultant impairment is necessary to accomplish the purpose for acquiring the land" (USFWS 1990a:213). Again, we agree. Legislation now before Congress would do just that.

A Lack of Direction

But how do we move beyond talking about what refuges should not be to begin focusing on what they should be? How can we achieve the logical development of the Refuge System long sought by the Leopold Commission? The Commission recommended a continuing appraisal of the System with a view to perfecting long-range plans for its expansion and development (Leopold et al. 1969). It envisioned plans for individual refuges that would preserve or restore natural ecosystems for the benefit of all native animals and plants while achieving the refuges' primary management objectives.

Such plans are still needed today. Some progress is being made. The Fish and Wildlife Service is producing "Refuges 2003—A Plan for the Future of the National Wildlife Refuge System." If all goes well, the plan will address the major issues facing the National Wildlife Refuge System, including conservation of biological diversity, waterfowl management and land protection. At Sheldon National Wildlife Refuge, a plan is being developed to identify an integrated management program that best benefits fish and wildlife.

Unfortunately, these efforts have grown out of controversy and conflict. The Service needs a regular planning process for the system and individual refuges to ensure that both are achieving their potential. If these plans are truly to shape the future of the refuge system, Congress must require, as is now proposed in pending legislation, that the Service complete plans for the System and each individual refuge on a periodic basis and manage the lands in accordance with those plans.

A Time for Action

The National Wildlife Refuge System has been fastened together under a variety of diverse legislative authorities and Presidential decrees. But its history is not without visionaries. President Theodore Roosevelt founded the System at the turn of the century by setting aside dozens of areas from the federal domain for the protection of plume birds and big game species. These areas were established to preserve remnant populations of wildlife that were suffering from the excesses of market trades and game hogs. Heroic individuals were hired by the American Ornithologists' Union and the National Association of Audubon Societies to protect these areas and their wildlife. In the 1930s, Director of the Biological Survey J.N. "Ding" Darling and his chief of refuges J. Clark Salyer II put together a grand scheme to purchase, restore and manage millions of acres of wetlands for the benefit of declining waterfowl populations (Gabrielson 1943). At the dawning of the modern environmental age, the Leopold Commission laid out a vision for the refuge system.

Yes, the National Wildlife Refuge System has had its visionaries. What has been missing is the determination to follow through on their visions. In this time of biological crisis, what is needed is a renewed vision for the refuge system and a mechanism to ensure that vision is fulfilled. The legislation now before Congress, S. 1862, will achieve these ends by codifying the purposes of the System, providing a mechanism for controlling secondary uses, and requiring comprehensive planning for the System and each refuge. Now is the time for bold Congressional action to fulfill the vision of the Leopold Commission and others who have fought to rid the National Wildlife Refuge System of incompatible uses and refocus it on the job of meeting the needs of our nation's wildlife diversity.

References

Gabrielson, I. N. 1943. Wildlife Refuges. The MacMillan Company, NY. 257 pp.

General Accounting Office. 1984. Economic uses of the national wildlife refuge system unlikely to increase significantly. Comptroller General of the United States. U.S. Govt. Print. Off., Washington, D.C. (RCED-84-108). 100 pp.

Leopold, A. S., C. Cottam, I. M. Cowan, I. N. Gabrielson, and T. L. Kimball. 1969. A study of the national wildlife refuge system: The report of the advisory committee on wildlife management, appointed by Interior Secretary Stewart L. Udall. Trans. N. Am. Wildl. and Nat. Resour. Conf. 33:30–53.

Meier, B. 1991. Refuges feel strain as wildlife and commerce collide. *The New York Times*. December 1.

U.S. Fish and Wildlife Service. 1990a. Report to the director: A review of secondary uses occurring on national wildlife refuges, submitted by the Compatibility Task Group. June. 232 pp.

———. 1990b. Purposes of National Wildlife Refuges. Updated September 20. 68 pp.

———. 1991. Refuges 2003—A plan for the future of the national wildlife refuge system: A reasonable range of alternatives. November 1991 newsletter.

Biological Farming: An Effective Program for Wildlife Agriculture

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Introduction

DeSoto National Wildlife Refuge is located in the Missouri Valley Basin, 20 miles north of the metropolitan Omaha/Council Bluffs area. The refuge sits astride the Missouri River in what has been characterized as a "sea of corn." This refuge comprises over 7,800 acres of rich bottomlands, which would naturally revert to monotypic cottonwoods, willows and roughleaf dogwood, with an understory of poison-ivy, if the lands were not intensively managed for a diversity of habitats.

The refuge has been farmed for wildlife ever since its establishment in 1958. In the early years, farming emphasis was on migratory waterfowl. Historically, the refuge sustained average peak populations of 125,000 mallards and 200,000 snow geese during the fall flight. Early on, some 3,700 acres of cropland were farmed under 12 cooperative agreements with local producers. Eventually, a more balanced program evolved, which included considerations for resident wildlife and the viewing public. Food plots were provided along auto-tour routes and near overlooks to attract wildlife close for viewing. And, farming acreages were eventually reduced. Smaller fields which didn't attract waterfowl were reverted to native grasslands, cool-season grasslands, tree and shrub plantings. Hydric soils were taken out of production, and reverted into wetlands and moist-soil developments.

But, for 20 years, conventional farming practices (with corn-following-corn or a corn and soybean rotation) were permitted. Some restrictions were placed on commercial use of fertilizers and pesticides, but not many. We were a party to local agribusiness, and probably contributed to local contaminant problems, although our managers didn't realize the impacts at the time.

Components of the Program

With realization comes change. In 1979, the refuge began converting from conventional crop rotations, using essentially the same cooperative farmers. The accepted conventional rotation used by these farmers consisted of corn and soybeans in a two-year rotation. The refuge's new biological rotation included a legume, usually sweet clover, in a three-year rotation with corn and soybeans, which essentially took a third of refuge croplands out of grain production. Refuge farmers were not happy with this requirement. There was criticism. But, nobody quit farming, and they still bought new pickup trucks each spring.

Routine soil sampling dictates annual soil requirements in a biological program. Some amendments are permitted, but cooperators are dependent on legume production for their nitrogen requirements, so timing and stand density are crucial. Soil tests have shown that a good stand of sweet clover is capable of providing sufficient available nitrogen to produce 160 bushels of corn per acre, an Iowa standard for dryland farming. So, with wise management, the farmer has adequate nitrogen for the following corn crop when he incorporates the clover into the soil during the fall. And, even soybeans produce some nitrogen and improve soil tilth when this crop follows corn. Thus, this rotation works well at DeSoto.

Other rotations have been tried with varying success. Plantings of clover and oats produced a nice cash crop for cooperators, but timing was critical. We also found that our cooperators were more concerned about oat production than the sweet clover's vigor. Since their priority should be nitrogen production, this short-sighted practice was discontinued in 1989. Alfalfa also has been used as a nitrogen producer in the past, but it does its job best in longer rotations, it is more difficult to incorporate into the soil and, locally, problems with alfalfa weevil discourage its use.

Approximately 85 percent of the refuge's croplands are biologically farmed. The remaining 15 percent are maintained in a conventional rotation, as a control for comparison of inputs and yields. Cooperators are permitted to use inorganic nitrogen fertilizers on conventional-rotation fields. However, U.S. Fish and Wildlife Service policy restricts the use of pesticides on Service lands. No insecticides are permitted on refuge croplands. And, only a restricted-use list of herbicides is allowed, at specified rates of application. Restricting herbicide options encourages the cooperator's use of mechanical tillage for weed control. While this method is more labor-intensive, there are still considerable cost savings, when compared to the more typical pesticide applications used by local producers on their private farms. These restrictions reduce potential contamination of refuge ground and surface waters: a growing refuge concern.

Of far greater concern to the cooperative farmers are harvest yields. While refuge croplands may sport more weeds and sustain more damage from insect pests than the cooperators would allow on their own farms, refuge yields have remained quite comparable between biological and conventional rotations. Despite low-yield environments, due to some drought years (1983, 1988 and 1989), the overall average yields for the period 1979–91 are surprisingly close for both corn and soybeans. The average yield for biological-rotation corn was 95.8 bushels per acre. Conventional-rotation corn did slightly better, with an average yield of 96.1 bushels per acre. For soybeans, biological rotations produced an average of 35.5 bushels per acre, as compared with 33.4 bushels per acre for conventional-rotation fields. The biological-rotation soybeans have outyielded conventional-rotation soybeans in 11 out of 13 of the above years.

Throughout these years, this refuge experimented with a variety of biological farming techniques. Humates were shipped in from the southwest to build organic matter and enhance certain chemical releases in the soil. Sludge management was incorporated on a 100-acre plot under a six-year cooperative demonstration project with the city of Omaha. Most recently, a three-year integrated pest management study was undertaken in cooperation with the Leopold Center for Sustainable Agriculture at Ames, Iowa, and the Iowa Cooperative Extension Service, Iowa State University.[1] One of the significant findings of this study is that seven agricultural

[1]Copies of DeSoto National Wildlife Refuge Demonstration and Education Project (88–4), a final report prepared for the Leopold Center for Sustainable Agriculture, September 25, 1991, are available from the Refuge Manager.

herbicides are present in refuge ground and surface waters at detection levels. All, except one, are prohibited from use on the refuge. Atrazine and Cyanazine were the most frequently detected. These herbicides were detected in inflow drainages from adjoining farms and the 788-acre DeSoto Lake during routine sampling, and following rainfall events. Also, insecticides were detected in these drainages following seasonal rainfall. Atrazine and cyanazine were detected in DeSoto Lake throughout the year. And, Atrazine concentrations exceeded the aquatic population advisory level in 1990 and 1991. This is disturbing news, especially when one considers the fact that we are trying to maintain a viable sport fishery in this lake, which was renovated in 1985.

Today's Program

Today, the refuge hosts roughly 400,000 people a year, and an equal number of snow geese in season. Today, the refuge has ten cooperators, farming approximately 2,000 acres under cooperative farming agreements. They receive two-thirds of the harvest. Their services to the refuge are documented at the prevailing custom rate, as listed on the current Iowa Custom Rate Survey, which is produced annually by the Iowa Cooperative Extension Service. The cooperators are responsible for all costs of ground preparation, seed, chemicals, tillage and harvesting of crops. While the refuge is interested in leaving much of its one-third share of corn standing for wildlife use, it has the cooperator harvest its share of soybeans (and corn, in some instances), and deliver the grain to a local commercial elevator for sale. Proceeds from the sale of this grain are then used to reimburse individual cooperators for food-plot establishment or other required farming services that they have rendered; again, based on the Iowa Custom Rate Survey. The local elevator is instructed to issue specified payments directly to individual farmers for these services. In that way, the refuge does not actually handle receipts, except when excesses are returned to the U.S. Treasury.

One unique aspect of DeSoto's farming program is inter-elevator transfers of any surplus grain to other national wildlife refuges, on a first-come, first-served basis. Approximately 1,200 bushels of corn are retained over winter at this station for potential depredation or disease emergencies within the Service, as per existing contingency plans. Any remainder of the held-over grain is transferred in the spring by inter-elevator to other refuges for use in their operations. Such transfers require a detailed system of accountability.

Today, integrated pest management is being actively used in DeSoto's farming program. It involves the use of pest management techniques to keep crop pest populations below economically damaging levels, while striving to avoid adverse effects on humans, wildlife and the environment. These tactics include encouraging natural enemies to control pests, using crop rotations to disrupt the pest's life cycle, mechanical cultivation for weed control and careful use of herbicides. During the past three summers, we have employed the services of a trained crop scout to monitor crop conditions and pest populations. The scout routinely walks each field and records observations on the presence of crop pests, pest development, extent of pest damage and the development stage of the respective crop. Using this information, the producer can make sound management decisions. Often, the use of post-emergent herbicides can be averted by timely rotary hoeing, and the use of insecticides on off-refuge fields can be limited or avoided, because conditions have not reached a threshold beyond which insecticide control would be economically beneficial. Occasionally, the scout can even isolate the extent of an infestation within a portion of a field, so that excessive chemical treatment can be avoided.

Results and Conclusions

The most effective and economic means of achieving necessary farming practices on refuges today is through cooperative farming. Today's farming practices require a large inventory of expensive equipment. Purchase costs, repairs and labor costs make force-account farming far too expensive for most refuge operations.

National wildlife refuges can be economically managed by using biological farming techniques. The existing refuge manual includes guidelines for cooperative farming practices. Existing policy and regulations permit cooperative biofarming through use of an approved Cropland Management Plan. Such a plan must incorporate full accountability, equability and a system of safeguards for cooperator activities. With good planning, a wide spectrum of benefits can be achieved.

DeSoto's managers will continue to analyze and refine biological farming techniques. We will be incorporating integrated pest management techniques into our cooperative farming agreements. Crop scouting will become a required cooperator service in DeSoto's revised Cropland Management Plan this year, a cost of doing business. We also will continue to monitor ground and surface water. And, we will work with local producers who are contributing to the contamination of the agricultural community and refuge waters. The day is fast approaching when we will see proscribed changes in chemical application rates, more restrictive use of pesticides, some rethinking on refuge overflights and aerial application routes which intersect or cross inflow ditches, and more grassed filter strips along private drainages which flow into this refuge.

Most of the benefits of biofarming are refuge-specific. They include a reduction in the use of nitrogen fertilizers and reductions in the use of pesticides, which, in turn, reduce the potential contamination of refuge groundwater and surface water. Other benefits are reduced soil erosion and improved habitats for resident and migratory wildlife. In DeSoto's instance, biofarming produces food and shelter, and increases the edge effect for a diversity of wildlife species which might not even visit or live within the otherwise monotypic bottomlands of the Missouri Valley Basin. So, biofarming actually contributes to biodiversity.

And, biofarming aids our managers in manipulating wildlife populations for public enjoyment. Sometimes, it is as simple as placement of a food plot alongside an auto-tour route or the sequential timing of a cropland harvest near a public viewing area.

Biofarming works for us at DeSoto. It produces comparable yields to conventional farming practices and it's a more environmentally-sound alternative. I am convinced that, during the 1990s, we can fine-tune biofarming practices for refuges into an art form.

Grazing on National Wildlife Refuges: Do the Needs Outweigh the Problems?

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Introduction

The relation among wildlife, livestock and range management has been a topic of debate since at least the early 1900s (Leopold 1933). The scale of the arguments and the stakes seem to increase each year. For example, in a recent address, Richard J. Mackie (1991), President of The Wildlife Society, listed grazing as one of the major land-use practices in need of a leadership role from professionals in the wildlife sciences.

In this paper, we summarize the current extent and projected trends for grazing on the National Wildlife Refuge System (NWRS), address recent debates about grazing on U.S. Fish and Wildlife Service (Service) lands, and define the differences between the purposes of grazing on federal lands administered by the Service and the lands administered by other federal land-management agencies. We then define the appropriate debate about grazing on National Wildlife Refuges by refocussing the issue on the need to evaluate grazing as one of a series of alternative grassland management tools, instead of an economic use of Service lands. In this context, we address livestock grazing in management of breeding waterfowl (Anatidae), a major U.S. Fish and Wildlife Service trust responsibility. Finally, because our extensive review of the literature disappointingly revealed few studies that asked the right questions about grazing on National Wildlife Refuges, we suggest means to devise statistically sound grazing/wildlife research as an integral portion of management of the NWRS.

Grazing and Grassland Management on National Wildlife Refuges

The mission of the NWRS is to provide, preserve, restore and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's needs for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available (U.S. Fish and Wildlife Service 1982: Manual 2RM 1.3). In practice, management of National Wildlife Refuges is guided by legal mandates, including the Refuge Recreation Act of 1962, the National Wildlife Refuge System Administration Act of 1966 and the Endangered Species Act of 1973. Guidance for management of grazing on National Wildlife Refuges (hereafter defined to include land owned by the Service in fee title, including Waterfowl Production Areas) is found in the U.S. Fish and Wildlife Service's (1982) Refuge Manual 5 RM 17 (Administration of Specialized Uses), 6RM 5 (Grassland Management) and 6RM 9 (Grazing and Haying Management). Livestock grazing is permissible on Service lands if it is compatible with the purposes for which the area was established pursuant to section 4(d) of the National Wildlife Refuge System Administration Act, 16 U.S.C. 668dd(d), current goals and objectives of the refuge within applicable laws and regulations, and Department of the Interior and Service policies. The NWRS considers grazing a habitat management tool that is permitted when it contributes to established wildlife management objectives. Grazing also is permitted on a secondary basis when this use of a renewable resource (forage) is compatible with refuge purposes.

Grazing is not an objective of management in the NWRS, but it may be one of a number of uses for which the Service has no jurisdiction on some of its lands. For example, grazing may be mandated by purchase agreements or the Service may have no legal mandate to control grazing. The latter occurs where only limited interests were acquired (e.g., wetland easements), when primary jurisdiction is retained by another agency (e.g., overlay refuges), or when other laws specifically authorize such use (such as in Alaska).

Current Status of Grazing on Refuges

In a review of the status of the NWRS in 1989–91, the Compatibility Task Group (Coleman et al. 1990) found grazing on 183 (38 percent) of the Service's 478 Refuge System units. On 64 of these 183 units, the Service has no authority over grazing because it is a reserved use by the primary land ownership agency (n = 4), is a reserved or granted property interest (n = 58), or other (n = 2). On 12 of the 119 units where the Service can control grazing, the current managers judged it to be an incompatible activity and steps have been initiated to terminate such use (Coleman et al. 1990). The Compatibility Task Group (Coleman et al. 1990:17) identified a use as "harmful" if "the net result was that it adversely affected the ability of the refuge manager to conserve or manage in accordance with refuge . . . goals and objectives." When asked, refuge managers defined as harmful 76 (42 percent) of the current grazing arrangements. Fifty-six (74 percent) of these "harmful" uses were thought to result from limited Service ownership and control of the lands being affected. Refuge managers identified several common consequences of harmful grazing (Table 1).

The Refuges 2003 effort—a combined environmental impact statement and long-range planning effort currently in progress (e.g., Shallenberger 1992)—used a method

Table 1. Perceived consequences of harmful grazing as reported by 69 refuge managers west of the Mississippi River in the 1989 secondary uses survey (Coleman et al. 1990).

Consequence	Number of refuges reporting[a]
Habitat destruction/degraded	9
Waterfowl production goals prevented	2
No management benefits	4
Whooping crane mortality on fences	1
Wildlife disturbance	2
Perceived political pressures	1
Hawaiian Forest Bird habitat degradation	1
Freshwater pond/aquatic vegetation damage	1
Sensitive barrier island ecosystem damage	1
Loss of nesting cover	57

[a]The total does not equal the number of refuges reporting "harmful" uses because these categories were not considered mutually exclusive by the respondents and some refuges reported more than one harm.

of gathering data that differed from that of the Compatibility Task Group in that it combined data from satellite stations within Refuge Complexes. Compilations identified 134 National Wildlife Refuges whose ecosystems are managed by livestock grazing (Figure 1). On 2.059 million acres (0.833 million ha) livestock grazing was most commonly applied to grasslands (n = 108 refuges), wetlands (n = 62), riparian areas (n = 21) and deserts (n = 6). Migratory birds, particularly waterfowl, were the targeted beneficiaries of management in these habitats (Table 2).

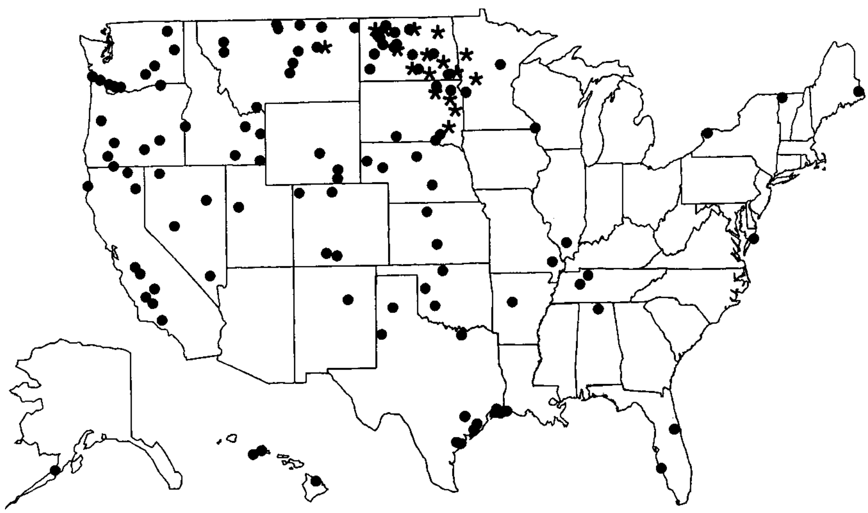

Figure 1. National Wildlife Refuge System units with livestock grazing during 1989–90 as reported during the Refuges 2003 survey (Division of Refuge Management, Arlington, Virginia).

Table 2. Primary and secondary beneficiaries of management of grasslands, riparian areas, wetlands, and deserts reported by managers of National Wildlife Refuges included in the Refuges 2003 data base.

	Habitat[a]							
	Grassland		Riparian		Wetland		Desert	
Group of species	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
Birds								
Waterfowl	143	11	75	13	325	31	0	0
Other migratory game	7	33	4	21	3	43	0	0
Nongame migratory	32	92	54	74	32	263	4	4
Big game	10	21	21	33	4	25	8	2
Upland game	13	65	10	26	2	20	1	6
Threatened/ endangered	22	12	24	24	34	34	4	0
Resident nongame	14	31	7	48	3	3	3	9

[a]N = number of refuges reporting in each habitat category.

Criticism of Grazing on National Wildlife Refuges

Formal debate on grazing in the Refuge System was initiated by the National Wildlife Refuge System Task Force (1979), which suggested grazing may be abusive in some parts of the Refuge System. In response, the Service developed additional specific guidance for management of grazing in the Refuge Manual and strengthened the definition of compatibility on Service lands. Concurrently, the Conservation Committee of the Wilson Society (Braun et al. 1978) suggested grazing should be reduced on many refuges. Following a system-wide review, Strassmann (1987) also concluded that cattle grazing should be replaced with different habitat manipulation on refuges. More recently, the United States General Accounting Office (U.S. GAO) conducted a review of National Wildlife Refuge lands and determined that the Service permits some land uses (including grazing) that conflict with wildlife values (U.S. GAO 1981). They later concluded that harmful secondary uses, including grazing, were still practiced on many units of the NWRS (U.S. GAO 1989). In response, the Service Compatibility Task Group reviewed secondary uses on the NWRS and found grazing was one of the most frequent incompatible and harmful uses of Service lands (Coleman et al. 1990). Grazing on refuges continues to draw substantial criticism in the popular press (Ferguson and Ferguson 1983, Fischer 1985, Wuerthner 1989, Drew 1992).

What are the Problems?

The Service contemplates no action on its lands for which it has no control over grazing except perhaps renegotiation of existing land-use contracts or deeds. (The

Service is currently reviewing easement refuges to determine whether additional rights should be purchased, existing rights relinquished, or the status quo retained.) Elsewhere, the Service intends to eliminate clearly incompatible grazing from its lands. Additionally, managers have been asked to carefully assess those instances wherein grazing is deemed harmful, with the consideration that grazing might be removed from those areas as well. Thus, an optimistic view is that more finely tuned management of natural resources is imminent with regard to grazing. Regrettably, this is not entirely true.

For a determination of compatibility and any decision to use grazing in management of wildlife habitat, the effects of grazing must be known, or at least predictable with reasonable assurance. Ideally, data from well-designed scientific experiments are available for such determinations. Unfortunately, sound experiments on the effects of livestock grazing on wildlife populations have not been performed. The lack of reliable scientific data is the greatest obstacle to the proper use of livestock grazing in wildlife management.

Reliable data are required prior to implementing a grazing program (Figure 2). At "A" there must be some knowledge of what grazing might accomplish on the refuge in question. At "B" there must be information on the costs of reducing the wildlife benefits through selection of a less than perfect habitat management (grazing) regime. Finally, at "C" there must be some means of relating the habitat management

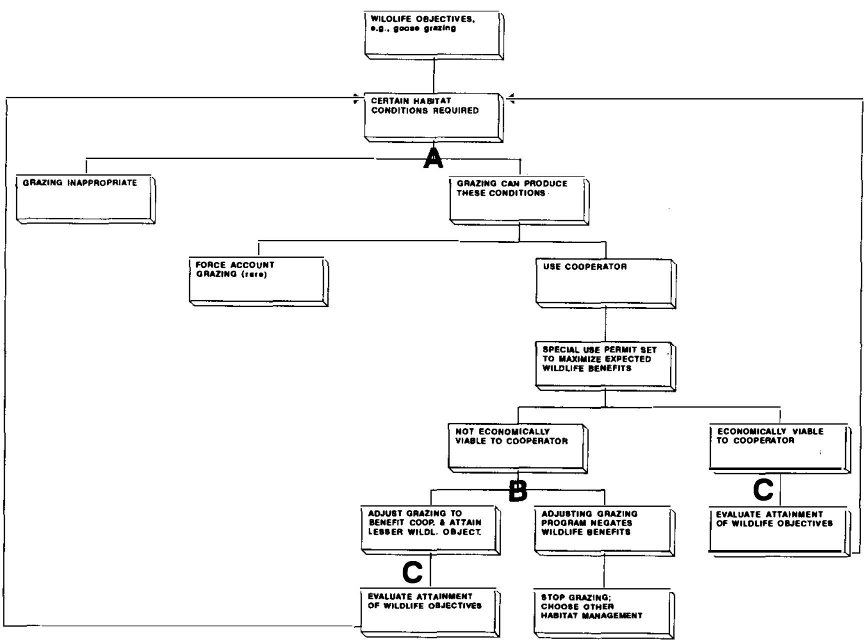

Figure 2. The refuge manager's decision process for evaluating grazing as a potential habitat management tool to meet wildlife objectives in grasslands. The letters (A-C) indicate critical decision points for which unequivocal data are needed.

technique to the selected wildlife objectives so that the process may be fine-tuned in succeeding years. Compromises also are part of the process; one outcome that selects grazing results in full attainment of wildlife objectives and the other does not because of the need to compromise objectives to enlist the assistance of a cooperator. Nonetheless, this compromise may still be the optimum decision for long-term habitat management needs on some refuges.

The Effects of Grazing on Wildlife and Wildlife Habitat on Refuges

Range scientists have compiled substantial information on the effects of grazing on grasslands, especially on plant species composition, accumulation of litter, and annual vegetative productivity. Although these major phenomena are known and lend themselves to generalized grassland management prescriptions (e.g., Vallentine 1990), debates on the relative merits of different grazing systems continue. However, such debates are not framed in the context of designing management that benefits wildlife at the possible expense of livestock production. Instead, assessment of alternative range management practices usually begins with the assumptions that optimization of commodity production is the major, if not the sole objective (Vallentine 1990) and that multiple use is the land-use philosophy (e.g., Holechek et al. 1982). Neither of these assumptions determines management of National Wildlife Refuges.

Negative effects of grazing livestock on refuges include aesthetic issues, such as the visual impact of large numbers of cattle in wildlife areas, extensive fencing on public lands, concentrations of dung and insects (especially in shaded areas and near water where campers and other recreationists congregate), and destruction of springs, fishing sites, streambanks and trails by livestock. More complex, and usually only identifiable after long periods of grazing, are landscape-scale effects, such as changes in composition of plant and animal communities and thus, biotic diversity (Archer and Smeins 1991), transmission of disease between livestock and wildlife, such as the recent controversy surrounding brucellosis and bison (*Bison bison*) in the Yellowstone ecosystem (Thorne and Herriges 1992), and increases in exotic and pest plants in heavily grazed ecosystems (Vallentine 1990:331).

Soils are affected by livestock through removal of protective vegetation, compaction, and penetration and disruption of the soil surface, which in turn reduce infiltration, decrease soil organic matter and soil aggregates, and increase soil crusting (Blackburn 1984). Watershed hydrology is affected by subsequent erosion from displacement of soils on slopes, development of trails, and loss of mass in overland flow (Blackburn 1983, 1984, Branson 1984). These may increase runoff and reduce soil water content. Effects are especially extreme in riparian and aquatic zones, which are disproportionately favored by livestock for resting and drinking areas and seasonally high quality forage (Platts and Raleigh 1984, Skovlin 1984, Clary and Webster 1989). Trampling and defoliation, even with low livestock numbers, can negatively affect streamside vegetation, stream channel dimensions and condition, shape and quality of the water column, and structure of soils on the streambank (Platts 1986). Cumulative effects include channel degradation and lowering of the surrounding water table, which may eliminate the riparian vegetation; increased coliform bacteria levels, which affect downstream water quality; raised water temperatures, which in turn change the aquatic fauna; and excessive sedimentation, which may halt fish reproduction (Kauffman and Kreuger 1984).

Livestock grazing affects plant communities through defoliation and trampling of plant material and soils, and removal of nutrients and their redistribution through excreta (Bartolome 1984, Dwyer et al. 1984, Skovlin 1984, Vallentine 1990). Many plants are normally grazed by vertebrate and invertebrate herbivores and, thus have evolved in ecosystems with substantial herbivory, disturbance, and often severe conditions for plant growth (Low and Berlin 1984). Depending on its seasonality, intensity, frequency, and duration, the immediate effects of grazing on a plant may range from reducing plant vigor or killing it, to increasing plant size or growth rate. Because herbivores are selective feeders, some grasses, forbs, and shrubs may decrease, whereas others increase as the grazing regime changes or is extended in time. Species composition and the physical structure of the vegetation can be changed by grazing (Vallentine 1990), especially when the stress from defoliation and trampling prevents acquisition of soil moisture and nutrients in a limited growing season. Undoubtedly, herbivory by livestock has had a dramatic effect upon the species composition and plant biomass of the arid grasslands of the midwestern, western and southwestern United States (Donart 1984, Herbel 1984, Low and Berlin 1984, Young et al. 1984). From our observations, this is true on units of the NWRS as well, with severe changes in the plant community typically found on those areas over which the Service has had limited or no control over grazing, sacrifice areas near corrals, minerals and water, and where stocking rates on sensitive sites, such as riparian corridors, have been excessive.

The effects of livestock grazing on wildlife—especially under differing grazing schemes—are poorly understood, largely because of a dearth of comprehensive studies (Carpenter 1984, Severson 1990). In general, vegetation diversity decreases as grazing intensity increases, and this has direct effect on the distribution and diversity of wildlife (Carpenter 1984). One extreme can thus be generalized: heavy, long-term, continuous grazing is universally detrimental to nearly all wildlife populations (Dwyer et al. 1984). However, livestock grazing has been proposed as a tool with benefits for wildlife species ranging from mule deer (*Odocoileus hemionus*) (Willms et al. 1979, Urness 1990) to northern bobwhites (*Colinus virginianus*) (Moore and Terry 1980, Schulz and Guthery 1988). Examples of applying livestock grazing to meet specific wildlife habitat objectives on refuges include use of fall burning and winter grazing of three-square bulrush (*Scirpus olneyi*) marshes to maintain a subclimax plant community used by wintering geese and ducks on Anahuac and McFaddin National Wildlife Refuges in Texas; use of short duration-high density grazing where fire cannot be used to remove excessive accumulations of mulch and woody invaders of upland waterfowl nesting habitat on the Morris Wetland Management District, Minnesota; use of grazing to maintain short swards for migrating and wintering Canada geese (*Branta canadensis*) at the Iroquois National Wildlife Refuge, New York, and the Ridgefield National Wildlife Refuge, Washington; and maintenance of heavily grazed pastures at the Pixley National Wildlife Refuge, California, as habitat for the mountain plover (*Charadrius montanus*).

Although it strives to appropriately manage the entire complement of biotic diversity on its land, the U.S. Fish and Wildlife Service has a major mandate to manage the continental migratory bird resource. Appropriately, waterfowl were the intended primary beneficiaries on 59 percent of the refuges using grazing as a habitat management technique in grasslands and 81 percent of the refuges that graze livestock in wetlands (Table 2). Because the literature on waterfowl management is extensive, and the Service and many state and private agencies, such as Ducks Unlimited, have a long history of developing management activities especially for the benefit of waterfowl, we use breeding waterfowl as a focus of further discussion about the effects of grazing on wildlife.

Effects of Grazing on Breeding Waterfowl—A Critique

We reviewed more than 100 papers written on the relation between grazing and waterfowl habitat. Most studies were about the effects of grazing on the structure and species composition of either wetland plants or upland vegetation waterfowl prefer for nesting. Two sensitive habitats, wetlands and riparian zones, seem particularly prone to abuse from intensive grazing. On the positive side, light to moderate grazing can be used occasionally to open up dense, monotypic stands of robust emergent vegetation, such as cattails (*Typha* spp.), phragmites (*Phragmites* spp.) or bulrushes (*Scirpus* spp.) (Kantrud 1986). Openings created by trampling, uprooting and consuming vegetation enhance the interspersion of water and plants, which seems to increase use by breeding pairs of ducks and their broods (Weller 1978, Kaminski and Prince 1981, Kie and Loft 1990). However, destruction of shoreline vegetation reduces waterfowl nesting (Bue et al. 1952) and some waterfowl foods (Whyte et al. 1981). Thus, fencing to exclude cattle from wetland shorelines has been beneficial for breeding waterfowl (Bue et al. 1952, Berg 1956, Whyte and Cain 1981).

Riparian vegetation occurs in less than 1 percent of the western North American landscape but provides habitat for more bird species than all other vegetation types combined (Knopf et al. 1988), as well as a wealth of other wildlife (e.g., Brode and Bury 1984, Thomas et al. 1979). Range scientists, wildlife biologists, and fishery biologists agree that grazing causes major deterioration of riparian systems (e.g., Johnson et al. 1985, Platts 1991), the recovery from which may be very slow (Knopf and Cannon 1982). Maintaining the value of these areas for waterfowl requires the same actions as those required for all fish and wildlife: strict control, if not complete exclusion, of livestock (Dwyer et al. 1984, Platts and Raleigh 1984, Clary and Webster 1989). However, few investigations of grazing in riparian areas evaluated effects under proper stocking rates and intensities of use (Kauffman and Kreuger 1984, Sedgwick and Knopf 1987, F. L. Knopf personal communication: 1992).

The effects of grazing on upland vegetation used by nesting ducks are less clear. Most studies emphasized the importance of maintaining residual and other cover for nesting waterfowl (Kirsch 1969, Kaminski and Weller 1992), through either eliminating grazing entirely (Kirsch 1969, Kirsch et al. 1978), changing the season of use (Ruyle et al. 1980), or establishing a rotational scheme allowing some grazing rest and, thus, development of cover (Gjersing 1975, Mundinger 1976, Rees 1982, Duebbert et al. 1986). Almost all researchers reported that grazing systems reduce waterfowl nest densities or nest success, but a few found no detrimental or even beneficial effects to nesting ducks (e.g., review by Kirsch et al. 1978 versus Barker et al. 1990). We believe that the reliability of knowledge provided by these and most grazing studies is low, and contend that poor study designs, rather than differential response of waterfowl to grazing treatments, are often the cause of inconclusive or contradictory findings.

About 90 percent of the papers about grazing that we reviewed relied on inductive measures of inference that prohibit insights into the mechanisms of grazing effects (Romesburg 1981). For example, waterfowl nest densities or nest success on grazed land often are compared with the same metrics collected on ungrazed sites, and a causal relationship is assumed between the grazing treatment and response by waterfowl. Experiments of this type have been performed many times throughout North America, but findings are equivocal. Retroductive inferences about the effects of grazing on waterfowl have increased as researchers began (based on earlier causal studies) to relate attractiveness of nesting cover, as indexed by the height, density and species composition of residual vegetation, to successful nesting by waterfowl. Visual obstruction readings, biomass of residual cover and similar measures were used to quantify habitat responses to grazing. Then, responses by waterfowl were either inferred by inductive reasoning from information on waterfowl/vegetative relations or by collecting more data on waterfowl usage and then presuming they reflected a response to altered vegetation (e.g., Kaiser et al. 1979, Duebbert et al. 1986). This approach, however, does not rule out alternative hypotheses that can be generated from the same set of facts (Romesburg 1981).

Design of Experiments to Test the Effects of Grazing

The response variable in studies of waterfowl is most frequently nest density or nest success, and, occasionally, animal abundance or density. Proper experimentation relies on three critical elements to justify valid inference about the effect of a treatment (in this case, grazing) on the response variable.

First, one or more controls must be available, thus allowing a treatment versus control contrast (i.e., grazed area versus ungrazed area). Few investigations of grazing have had adequate experimental controls, yet without them, covarying factors, such as drought, predator populations and wetland juxtaposition, may cause invalid inferences about grazing-treatment effects. This problem has been recognized by some; for example, Cornely (1982) noted that large changes in waterfowl production at the Malheur National Wildlife Refuge could be attributed to several interacting factors, including cessation of grazing. In contrast, a recent study of grazing and waterfowl production in North Dakota concluded that waterfowl production was greater on grazed than on idle areas under several grazing regimes (Barker et al. 1990, Sedivec et al. 1990). This incongruous result may have been influenced by an experimental design that did not account for the relative distribution of red foxes (*Vulpes vulpes*), a major predator on waterfowl nests, and coyotes (*Canis latrans*), a lesser predator on waterfowl nests that excludes red foxes from its territories (Sargeant and Arnold 1984, Johnson et al. 1988).

Second, assignment of the grazing treatment must be done randomly. A common error has been to pick an area that has already been grazed as the "treatment" area and another that has not been grazed (recently) as the "control" area. Often, however, pastures are selected based on the ability of the land to produce more forage (potential duck nesting cover) than areas not selected for grazing. This bias can cause incorrect inferences about grazing effects *per se*. Thus, the assignment of a treatment to experimental units (areas) must be done with a random number table or some similar scheme. None of the grazing studies we reviewed incorporated random assignment of grazed or ungrazed treatments to pastures. Although valid inference is possible from non-randomized studies, such quasi-experiments (Cook and Campbell 1979) fall short of providing irrefutable information about the mechanisms of grazing effects.

Third, there must be replication of the randomly assigned treatment versus control combinations. In testing of the effects of grazing, this replication must be done over both years and areas. Most researchers whose studies we reviewed incorporated temporal and spatial replication of grazing treatments which were inadequate to justify the explicit or implicit scope of their conclusions. Climate, soils, geomorphology, and other environmental factors create the wide diversity of upland plant communities used by nesting waterfowl, and it is reasonable that a high degree of spatial replication is justified if inferences about the effects of grazing are to be applied to large areas (e.g., Hurlbert 1984). Temporal replication over several years also is necessary to overcome the annual variability in nest density and nest success evident in some short-term studies.

Rigorous experimental designs, including control, replication and randomization, are well suited to studies of grazing. Proper replicates can easily be created by delineating pastures of suitable size and location. Random assignment of control and treatment areas is straightforward and easily achieved. Perhaps the greatest obstacle to conducting good experiments with grazing is mustering the commitment to collect data for many (more than 10) years in a variety of habitats, a design necessitated by the characteristically large annual and spatial variability in wildlife parameters, such as waterfowl nesting success. Supplemental information, such as the abundance of predators in an experimental area, also should be collected for possible use as co-variates in subsequent analyses. Alternatively, management practices can be included in a more sophisticated design so that interactions among nest success, grazing intensity, predator removal, and other factors can be assessed. Sound theory and computer software are available to assist design and analysis of grazing studies at any level of complexity.

Grazing—Do the Needs Outweigh the Problems?

There are some healthy trends in the current internal review of grazing on Service lands. For the first time, a compilation clearly indicated that some grazing, even though currently deemed compatible, is nonetheless considered not in the long-term best interest of management of Service lands by refuge managers (Coleman et al. 1990). Steps are being taken to resolve these situations. Activities also are underway to remove incompatible grazing within a reasonable time from lands on which the Service has authority over grazing. Nonetheless, concern about the remaining grazing programs persists, and additional critical evaluation is warranted. As we discovered in our review of the literature on breeding waterfowl, data from appropriately designed studies do not exist to indicate that upland nesting ducks benefit from livestock grazing, and some circumstantial results from poorly designed experiments suggest the opposite. We also note that discussion within the professional Range Science community clearly indicates that grazing systems often work in unpredictable ways and that the claims for some systems are without rigorous, scientific foundation, particularly Savory's (Savory and Parsons 1980, Savory 1988) High-Density Short-Duration Grazing (Pieper and Heitschmidt 1988, Bryant et al. 1989, Guthery et al. 1990). Similarly, we still have no appropriate grazing systems for completely protecting sensitive habitats, such as riparian areas and deserts that evolved without high densities of grazing herbivores (Laycock 1983, Pieper and Heitschmidt 1988, Bryant et al. 1989, Clary and Webster 1989). This underscores the need for wildlife managers and biologists to carefully assess all aspects of grazing and its effects on wildlife before initiating grazing programs or drawing management conclusions from existing programs.

None of the above should be taken as a proscription of grazing on National Wildlife Refuges. ''No management'' (i.e., no anthropogenic treatment) is actually a course of management for grasslands with predictable consequences. Most grasslands, if left undisturbed for too long, become less productive and begin to lose necessary attributes for certain wildlife species (Duebbert et al. 1981). Grassland plant species composition will change, vigor of individual plants will decrease, and woody species will invade the grass community. Livestock grazing is a tool (controlled burning another) that refuge managers use to modify species composition, amount of residual cover, and plant density, height, and vigor in several types of plant communities (Duebbert et al. 1981, Higgins et al. [1989]). Thus, grazing must remain in the refuge manager's tool kit. However, the status of wildlife habitat and objectives of a refuge define the need for a particular grazing (or fire) regime.

When benefits for wildlife are the reason for a grazing program, there is little justification for continuous annual grazing of any type on most lands. Furthermore, few choices exist for some sensitive areas. For example, if immediate restoration of riparian habitat damaged by grazing is the goal, no measure will be as successful as completely excluding livestock. Rotation and rest systems optimally designed for the needs of the habitat can be devised if modification of grassland species composition, residual cover, or plant density is desired for the benefit of wildlife. However, many of these systems are not economically feasible for private livestock graziers (Figure 2). In some circumstances, long-term benefits for the habitat may offset short-term detriments to portions of the refuge lands. However, permitting damage to wet meadows, riparian systems, or extremely arid grasslands, the latter two of which may have recovery times on the order of decades, cannot be condoned under any circumstances.

How Should National Wildlife Refuge Managers Think About Grazing?

Habitat management goals and objectives for the benefit of selected wildlife species or populations define what type and degree of manipulation by grazing is needed, if at all. We believe this to be the only appropriate context within which to discuss grazing on refuges. Unfortunately, even when stated unequivocally in this fashion, managers historically have tended to cast management objectives in terms of units of habitat grazed. We suggest that this is a wrong approach. If management objectives are stated in terms of the abundance, distribution, survival, or fecundity of wildlife populations of concern, grazing programs can be evaluated in terms of how they contribute to wildlife objectives. We recognize that measuring these population attributes is often difficult or expensive. Likewise, separating confounding effects (predation, weather, adjacent land use, etc.) can be impossible without comprehensive efforts. Nonetheless, our current lack of knowledge of livestock grazing effects on most species of wildlife, especially nongame species, suggests that this is an important, and yet unresolved aspect of NWRS management that is appropriate for experimentation. We advocate not only critical review of existing grazing programs, but also substantial research and closely monitored field application of grazing to specific wildlife management objectives.

The Service has recently recommitted itself to maintenance of biological diversity on Service lands (U.S. Fish and Wildlife Service 1991) and listed as a priority goal for 1992 the restoration, enhancement, management, and protection of a healthy diversity and desired distribution of wildlife species and their habitats (Smith 1992). Specifically, this latter goal includes directing acquisition and management of lands in the NWRS to protect areas of high species diversity; critical, declining or vulnerable habitats; and corridors to link protected habitats. Livestock grazing, used uncritically and indiscriminately, wreaks havoc with such goals and leads to long-term changes in biological diversity in any landscape. However, plant communities coevolved with native wildlife communities, and most grassland ecosystems originally supported grazing herbivores. Thus, we suggest that one unexplored avenue for modifying the plant community to achieve specific objectives may be the judicious use of native grazing herbivores. Although logistical problems may be more numerous than those encountered with domestic livestock, such an approach would help accomplish the consummate goal of re-establishing biotic diversity on Service lands, while simultaneously enhancing the aesthetics of grazing treatments.

All too often, change wrought by livestock grazing is gradual. Without an historical perspective, one does not realize what has been lost. The National Wildlife Refuge System has an opportunity to manage, in perpetuity, portions of the landscape with approximately its full complement of natural diversity. In western lands, where grazing has long been a part of the land-use treatment, thoughtful managers and researchers can examine trends caused by modern anthropogenic actions during the past 100 or more years and can carefully assess all livestock grazing for its effect on wildlife species of concern. If managed correctly, National Wildlife Refuges can be islands of biological diversity in a sea of otherwise depauperate landscapes—models for all to emulate.

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References

Archer, S. and F. E. Smeins. 1991. Ecosystem-level processes. Pages 109–139 *in* R. K. Heitschmidt and J. W. Stuth, eds., Grazing management: An ecological perspective. Timber Press, Portland, OR.

Barker, W. T., K. K. Sedivec, T. A. Messmer, K. F. Higgins, and D. R. Hertel. 1990. Effects of specialized grazing systems on waterfowl production in southcentral North Dakota. Trans. N. Am. Wildl. and Nat. Resour. Conf. 55:462–474.

Bartolome, J. W. 1984. Impacts of grazing intensity and grazing systems on vegetation composition and production. Pages 917–925 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Berg, P. F. 1956. A study of waterfowl broods in eastern Montana with special reference to movements and the relationship of reservoir fencing to production. J. Wildl. Manage. 20:253–262.

Blackburn, W. H. 1983. Livestock grazing impacts on watersheds. Rangelands 5:123–125.

———. 1984. Impacts of grazing intensity and specialized grazing systems on watershed characteristics and responses. Pages 927–983 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Bock, C. E. and J. H. Bock. 1988. Grassland birds in southeastern Arizona: Impacts of fire, grazing, and alien vegetation. ICBP Tech. Publ. 7:43–58.

Branson, F. A. 1984. Evaluation of "Impacts of grazing intensity and specialized grazing systems on watershed characteristics and responses." Pages 985–1,000 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Braun, C. E., K. E. Harmon, J. A. Jackson, and C. D. Littlefield. 1978. Management of National Wildlife Refuges in the United States: Its impacts on birds. Wilson Bull. 90:309–321.

Brode, J. M. and R. B. Bury. 1984. The importance of riparian systems to amphibians and reptiles. Pages 30–36 *in* R. E. Warner and K. M. Hendrix, eds., California riparian systems: Ecology, conservation, and productive management. Univ. California Press, Berkeley.

Bryan, F. C., B. E. Dahl, R. D. Pettit, and C. M. Britton. 1989. Does short-duration grazing work in arid and semiarid regions? J. Soil Water Conserv. 44:290–296.

Bue, I. G., L. Blankenship, and W. H. Marshall. 1952. The relationship of grazing practices to waterfowl breeding populations and production on stock ponds in western South Dakota. Trans. N. Am. Wildl. Conf. 7:396–414.

Carpenter, L. H. 1984. Impacts of grazing intensity and specialized grazing systems on faunal composition and productivity: A discussant paper. Pages 1,119–1,128 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Clary, W. P. and B. F. Webster. 1989. Managing grazing of riparian areas in the Intermountain region. U.S. For. Serv. Gen. Tech. Rept. INT–263. 11 pp.

Coleman, R. A., N. Fuller, J. P. Mazzoni, R. Berry, J. Davis, D. Adams, D. G. Young, R. Fries, and T. Heuer. 1990. Report to the Director: A review of secondary uses occurring on National Wildlife Refuges. U.S. Fish and Wildl. Serv., Washington, D.C. 232 pp.

Cook, T. D. and D. T. Campbell. 1979. Quasi-experimentation: Design and analysis issues for field settings. Houghton Mifflin Co., Boston, MA. 405 pp.

Cornely, J. E. 1982. Waterfowl production at Malheur National Wildlife Refuge, 1942–1980. Trans. N. Am. Wildl. and Nat. Resour. Conf. 47:559–571.

Donart, G. B. 1984. The history and evolution of western rangelands in relation to woody plant communities. Pages 1,235–1,258 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Drew, L. 1992. Wrangling for change on the range. Nat. Wildl. 30(2):46–49.

Duebbert, H. F., E. T. Jacobson, K. F. Higgins, and E. B. Podoll. 1981. Establishment of seeded grasslands for wildlife habitat in the prairie pothole region. U.S. Fish and Wildl. Serv. Spec. Sci. Rept.—Wildl. 234. 21 pp.

Duebbert, H. F., J. T. Lokemoen, and D. E. Sharp. 1986. Nest sites of ducks in grazed mixed-grass prairie in North Dakota. Prairie Nat. 18:99–108.

Dwyer, D. D., J. C. Buckhouse, and W. S. Huey. 1984. Impacts of grazing intensity and specialized grazing systems on the use and value of rangeland: Summary and recommendations. Pages 867–884 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Ferguson, D. and N. Ferguson. 1983. Sacred cows at the public trough. Maverick Publications, Bend, OR. 250 pp.

Fischer, H. 1985. A new problem in the old West: Grazing on the Charles M. Russell Wildlife Refuge. West. Wildlands 11(1):8–11.

Gjersing, F. M. 1975. Waterfowl production in relation to rest-rotation grazing. J. Range Manage. 28:37–42.

Guthery, F. S., C. A. DeYoung, F. C. Bryant, and D. L. Drawe. 1990. Using short duration grazing to accomplish wildlife habitat objectives. Pages 41–55 *in* K. E. Severson, tech. coord., Can livestock be used as a tool to enhance wildlife habitat? 43rd Annual Meeting of the Society of Range Management, Reno, Nevada, 13 February 1990. U.S. For. Serv. Gen. Tech. Rept. RM–194.

Herbel, C. H. 1984. Successional patterns and productivity potentials of the range vegetation in the warm, arid portions of the southwestern United States. Pages 1,333–1,365 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Higgins, K. F., A. D. Kruse, and J. L. Piehl. [1989]. Effects of fire in the northern great plains. South Dakota St. Univ. Ext. Circ. EC 761. 47 pp.

Holechek, J. L., R. Valdez, S. D. Schemnitz, R. D. Pieper, and C. A. Davis. 1982. Manipulation of grazing to improve or maintain wildlife habitat. Wildl. Soc. Bull. 10:204–10.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecol. Monogr. 54:187–211.

Johnson, D. H., A. B. Sargeant, and R. J. Greenwood. 1988. Importance of individual species of predators on nesting success of ducks in the Canadian prairie pothole region. Can. J. Zoo. 67:291–297.

Johnson, R. R., C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre. 1985. Riparian ecosystems and their management: Reconciling conflicting uses. First North American riparian conference, April 16–18, Tucson, Arizona. U.S. For. Serv. Gen. Tech. Rept. RM–120. 523 pp.

Kaiser, P. H., S. S. Berlinger, and L. H. Fredrickson. 1979. Response of blue-winged teal to range management on Waterfowl Production Areas in southeastern South Dakota. J. Range Manage. 32:295–298.

Kaminski, R. M. and H. H. Prince. 1981. Dabbling duck and macroinvertebrate responses to manipulated wetland habitat. J. Wildl. Manage. 45:1–15.

Kaminski, R. M. and M. W. Weller. 1992. Breeding habitat of northern hemispheric waterfowl. *In* B. D. J. Batt, ed., The ecology and management of breeding waterfowl. Univ. Minnesota Press, Minneapolis. In press.

Kantrud, H. A. 1986. Effects of vegetation manipulation on breeding waterfowl in prairie wetlands—a literature review. U.S. Fish and Wildl. Serv. Fish Wildl. Tech. Rept. 3. 15 pp.

Kauffman, J. B. and W. C. Kreuger. 1984. Livestock impacts on riparian ecosystems and streamside management implications . . . a review. J. Range Manage. 37:430–438.

Kie, J. G. and E. R. Loft. 1990. Using livestock to manage wildlife habitat: Some examples from California annual grassland and wet meadow communities. Pages 7–24 *in* K. E. Severson, tech. coord., Can livestock be used as a tool to enhance wildlife habitat? 43rd Annual Meeting of the Society of Range Management, Reno, Nevada, 13 February 1990. U.S. For. Serv. Gen. Tech. Rept. RM–194.

Kirsch, L. M. 1969. Waterfowl production in relation to grazing. J. Wildl. Manage. 33:821–828.

Kirsch, L. M., H. F. Duebbert, and A. D. Kruse. 1978. Grazing and haying effects on habitats of upland nesting birds. Trans. North Am. Wildl. and Nat. Resour. Conf. 43:486–497.

Knopf, F. L. and R. W. Cannon. 1982. Structural resilience of a willow riparian community to changes in grazing practices. Pages 198–207 *in* J. M. Peek and P. D. Dalke, eds., Wildlife-livestock relationships symposium: Proceedings 10. Univ. Idaho, For., Wildl. and Range Exp. Sta., Moscow.

Knopf, F. L., R. R. Johnson, T. Rich, F. B. Samson, and R. C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Wilson Bull. 100:272–284.

Laycock, W. A. 1983. Evaluation of management as a factor in the success of grazing systems. Pages 166–171 *in* S. B. Monsen and N. Shaw, comps., Managing Intermountain rangelands—improvement of range and wildlife habitats: Proceedings. Twin Falls, Idaho, 1981 September 15–17; Elko, Nevada 1982 June 22–24. U.S. For. Serv. Gen. Tech. Rept. INT–157.
Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, NY. 481 pp.
Low, B. S. and J. A. Berlin. 1984. Natural selection and the management of rangelands. Pages 1,179–1,234 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.
Mackie, R. J. 1991. President's corner. The Wildlifer 249:51.
Moore, W. H. and W. S. Terry. 1980. Short-duration grazing may improve wildlife habitat in southeastern pinelands. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 33:279–287.
Mundinger, J. G. 1976. Waterfowl response to rest-rotation grazing. J. Wildl. Manage. 40:60–68.
National Wildlife Refuge System Task Force. 1979. Final recommendations on the management of the National Wildlife Refuge System. U.S. Dept. Interior, Fish and Wildl. Serv., Washington, D.C. 59 pp.
Pieper, R. D. and R. K. Heitschmidt. 1988. Is short-duration grazing the answer? J. Soil Water Conserv. 43:133–137.
Platts, W. S. 1986. Managing fish and livestock on Idaho rangelands. Rangelands 8:213–216.
———. 1991. Livestock grazing. Pages 389–423 *in* W. R. Meehan, ed., Influences of forest and rangeland management on salmonid fishes and their habitats. Am. Fish. Soc. Spec. Publ. 19.
Platts, W. S. and R. F. Raleigh. 1984. Impacts of grazing on wetlands and riparian habitat. Pages 1,105–1,117 *in* B. D. Gardner, chair., Developing strategies for rangeland management. A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.
Rees, J. R. 1982. Potential uses of cattle grazing to manage waterfowl nesting cover on Turnbull National Wildlife Refuge. Pages 86–93 *in* J. M. Peek and P. D. Dalke, eds., Wildlife-livestock relationships symposium: Proceedings 10. Univ. Idaho, For., Wildl., and Range Exp. Sta., Moscow.
Romesburg, H. C. 1981. Wildlife science: Gaining reliable knowledge. J. Wildl. Manage. 45:293–313.
Ruyle, G. B., J. W. Menke, and D. L. Lancaster. 1980. Delayed grazing may improve upland waterfowl habitat. California Agric. 34(11–12):29–31.
Sargeant, A. B. and P. M. Arnold. 1984. Predator management for ducks in waterfowl production areas in the northern plains. Proc. Vert. Pest Conf. 11:161–167.
Savory, A. 1988. Holistic resource management. Island Press, Washington, D.C. 558 pp.
Savory, A. and S. D. Parsons. 1980. The Savory grazing method. Rangelands 2:234–237.
Sedgwick, J. A. and F. L. Knopf. 1987. Breeding bird response to cattle grazing of a cottonwood bottomland. J. Wildl. Manage. 51:230–237.
Sedivec, K. K., T. A. Messmer, W. T. Barker, K. F. Higgins, and D. R. Hertel. 1990. Nesting success of upland nesting waterfowl and sharp-tailed grouse in specialized grazing systems in southcentral North Dakota. Pages 71–92 *in* K. E. Severson, tech. coord., Can livestock be used as a tool to enhance wildlife habitat? 43rd Annual Meeting of the Society of Range Management, Reno, Nevada, 13 February 1990. U.S. For. Serv. Gen. Tech. Rept. RM–194.
Severson, K. E. 1990. Summary: Livestock management as a wildlife habitat management tool. Pages 3–6 *in* K. E. Severson, tech. coord., Can livestock be used as a tool to enhance wildlife habitat? 43rd Annual Meeting of the Society of Range Management, Reno, Nevada 13 February 1990. U.S. For. Serv. Gen. Tech. Rept. RM–194.
Schulz, P. A. and F. S. Guthery. 1988. Effects of short duration grazing on northern bobwhites: A pilot study. Wildl. Soc. Bull. 16:18–24.
Shallenberger, R. J. 1992. Refuges 2003—A plan for the future. Trans. N. Am. Wildl. and Nat. Resour. Conf. 57: this volume.
Skovlin, J. M. 1984. Impacts of grazing on wetland and riparian habitat: A review of our knowledge. Pages 1,001–1,103 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.
Smith, R. N. 1992. National policy issuance #92–02. U.S. Fish and Wildl. Serv., Washington, D.C. 1 p. + appendix [36 pp.]

Strassmann, B. I. 1987. Effects of cattle grazing and haying on wildlife conservation at National Wildlife Refuges in the United States. Environ. Manage. 11:35–44.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Wildlife habitats in managed rangelands—the Great Basin of southeastern Oregon—riparian zones. U.S. For. Serv. Gen. Tech. Rept. PNW-80. 18 pp.

Thorne, E. T. and J. D. Herriges, Jr. 1992. Brucellosis, wildlife and conflicts in the Greater Yellowstone area. Trans. N. Am. Wildl. and Nat. Resour. Conf. 57: this volume.

United States Fish and Wildlife Service. 1982 [and subsequent releases]. National Wildlife Refuge System refuge manual. Division of Refuge Management, U.S. Fish and Wildl. Serv., Arlington, VA.

———. 1991. Vision for the future. U.S. Fish and Wildl. Serv., Washington, D.C. 12 pp.

United States General Accounting Office. 1981. National direction required for effective management of America's fish and wildlife. GAO/RCED–RCED–81–107. 93 pp.

———. 1989. National Wildlife Refuges: Continuing problems with incompatible uses call for bold action. GAO/RECD–89–196. 84 pp.

Urness, P. J. 1990. Livestock as manipulators of mule deer winter habitats in northern Utah. Pages 25–40 *in* K. E. Severson, tech. coord., Can livestock be used as a tool to enhance wildlife habitat? 43rd Annual Meeting of the Society of Range Management, Reno, Nevada, 13 February 1990. U.S. For. Serv. Gen. Tech. Rept. RM–194.

Vallentine, J. F. 1990. Grazing management. Academic Press, San Diego, CA. 533 pp.

Weller, M. W. 1978. Management of freshwater marshes for wildlife. Pages 267–284 *in* R. E. Good, D. F. Whigham, and R. L. Simpson, eds., Freshwater wetlands. Academic Press, NY.

Whyte, R. J. and B. W. Cain. 1981. Wildlife habitat on grazed or ungrazed small pond shorelines in south Texas. J. Range Manage. 34:64–68.

Whyte, R. J., N. J. Silvey, and B. W. Cain. 1981. Effects of cattle on duck food plants in southern Texas. J. Wildl. Manage. 45:512–515.

Willms, W., A. McLean, R. Tucker, and R. Ritcey. 1979. Interactions between mule deer and cattle on big sagebrush range in British Columbia. J. Range Manage. 32:299–304.

Wuerthner, G. 1989. Public lands grazing: What benefits at what cost? West. Wildlands 15(3):24–29.

Young, J. A., R. E. Evans, and R. E. Ekert, Jr. 1984. Successional patterns and productivity potentials of the sagebrush and salt desert ecosystems. Pages 1,259–1,299 *in* B. D. Gardner, chair., Developing strategies for rangeland management: A report prepared by the Committee on Developing Strategies for Rangeland Management of the National Research Council/National Academy of Sciences. Westview Press, Boulder, CO.

Special Session 9. *International Resource Issues and Opportunities*

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Accommodation With Socio-economic Factors Under the Endangered Species Act—More Than Meets the Eye

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We intend to explore myths and realities about how much attention is paid to socio-economic consequences when applying the Endangered Species Act (ESA) of 1973 (U.S. Laws, Statuses, etc. Public Law 93–205). We will examine the circumstances surrounding the development and adoption of a conservation strategy for the northern spotted owl (*Strix occidentalis caurina*) and other activities, including the listing of the subspecies as "threatened," delineation of critical habitat, development of a recovery plan, development of Habitat Conservation Plans (HCPs) and other actions (Corn and Baldwin 1990). Our objective is to point out that what is perceived by many as a relentless and inexorable process soley based on biology to protect imperiled species without consideration of socio-economic impacts is, in fact, a procedure subject to repeated accommodation between the listed species' welfare and the associated socio-economic consequences.

This analysis is based on our experiences as members of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl (ISC). This team was appointed by the Directors of the Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (FWS), National Park Service (NPS) and the Chief of the USDA Forest Service (FS). The ISC report (Thomas et al. 1990) has provided the FS's management strategy for the owl since 1990, and is the foundation of the FWS's draft recovery plan (U.S. Department of Interior 1992).

Accommodation in the Listing Process

Accommodation first occurs in the determination of whether or not to list a species as threatened or endangered. An underlying reluctance commonly exists to list a species, thereby setting off a series of actions that are inevitably technically and politically contentious—and frequently agonizingly prolonged in nature. The more expensive in social, political and economic terms the listing of a species is apt to be, the stronger the caution or reluctance applied to the listing decision.

To some people at least, the northern spotted owl was obviously on the way to listing as early as 1975, when the Oregon Department of Fish and Wildlife (1975) first described the subspecies as "threatened." Research that was initiated in 1972 by Eric Forsman, a Master of Science student at Oregon State University, continued and additional research became increasingly fashionable as the owl's welfare gradually became more and more identified with old-growth and mature forests. In 1983, the FS designated the owl as an "indicator species" for the health of old-growth forest ecosystems in the Pacific Northwest (USDA FS 1983). By the early 1980s, most of the older-age forests on private lands had been cut, leaving the vast majority of extant suitable owl habitat on FS and BLM lands. So, both the BLM and the FS began to fashion plans to accommodate the owl's habitat needs (Airola 1980, Beckstead 1985, Ruediger 1985, Oregon-Washington Interagency Committee 1988).

That the owl was most commonly found in mature and old-growth forests became increasingly obvious as research results accumulated. And, as the remaining 10–15 percent of those forests in the Pacific Northwest were being inexorably cut at a rate of 70,000 acres per year in National Forests in Oregon and Washington alone, with at least 100,000 acres per year being cut on all ownerships combined, the trend of the owl's habitat and the inevitability of listing were clear (Thomas et al. 1990).

The Status Reviews

In 1981, the Portland office of the FWS undertook a status review of the owl and called the subspecies "vulnerable," but said that threatened status was not yet justified (U.S. Department of Interior 1982). The slide toward threatened status, recognized six years earlier by the Oregon Department of Fish and Wildlife (1975), was confirmed. As a result, even more intensive research was initiated, and the BLM and FS instituted management to maintain "*minimum* viable populations" of this declining and "vulnerable" subspecies.

The FS, in 1984, issued the Regional Guide for the Pacific Northwest Region (USDA 1984) with instructions for managing the first 375 pairs of owls located on National Forests in Oregon. This was appealed by environmental groups contending that the standards and guidelines were inadequate and this was an action for which an Environmental Impact Statement (EIS) should have been prepared, as required by the National Environmental Policy Act of 1969 (NEPA) (U.S. Laws, Statutes, etc. Public Law 91–190). The FS Chief rejected that appeal but was overruled by the Assistant Secretary of Agriculture. In response, the FS began preparation of a Supplemental EIS to the Regional Guide for managing the owl on National Forests (USDA FS 1988).

In 1985, the National Audubon Society's Advisory Panel on the Northern Spotted Owl, commonly called the ''Audubon Blue-Ribbon Panel,'' echoed previous warnings that the subspecies was headed toward listing and suggested that immediate, forceful management action was warranted (Dawson et al. 1986). Hence, one more warning flag was raised four years after the FWS confirmed that the subspecies was ''vulnerable'' and 10 years after the Oregon Department of Fish and Wildlife cautioned that the owl was ''threatened.''

In 1986, the BLM (1987a and 1987b) performed an Environmental Assessment to decide if information obtained in the previous decade warranted preparation of a Supplemental EIS to their forest plans for managing owl habitat in western Oregon. BLM concluded that such a supplement was not warranted. In 1992, a District Federal Court Judge would find that conclusion inappropriate (Frye 1992).

In 1987, the FWS was petitioned by Greenworld to list the owl as threatened. After this second status review (U.S. FWS 1987), the FWS determined, yet again, that listing was not warranted. That decision was appealed to the Federal Courts in 1988 by a coalition of environmental groups. The Federal District Court ruled that the decision not to list the northern spotted owl was arbitrary and capricious, and directed the FWS to readdress the issue. So, the FWS began a third status review employing a team of 12 biologists. Also during 1988, the State of Washington officially declared the subspecies ''endangered'' and the State of Oregon officially determined the owl to be ''threatened'' (Thomas et al. 1990).

Later in 1988, the FS issued its Final Supplemental EIS (USDA FS 1988) and adopted a management alternative in a formal Record of Decision (Robertson 1988). The selected alternative was rated in the EIS itself as having a ''poor'' long-term chance of success. The rationale for selecting that management option was that, for the owl, numbers would not be seriously eroded over the five-year period covered by the proposed management action. Further, it was assumed that information forthcoming from stepped-up research and monitoring efforts would allow a better, more fully-informed decision at the end of that time. Meanwhile, logging of suitable owl habitat would continue at near the rates of the previous decade. Latter assessments, published in early 1990, would seriously question those assumptions (Thomas et al. 1990, Anderson et al. 1990).

The Washington Department of Wildlife, several environmental groups and The Wildlife Society (the professional society for wildlife biologists) appealed the FS's decision on the grounds that the plan was inadequate to maintain the owl in viable numbers and well-distributed over its range on the National Forests as required by regulations issued pursuant to the National Forest Management Act of 1976 (NFMA) (U.S. Laws, Statutes, etc., Public Law 91–190). Conversely, timber industry interests also appealed, claiming unwarranted negative impacts on timber supply. The Assistant Secretary of Agriculture denied both appeals (Thomas et al. 1990).

The Northwest Compromise of 1989

The continuing dispute and subsequent injunctions on timber sales on BLM lands near owl sites in 1988 and 1989 led to the ''Northwest Compromise of 1989,'' which was a rider to the Appropriations Bill for Interior and Related Agencies (Section 318 of Public Law 101–121). This action was a one-year compromise worked out between environmental groups and timber industry interests under the auspices of Senators Mark Hatfield of Oregon and Brock Adams of Washington. This rider enhanced extant owl protection, designated a timber sale level for FY 1990, and declared that the FS's Final Supplemental EIS and the BLM's 1980 vintage spotted owl management plans were legally adequate for preparing fiscal year 1990 timber sales (USDA 1987). Section 318 also acknowledged the existence of the ISC and directed federal agencies to note the results of that effort (Baldwin 1989, 1990, Thomas et al. 1990).

Provisions of the Northwest Compromise of 1989 prohibiting legal challenges to agency actions were questioned in the Federal District Court on constitutional grounds of the separation of powers doctrine. The District Court upheld the appropriateness of Section 318. On appeal, the Ninth Circuit Court of Appeals, in September 1990, overturned the District Court opinion and declared the action unconstitutional. That decision was appealed to the Supreme Court, which ruled unanimously, on March 25, 1992, that the action was, after all, constitutional.

On April 21, 1989, the FWS completed the third status review of the northern spotted owl (FWS 1989) which recommended listing the bird as threatened throughout its range. The FWS concurred and a 12-month period for public comment before final ruling began. Later in 1989, the FWS named yet another team to consider the public comment and prepare yet another biological assessment on the owl's status.

The ISC

In early April 1990, the ISC delivered its report (Thomas et al. 1990) to the four agency heads and to Congress. The ISC strategy called for reservation of 5,848,000 acres of federal land, previously unreserved from timber cutting, combined with areas already preserved in Wilderness and National Parks to be included in a series of protected areas called Habitat Conservation Areas (HCAs). Ideally, each HCA would ultimately be capable of providing habitat for clusters of 20 or more owl sites. Realities of landscapes, soil types and other factors precluded 20-site HCAs in some cases and smaller size HCAs were designated. HCAs of 20 or more pair-sites were separated by 12 miles or less, and smaller HCAs by 7 miles or less. The ISC considered the subspecies "imperiled" over most of its range—the sixth such warning in 15 years.

The Owl Listed

Within two months of the release of the ISC report, the FWS released the findings of the team of five biologists assigned to perform the fourth status review—the 1990 Status Review of the Northern Spotted Owl (Anderson et al. 1990). This team recommended listing of the subspecies as threatened throughout its range. As a result, the FWS, after its fourth consideration of the status of the owl in 10 years and the second recommendation for listing by status review teams, and after considering the results of 12 months of public review and comment, determined that the subspecies was threatened. As a matter of perspective, this was 15 years after the Oregon Department of Fish and Wildlife first suggested that the bird was "threatened"; 9 years after the FWS itself described the owl's status as "vulnerable"; 2 years after the State of Washington officially declared the spotted owl as "endangered"; and 2 years after the State of Oregon designated it "threatened." Obviously accommodation and extreme caution had been exercised in the matter of listing.

What is now clear in hindsight is that, right or wrong, the process of listing the spotted owl as threatened was strongly influenced by the specter of the economic, social and political consequences that were obviously inherent in such action. Accommodation or, at least, extreme caution and numerous delays were repeatedly invoked in considering the subspecies for listing.

What resulted from these delays? Obviously, cutting of old-growth and mature forests (suitable owl habitat), at a rate at least double that now anticipated under the ISC strategy and the draft recovery plan, continued for some 10 years after the first FWS status review. This resulted in the loss of perhaps 1 million acres of suitable owl habitat from timber cutting alone during that time. On the other hand, that period provided many positive benefits from continued relatively high rates of timber cutting in employment, profits to industry, taxes to government, payments to counties from timber receipts in lieu of taxes, multiplier effects in the regional and national economies, and the supply of relatively inexpensive wood products to national and world markets.

Yet, the 10-year delay in listing also had negative effects that are now painfully obvious. Options for owl habitat conservation were rapidly eroded. This was particularly true on those areas now identified as "areas of special concern" (Thomas et al. 1990:379–380). Such areas include, among others, the Olympic Peninsula, the Oregon Coast Ranges and the BLM lands in Oregon. Most significantly, the delay cost federal land management agencies and the timber industry the ability to "ease into" a scientifically credible management strategy for the owl by gradually reducing logging rates on federal lands over a period of years. Instead, it became essentially impossible to gradually decrease timber sale levels from 1986–1990 levels to new and significantly reduced sustainable-yield levels without dramatic drops below that level over the longer term. This became a matter of pay now or pay even more later.

Should Socio-economic Factors be Considered?

Should socio-economic factors be considered in a decision to list a species? The ESA includes five considerations for listing. Socio-economic considerations are not among them (Corn and Baldwin 1990). As a result, it is generally believed that socio-economic considerations do not influence listing decisions. In fact, socio-economic factors do and will inevitably come into play in listing decisions. This is evident in the increasing level of caution exercised and the increasing amount of time required to make listing determinations related to the anticipated socio-economic costs of such decisions. While such caution and delay may be understandable, it should be recognized that delays in listing may decrease the chances of recovery due to the erosion loss of management options in the interim due to populations or habitats, or both.

Are economic, social and political aspects of the problem considered in the development of recovery plans? The answer is, obviously, yes. Again, let us examine the history of the northern spotted owl case. The ISC saw clearly that listing was probable. A FWS listing team had already suggested listing and yet another such team was working, at the same time the ISC was active, to perform a fourth status review. The ISC thus considered the strategy they were preparing a probable short-term management strategy for the owl and, perhaps, the basis for a recovery plan should the owl be listed. One of the ISC's operating sideboards was the recognition that (Thomas et al. 1990:11): "The best management for . . . the owl is to preserve all stands of mature and old-growth timber within the range of the bird and to grow more such stands as soon as possible. Recognizing the real-world situation, however, we will consider a less than optimum approach . . . that will, to the extent possible, simultaneously provide a high probability of population viability . . . well-distributed within its range, and still allow the cutting of old-growth and mature timber. . . ."

This approach, though most decidedly not the best for owl, was a pragmatic effort to strike a balance between meeting the requirements of the ESA and NFMA, and minimizing negative socio-economic impacts. By the time the ISC began work, in the fall of 1989, perhaps 90 percent of old-growth forests of the Pacific Northwest that make up the best habitat for owls that existed in the late 1800s had already been lost to fire, blow-down, clearing and timber cutting. More than 90 percent of the older forests that still existed and provided the best owl habitat was found on federal land, with most of that at relatively higher elevations with relatively lower owl densities.

Still, the ISC sought to devise an innovative management approach that would yield a high probability of the long-term survival of the owl in viable numbers and well-distributed across its presently occupied range on the federal lands. The ISC strategy, in a worst-case scenario, put a maximum of 50–60 percent of the extant owl pair sites at risk (Thomas et al. 1990:35). The ISC strategy sought to compensate for lowered owl numbers by emphasizing a long-term habitat condition formulated to protect against risk. This is, so far as we know, an unprecedented accommodation between the welfare of a threatened species and socio-economic considerations.

Socio-economic Impacts

When the FWS declared the owl threatened, the ISC strategy was the only extant management strategy with a mantle of scientific credibility. On 28 September 1990, the FS announced that it would follow the ISC strategy, while the BLM opted for a modified version (BLM 1990) called the Jamison Plan (named after the BLM Director) which was judged by Director Cy Jamison to have lower socio-economic costs than the ISC strategy, as well as being biologically adequate. This plan was never subject to peer or outside review.

BLM, FS and FWS economists, and other economists financed by environmentalists and the timber industry, immediately analyzed the economic and employment impacts of applying the ISC strategy. Estimates of job losses ranged from a few thousand (by economists supported by environmental groups) to nearly 140,000 (by economists whose studies were financed by the timber industry). The government economists concluded that the associated job losses attributable to the ISC strategy alone would be about 19,000 (Hamilton 1990). No matter which figures were accepted, it was clear that socio-economic impacts of applying the ISC strategy would be considerable (Beuter 1990, Greber et al. 1990, Gorte 1989, Maki and Olson 1991, Olson 1990, Rasmussen 1989, Lee 1990).

Understandably concerned by these estimates of job losses and economic impact, Secretary of Agriculture Clayton Yeutter and Secretary of Interior Manuel Lujan appointed a task force headed by Assistant Secretary of Agriculture James Moseley to examine the ISC report and to devise lower-cost alternatives. In the end, after numerous delays, that committee provided no report but issued a press release, on September 21, 1990, to the effect that the FS would operate in a ''manner not inconsistent with'' the ISC strategy and the BLM would proceed with timber sales under the Jamison Plan. These decisions were not accompanied by EISs, nor were they formally stated in a Record of Decision in the Federal Register.

The Courts Step In

In 1992, this course of action was challenged in Federal District Court by the Seattle Audubon Society, on the contention that the FS had failed to formally adopt a credible conservation strategy for the owl that would meet NFMA and ESA requirements, including preparation of an EIS as required by the NEPA. The issues of the socio-economic effects of constraining National Forest timber sales in owl habitat were argued at length before the U.S. District Court in Seattle.

The government attorneys, and intervenors representing timber industry groups, argued that the ISC strategy was both sound and adequate, or more than adequate. The attorneys for Seattle Audubon argued the opposite. Interestingly enough, these same groups (and, in some cases, the very same attorneys) would reverse roles in hearings before the Exemption Committee provided by the ESA that is described later. Another such reversal can be expected to occur in pending legal action.

On May 7, 1991, Judge William Dwyer ruled in favor of the plaintiffs, citing FS failure to comply with the NFMA and NEPA, and issued an injunction against further timber sales in owl habitat within National Forests pending FS adoption of a management plan for the owl as required by law, including a full-scale EIS. These actions were ordered to be completed by March 5, 1992. Further, it was made clear that the FS must comply, simultaneously, with NFMA and ESA (Dwyer 1991). The FS immediately put together an interdisciplinary team to prepare the required EIS. Dwyer's decision was appealed to the Ninth Circuit court of Appeals who upheld the original decision on December 23, 1991.

Designation of Critical Habitat

The FWS, upon listing of a species, is required by the ESA to designate ''critical habitat'' for that species. Critical habitat identifies all areas within which any proposed action that may adversely affect a listed species requires consultation with the FWS. The FWS initially declined to designate critical habitat for the owl because of the inherent imprecision in defining various aspects of owl habitat and the likely adverse socio-economic and political consequences—particularly to nonfederal landholders—of such an action. This decision was challenged in Federal District Court and, on February 2, 1991, Judge Thomas Zilly ordered the FWS to map critical habitat by April 29, 1991 (Zilly 1991).

On May 6, 1991, the FWS proposed 11 million acres as critical habitat (U.S. Department of Interior FWS 1991a), resulting in a flurry of public protest. The FWS reduced critical habitat to 8.2 million acres on August 13, 1991, (U.S. Department of Interior FWS 1991b). After receiving further, largely critical public comment, the FWS's final determination, issued on January 15, 1992, reduced critical habitat to 6.9 million acres—59 percent of the original acreage proposed (U.S. Department of Interior FWS 1992). So, the FWS obviously sought accommodation with socio-economic concerns and heeded public comment—first, through initial reluctance to designate critical habitat at all and, then, by progressively reducing the amount of area so defined by 59 percent in order to obtain the tightest rational fit between biological and legal requirements of the ESA and socio-economic concerns.

The Recovery Team

Meanwhile, Secretary of Interior Manuel Lujan established a Recovery Team for the northern spotted owl as required by ESA. The composition of this team was unprecedented. This 16-member team included Donald Knowles, Associate Deputy Secretary of Interior (an economist and water specialist), to act as a policy advisor for the Secretary, and John Beuter, Deputy Assistant Secretary of Agriculture (an economist) as Team members. In addition to the six biologists involved (who were in the minority on the team), representatives were selected by the Governors of Oregon (the Governor's Policy Advisor on Natural Resources—an attorney), Washington (Special Assistant to the Governor for Timber Policy and Rural Development—an economist) and California (the Assistant Secretary, Legal Affairs, The Resource Agencies of California—an attorney). Also appointed were the Chief of the Division of Forestry for BLM—a forester, the Assistant Director for Economic Analysis of the Office of Policy Analysis for the Department of Interior—an engineer and political scientist, the Supervisory Forester for the U.S. Bureau of Indian Affairs—a forester, the FS Program Manager for the Spotted Owl Research, Development, and Application Program—a forester, and a Professor of Forestry at Oregon State University—a silviculturist. Instructions from Secretary Lujan included direction to search diligently for a solution that would satisfy the ESA, while minimizing socio-economic costs. This recovery team was designed especially and specifically instructed to reach accommodation within the limits prescribed by the ESA.

After careful and prolonged deliberation, the Recovery Team brought forth a plan (U.S. Department of Interior 1992) modeled closely on the ISC strategy, but with modifications that allowed commercial thinning of young stands in HCAs set aside for owls. Such thinning activity was limited to stands unsuitable for owl use and to 5 percent of any HCA within a five-year period. The plan also allowed for salvage of timber damaged by fire, insects and diseases, or blown down within those areas. These adjustments to the ISC strategy were made, at least partially, to reduce socio-economic impacts by allowing more timber to be placed on the market over time. The plan was delivered to Secretary Lujan in mid-December 1991, with an anticipated public release date of February 12, 1992.

The Secretary ordered, on January 29, 1992 that the plan be held in abeyance for 90 days, as part of a government-wide delay in release of all proposed government regulations that might have negative economic impacts. This general delay was announced by President George Bush, in his State of the Union Address on January 28, 1992. Ironically, the release of the draft plan for public review had no regulatory effect and would have none until formally adopted after a period of several months for public comment. So, the recovery plan which had been scheduled for release about March 1, 1992 is now scheduled for release on or about April 15, 1992. This delay sets back the earliest possible effective date of a final plan until September 1992.

Back to the Drawing Board

Even with these proposed modifications, the socio-economic impacts projected from the recovery plan via press release of some 37,000 jobs were considered likely to be potentially politically unacceptable. As a result, on February 6, 1992, Secretary Lujan announced the formation of yet another team under the direction of Associate Deputy Secretary of the Interior Donald Knowles, who served as the Secretary's policy advisor to the Recovery Team, to develop alternatives for owl management. These alternative plans for consideration by Congress were to have significantly lower socio-economic costs than those forecast for the recovery plan. The Secretary recognized that such plans would produce a higher risk of the owl's extinction, or at least extirpation from parts of its range, as compared to the Recovery Plan. Further, it was acknowledged that such plans might well be illegal under NFMA, ESA and NEPA. So adoption of such an alternative plan would likely require alterations in, or variances from, existing laws. The process of developing and evaluating these alternatives is ongoing. A report outlining these alternatives is expected to be released about April 15, 1992.

Did the ISC and the Recovery Team deal strictly with the biology of the owl and ecological theory alone as criteria for developing a management strategy? Obviously not! Although both teams had an underlying mission to develop a scientifically credible management strategy for the owl, both were fully cognizant of and sensitive to the effects of the plans they developed on people, small isolated communities, and local, regional and national economies. Both teams were obligated, first, to obey the law. But both teams did strive to minimize socio-economic impacts.

Consultation

Section 7 of the ESA requires that federal agencies consult with the FWS before carrying out, authorizing or funding any action that may adversely affect a listed species or its habitat. Recent studies indicated that very few (less than 1 percent) such consultations conducted from 1987 through 1991 revealed irreconcilable conflicts that ultimately blocked a proposed activity. Again, a process of accommodation between the welfare of listed species and socio-economic concerns comes to bear in Section 7 consultations (Barry et al. 1992). Routinely, nonjeopardy opinions (i.e., the proposed is judged not to cause jeopardy to the listed species) are issued by FWS Field Supervisors, but jeopardy opinions must be issued by Regional Directors, who are one step up in the agency's hierarchy. Determinations of nonjeopardy for a proposed action are obviously expected to be much more common and less politically significant than determinations of jeopardy with their attendant socio-economic costs and political distress.

Future consultations over proposed actions that will affect the spotted owl will almost surely include requests for exemptions to or modifications of the recovery plan to deal with such situations as timber salvage following fire and blow-down from windstorms, loss to insects and diseases, road construction, developments, such as reservoirs, etc. Accommodation seems likely to occur in many such cases. In fact, both the ISC strategy and the recovery plan provided a mechanism to provide the flexibility to deal with such situations on a case-by-case basis (Thomas et al. 1990).

Habitat Conservation Plans

Section 10 of the ESA provides a means whereby nonfederal landowners may work with state wildlife agencies to formulate HCPs for listed species, whereby habitat may be managed in keeping with that plan without further consultation with the FWS. Opportunities exist within the HCP process to facilitate accommodation between the objectives of the states, nonfederal landholders and requirements under the ESA.

Some seven HCPs are currently being prepared to deal with the northern spotted owl on non-federal lands. In one, involving industrial forest lands in northwestern California, the ISC was promised, by the State of California and corporate landowners, provision of habitat for approximately 250 pairs of owls. The HCP, to achieve this goal, was to be developed cooperatively by the State of California, those landholders and the FWS through means to be determined in mutual planning and negotiation. The forests of this area are dominated by redwoods and Douglas-fir, on highly productive lands that produce suitable owl habitat in 40–60 years. Given those circumstances, the quality of the professional biologists and foresters—both from public and private sectors—taking part in the exercise, and the attitude of the private landowners, the ISC was optimistic that 250 or more pairs of owls would indeed be sustained over time. Once the owl declared threatened by the FWS, a formal HCP process was instituted and is now nearly complete. HCPs can be expensive and time-consuming to formulate, but they also offer an additional means of accommodation.

A Turn to the Exemption Committee

In June 1991, BLM received "jeopardy opinions" from the FWS after regional consultation on 44 timber sales in southwestern Oregon (U.S. Department of Interior FWS 1991). The FWS ruled that the sales would jeopardize the long-term survival of the owl, mostly due to loss of habitat crucial to successful dispersal by juvenile owls. BLM called for a review of this decision by the Exemption Committee (the so-called "God Squad"), a Cabinet-level committee empowered under the ESA to waive protective provisions of the ESA. The Exemption Committee was asked to evaluate whether the 44 timber sales were crucial in the socio-economic sense, whether feasible alternatives existed and, if not, to determine if the sales should proceed regardless of potential consequences to the owl.

Hearings were held February 8–22, 1992 in front of Administration Law Judge Harvey C. Sweitzer in Portland, Oregon, to establish a body of evidence for consideration by the Exemption Committee. In this adversarial process, the BLM and intervenors put on trial the "science" of the ISC report (and, by implication, that of the recovery plan), which was assumed to underlie the reasoning of the FWS in issuing its jeopardy opinion. The intervenors now reversed their position from the Seattle Audubon case and sought, as one attorney was quoted in the *Portland Or-*

egonian, to "defrock the high priests of the cult of biology" that had put together the ISC strategy.

This trial of the ISC Strategy was in addition to the attempt to make a case on socio-economic grounds for relief from the jeopardy opinions issued by the FWS. The Department of Interior's report to the Exemption Committee was originally scheduled for February 28, 1992. The report was first delayed until March 25, 1992 and then again to April 15, 1992 on the basis that the voluminous record had to be reduced to a review document. Once the report is delivered to the Exemption Committee, the Committee has 30 days to render a decision.

All BLM timber sales in spotted owl habitat were shut down by Federal District Court Judge Helen Frye on February 20, 1992 for failure by BLM to prepare an EIS on the impacts of old-growth logging on spotted owl welfare. The connection between the effect of this injunction and potential decisions by the Exemption Committee is unclear. Then the U.S. Court of Appeals, 9th Circuit (1992), granted yet another such injunction maintaining the BLM must consult with the FWS prior to implementation of the Jamison Plan.

The appeal to the Exemption Committee is the point in the overall process where politically appointed officials of the highest rank must evaluate whether compliance with the ESA in a particular situation exacts too high a socio-economic cost to be acceptable. The Exemption Committee is composed of the Secretaries of Agriculture and Interior; Directors of the Environmental Protection Agency, National Atmospheric and Oceanographic Administration, and Council of Economic Advisors; the Secretary of the Army; and a Representative of the Governor of the State of Oregon. Not only are socio-economic effects not ignored at this stage—they *are* the issue and are directly weighed against the welfare of a listed species.

Research and Monitoring

But, in the meantime, research and monitoring continued simultaneously with the effort to produce a recovery plan. The objectives were to monitor the success of current management plans and to obtain new insights into the biology of the owl. Such monitoring and research had already revealed that previous FS and BLM management plans for the owl were not likely to be successful over the long term (Allen et al. 1987, O'Halloran et al. 1987, USDA FS 1987). This research and monitoring data plus their own analyses led the ISC team to call these management schemes a "prescription for . . . extinction" for the owl (Thomas et al. 1990:39).

Results from monitoring and new research may make new management schemes possible that will enhance the chances of recovery of the owl at lower socio-economic cost. Much of the support for such research and monitoring is predicated on the hope of finding some way of lessening the socio-economic impact of the recovery effort. Little thought is given to the probability that the results of monitoring and research may well be alterations in management with even more significant costs. Such is an equally likely outcome.

The FS team assigned to carry out Judge William Dwyer's order to complete an EIS on a management plant for the owl, completed its work in the late March of 1992 (USDA FS 1992). Assistant Secretary of Agriculture James Moseley signed the formal Record of Decision on March 3, 1992, formally adopting the ISC strategy (Moseley 1992:2) saying that, "This Record of Decision adopts a scientifically credible plan to protect spotted owl habitat on National Forests, while minimizing the loss of jobs and revenue in communities dependent on National Forest timber harvest. . . ." This decision was reached two years and one month after the ISC strategy was released.

Accommodation at Every Step

In practice, therefore, accommodation occurs between the welfare of listed species and socio-economic concerns at every step in the process of implementing applicable, interacting environmental laws (ESA, NEPA, NFMA). These steps include decisions about listing, designation of critical habitat, consultation on proposed activities in critical habitat, continuing search for alternative management approaches, production on a recovery plan, development of HCPs, the potential for a final appeal to the Exemption Committee of any jeopardy opinion by the FWS and consideration of exceptions to the recovery plan when unusual or unanticipated situations occur.

Any species that is listed is, by definition, already well along toward extinction or local extirpation, or both. Society and appointed and elected officials should recognize that accommodation is inherent and ongoing at every step in the application of the ESA. It is equally important to understand that results of this series of accommodations may be cumulative and interactive in their consequences.

This series of interacting and cumulative accommodations should be remembered when the cry comes, as it inevitably does and will, for "balance" between the recovery of a listed species and the attendant socio-economic costs. A myth persists that activities leading to the listing, the designation of critical habitat, the preparation of a recovery plan, and the implementation of that plan are carried out through a process of cold-blooded scientific and technical evaluations immaculately divorced from concern about socio-economic impacts. The fact is that each step along the way was likely carried out in full recognition of, and with response to, the need for balance.

The Cry for Balance

It is probable, therefore, that all the balance possible between meeting biological requirements of a listed species and socio-economic factors has already occurred by the time a recovery plan is complete. And, additional accommodations will come in the day-to-day application of the plan. In the case of the northern spotted owl, where four different efforts (the ISC, "Moseley Committee," FS EIS Team, and Department of Interior's Recovery Team) to develop a management strategy for the owl arrived at essentially the same end result. And, it should be noted that the Moseley Committee and the Recovery Team contained high ranking political appointees and other technical specialists, such as economists and lawyers who significantly outnumbered biologists on those teams. Such *is* balance. Indeed, if a "free lunch" was hidden somewhere, it is almost a certainty that one of these teams would have found fit. And, if there were serious flaws in the underlying ISC strategy, it would have been revealed.

Clearly, any call for "balance" at this point should be recognized for what it is—a call for decreasing socio-economic impacts by increasing the risk to the recovery of a listed species. After considering the four tries by the four teams described earlier, four Congressional hearings, the "God Squad" proceedings and a court trial (likely with more to come), we contend that no further reductions in socio-economic costs are possible while remaining in compliance with ESA and, in this case, NFMA. Assuming that the law should and will ultimately be obeyed, it is highly likely that the "balance" was already in place when ISC released its report on April 1, 1990.

The search for appropriate means to identify threatened or endangered species and, then, to provide for their recovery with minimum social, economic and political costs is an increasingly significant challenge for professionals in natural resource management. The professional's responsibility is to understand the need for appropriate accommodation with socio-economic considerations, when balancing the application of available biological principles and information in the processes inherent in the ESA to produce scientifically credible results. Then comes the moment for considering the question of whether the associated costs are acceptable. The answer to that question appropriately lies not with technical experts, but with appointed and elected officials and, ultimately, with society as a whole.

Is such accommodation appropriate? We think so. Remember, as the ISC stated (Thomas et al. 1990:8): "Conservation problems cannot be solved through biological information alone, nor from applying 'scientific truth.' Rather, solution comes from a combination of considerations that satisfy society's interests. A strategy that has any chance of adoption in the short term or any chance of success in the long term must include consideration of human needs and desires. To ignore the human condition in a conservation strategy is to fail. . . ."

Accommodation exists at every stage in the application of the ESA process. We believe that is as it should be. To pretend otherwise is to persist in fantasy.

References

Airola, D. 1980. Habitat management for spotted owl and goshawk. USDA Forest Service, Lassen National Forest, Susanville, CA. 5 pp.

Allen, H. L., K. Dixon, K. L. Knutson, and A. E. Potter. 1987. Cooperative administrative study to monitor spotted owl management areas in National Forests in Washington. Progress Report No. 3. Washington Dept. Game, Olympia, WA.

Anderson, D. R., J. Bart, T. C. Edwards, Jr., C. B. Kepler, and E. C. Meslow, 1990. 1990 Status review—northern spotted owl. U.S. Fish and Wildl. Serv., Portland, OR. 95 pp.

Baldwin, P. 1989. Consideration of economic factors under the Endangered Species Act. CRS Report 89-274 A. Library of Congress, Congressional Res. Serv., Washington, D.C. 4 pp.

Barry, D., L. Harroun, and C. Havvarson. 1992. For conserving listed species, talk is cheaper than we think: The consultation process under the Endangered Species Act. World Wildlife Fund, Washington, D.C. 33 pp.

Beckstead, M. A. 1985. Olympic National Forest spotted owl habitat management; translating evolving management guidelines into action. Pages 14–20 *in* R. J. Gutierrez and A. B. Carey, eds., Ecology and management of the spotted owl in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rept. PNW-185. Portland, OR.

Bueter, J. H. 1990. Social and economic impacts of the spotted owl conservation strategy. Tech. Bull. No. 9003. Am. For. Resour. Alliance, Washington, D.C. 36 pp.

Bureau of Land Management. 1987a. Spotted owl environmental assessment. 3 February 1987. Oregon St. Off., Portland. 23 pp.

———. 1987b. Northern spotted owl analysis. 8 May 1987. Oregon St. Off., Portland, OR. 58 pp.

———. 1990. Management guidelines for the management of the northern spotted owl FY 1991 through FY 1992. Oregon St. Off. Portland. 21 pp.

Corn, M. L. and P. Baldwin. 1990. Endangered Species Act: The listing and exemption process. CRS Report 90-242 ENR. Library of Congress, Congressional Res. Serv., Washington, D.C. 29 pp.

Dawson, W. R., J. D. Ligon, J. R. Murphy, J. P. Meyers, D. Simberloff, and J. Verner. 1986. Report of the advisory panel on the spotted owl. Audubon Conservation Report 7. Nat. Audubon Soc. NY. 46 pp.

Dwyer, W. L. 1991. Order on motions for summary judgment and for dismissal. Seattle Audubon Society et al., plantiffs, v. F. Dale Robertson et al., defendants. No. 89099 (t)WD U.S. District Court, Western District of Washington at Seattle, WA. 28 pp.

Frye, H. 1992. U.S. District Court Record for the Case of Audubon et al. vs. Lujan et al., Civil Case no. 87–1160–FR, dated 19 February 1992. U.S. District Court, Portland, OR.

Gorte, R. W. 1989. Economic impacts of protecting the northern spotted owl. CRS Report 90–74 ENR. U.S. Library of Congress, Congressional Res. Serv., Washington, D.C. 48 pp.

Greber, B. J., K. N. Johnson, and G. Lettman. 1990. Conservation plans for the northern spotted owl and other forest proposals in Oregon: The economics of changing timber availability. Papers in Forest Policy I. For. Res. Lab., College of Forestry, Oregon St. Univ., Corvallis. 38 pp.

Hamilton, T. 1990. Economic effects of implementing a conservation strategy for the northern spotted owl. USDA For. Serv. and USDI Bur. Land Manage., Washington, D.C. 65 pp.

Lee, R. G. 1990. Social and cultural implications of implementing "A Conservation Strategy of the Northern Spotted Owl." College of Forest Resourc., Univ. Washington, Seattle. 42 pp.

Maki, W. R. and D. C. Olson. 1991. Economic and social impacts of preserving ancient forests in the Pacific Northwest. Tech. Bull. No. 91–07. Am. For. Alliance, Washington, D.C. 19 pp.

Moseley, J. R. 1992. Record of decision—final environmental impact statement on management of the northern spotted owl in the National Forests. USDA For. Serv., Nat. For. System, Washington, D.C. 22 pp.

O'Halloran, K. A., G. Gunderson, and R. S. Holthausen. 1991. Spotted owl monitoring in Washington and Oregon. Page 526 *in* L. F. Ruggiero, K. B. Aubrey, A. B. Carey, and M. H. Huff, Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rept. PNW–GTR–285, USDA For. Serv., Portland, OR.

Olson, D.C. 1990. Economic impacts of the ISC northern spotted owl conservation strategy for Washington, Oregon, and northern California. Mason, Bruce, and Girard, Portland, OR 37 pp.

Oregon Department of Fish and Wildlife. 1975. Threatened and endangered wildlife in Oregon. Unpublished. Portland, OR. 1 pp.

Oregon-Washington Interagency Wildlife Committee. 1988. Interagency management guidelines for the northern spotted owl in Washington, Oregon, and California. Spotted owl subcommittee. Files of the USDA For. Serv., Pacific Northwest Region, Portland, OR.

Rasmussen, M. 1989. Timber output impacts of the northern spotted owl conservation strategy prepared by the Interagency Committee of Scientists. Timber Data Co., Eugene, OR. 38 pp.

Robertson, F. D. 1988. Record of decision for an amendment to the Pacific Northwest Regional Guide—final supplement to the final environmental impact statement. USDA For. Serv., Washington, D.C. 19 pp.

Ruediger, W. C. 1985. Implementing a spotted owl management plan: The Gifford Pinchot National Forest experience. Pages 10–13 *in* R. J. Gutierrez and A. B. Gutierrez, eds., Ecology and management of spotted owl in the Pacific Northwest. USDA For. Serv. Gen. Tech. Rept. PNW–185. Portland, OR.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. USDA For. Serv., USDI Bur. Land Mange., U.S. Fish and Wildl. Serv., and Nat. Park Serv., Portland, OR. 427 pp.

U.S. Court of Appeals, 9th Circuit. 1992. Lane County Audubon et al. vs Jamison et al. Nos. 91–36019 and 91–36340. DC No. CV–91–06123 REJ. District of Oregon. Dated 4 March 1992. San Francisco, CA.

U.S. Department of Agriculture. 1984. Regional guide for the Pacific Northwest Region. USDA For. Serv., Pacific Northwest Region, Portland, OR.

USDA Forest Service. 1983. Internal letter of instruction, dated 9 February 1983, from the Regional Forester instituting guidelines for incorporating minimum management requirements in forest plans. pacific Northwest Region, Portland, OR.

———. 1987. FY 87 annual report on spotted owl inventory and monitoring. Pacific Northwest Region, Portland, OR. 22 pp.

———. 1988. Final supplement to the environmental impact statement for an amendment to Pacific Northwest regional guide. Volume 1—Spotted owl guidelines, 296 pp. Volume 2—Spotted owl guidelines, appendices. Pacific Northwest Region, Portland, OR. 321 pp.

———. 1990. Implementation of Section 318 of the Interior and Related Agencies Appropriations Act for Fiscal year 1990. Forest Service Report to Congress. Washington, D.C. 31 pp.
———. 1991. Final environmental impact statement on management for the northern spotted owl in the National Forests. 2 volumes. Portland, OR.
———. 1992. Final environmental impact statement on management for the northern spotted owl on the National Forests. 2 Volumes. Pacific Northwest Region, Portland, OR.
U.S. Department of Interior. 1982. The northern spotted owl: A status review. U.S. Fish and Wildl. Serv., Endangered Species Program, Portland, OR 29 pp.
———. 1991. "Northern Spotted Owl vs. Lujan; 758 F. Supplement 621 (Western District of Washington, 1991)." Federal District Court of Western Washington, Seattle, WA.
———. 1992. Recovery plan for the northern spotted owl—draft. Washington, D.C. 550 pp.
U.S. Fish and Wildlife Service. 1991. Memorandum to the State Director for Oregon, Bureau of Land Management; biological opinions on FY 91 timber sales. Dated 17 June 1991 and amended 3 July 1991. Regional Office, Portland, OR.
———. 1991a. Endangered and threatened wildlife and plants; revised proposed determination of critical habitat for the northern spotted owl; proposed rule. 50 CFR Part 17. 56(156):40,001–40,143.
———. 1991b. Endangered and threatened wildlife and plants; revised proposed determination of critical habitat for the northern spotted owl; proposed rule. 50 CFR Part 17. 56:20,816–20,859.
———. 1992. Endangered and threatened wildlife and plants; determination of critical habitat for the northern spotted owl. Fed. Reg. 57(10)1,796–1,838.
———. 1992. Endangered and threatened wildlife and plants; determination of critical habitat for the northern spotted owl; final rule. 50 CFR Part 17. Fed. Reg. 57(10):1,795–1,838.
———. 1987. The northern spotted owl status review. Portland, OR. 50 pp.
———. 1989. The northern spotted owl—a status review supplement 1989. Portland, OR. 10 pp.
U.S. Laws, Statutes. Public Law 91-190 (S.1075), Jan. 1, 1970. National Environmental Policy Act of 1969. United States statutes at large. 1969. Vol. 83, p. 852–856. U.S. Govt. Print. Off., Washington, D.C. 1970. (42 U.S.C. sec. 4321, et seq. 1970).
———. Public Law 93–205. S. 1983, December 28, 1973. Endangered Species Act of 1973. *In* United States statutes at large. 1973. Vol. 87, p. 884. 16 U.S.C. SEC. 668 (1976).
———. Public Law 94–588 (S.3091), Oct. 22, 1976. National Forest Management Act of 1976. United States code congressional and administrative news. 94th Congress, 2nd Session. Washington, D.C.
Zilly, T. 1991. Order granting plantiff's motion for summary judgment and motion to compel designation of critical habitat. Northern spotted owl (*Strix occidentalis caurina* et al., Plaintiffs V. Manuel Lujan et al.). No. C88-5737, U.S. District Court, Western District of Washington at Seattle, WA. 20 pp.

The Endangered Species Act: Prospects for Reauthorization in 1992

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Introduction

As the Endangered Species Act of 1973 (ESA), 16 U.S.C. §§ 1531, *et seq.*, approaches its twentieth birthday, it faces its stiffest test yet. In 1992, Congress must decide whether to reauthorize the ESA and, concomitantly, whether to amend it in any significant way. At a time when the world faces the greatest extinction spasm since the disappearance of the dinosaurs 65 million years ago (Jablonski 1986), it seems almost inconceivable that the ESA, the Nation's principal bulwark against the tide of extinction, could be weakened. Nevertheless, well-financed and vocal coalitions opposing the ESA are working toward precisely that end. To combat the anti-ESA forces, the conservation community across the country is rallying to the defense of the law and, indeed, will be seeking to strengthen it in several ways. The resulting clash may well produce the conservation battle of the century.

Discussion

The Endangered Species Act: An Overview

In enacting the ESA, Congress declared as its purposes the direct protection of threatened and endangered species, as well as indirectly protecting them through conservation of the ecosystems upon which they depend for survival (16 U.S.C. § 1531 (b)). To accomplish these goals, Congress established a system for identifying threatened and endangered species and their critical habitat, halting their slide toward extinction, and, ultimately, providing for their recovery to viable population levels.

Section 4 of the ESA provides for the listing of species as threatened or endangered by the Secretary of the Interior. Listing determinations are to be made solely on the basis of scientific considerations (16 U.S.C. § 1533 (b) (1) (A)). As of September 30, 1991, 1,167 species worldwide had been listed as threatened or endangered, including 639 species in the United States (U.S. Fish and Wildlife Service 1991). As of April 3, 1990, more than 3,500 species, known as candidate species, were under consideration by the U.S. Fish and Wildlife Service for listing as threatened or endangered (U.S. Fish and Wildlife Service 1990a).

Section 4 also requires the designation of critical habitat for threatened and endangered species. Critical habitat is defined as the geographical area that is essential to the conservation of the species, regardless of whether the species is actually found there at the time of listing. Under the ESA, critical habitat includes areas that are necessary for both the survival and recovery of the species. Unlike the decision to list a species, designation of critical habitat must take into account the economic costs of such a designation (16 U.S.C. § 1533 (b) (2)).

Section 4 further requires that recovery plans be developed and implemented for listed species (16 U.S.C. § 1533 (f)). As of December 1990, recovery plans were approved for 352 species, slightly more than half the total number of species listed in the U.S. (U.S. Fish and Wildlife Service 1990b).

Once a species is listed as threatened or endangered, it receives various legal protections. Section 9 prohibits, with limited exceptions, the "taking" of threatened and endangered species by any person (16 U.S.C. § 1538 (a)). "Taking" is broadly defined as "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (16 U.S.C. § 1532 (19)).

Section 7 of the ESA imposes an affirmative duty on all federal agencies to conserve threatened and endangered species and obligates each federal agency to consult with the U.S. Fish and Wildlife Service (FWS) or, in the case of marine species, the National Marine Fisheries Service (NMFS), to insure that any activity it authorizes, funds or carries out is not likely to jeopardize a listed species or adversely modify or destroy critical habitat (16 U.S.C. § 1536 (a)). If, as a result of Section 7 consultation, no jeopardy or adverse habitat modification is found, the agency action may go forward, subject to other required environmental reviews. If, however, jeopardy or adverse habitat modification is found (commonly referred to as a "jeopardy opinion"), FWS or NMFS must propose reasonable and prudent alternatives, if any are available, that will permit the agency action to go forward without resulting in jeopardy or adverse habitat modification (16 U.S.C. § 1536 (b) (3) (A)). An agency that proceeds with an action despite a jeopardy opinion, while failing to adopt proposed reasonable and prudent alternatives, violates the takings prohibitions of Section 9, unless it has first obtained an exemption from the Endangered Species Committee, the so-called "God Squad" (16 U.S.C. §§ 1536 (e)–(1)).

As with other federal environmental statutes, primary responsibility for enforcing the ESA rests with the federal government, which may levy civil penalties of varying magnitude for different ESA violations, or seek fines, imprisonment, forfeiture of federal licenses and permits, or confiscation of gear for criminal violations of the ESA (16 U.S.C. §§ 1540 (a)–(b). In addition, any person may file a citizen suit against other persons or federal agencies to enforce the ESA (16 U.S.C. § 1540 (g)).

The Current Reauthorization Controversy

As with several other federal environmental laws, the ESA is periodically reauthorized; that is, Congress authorizes the appropriation of funds for its implementation for a given number of years. The original ESA has been reauthorized on three occasions, in 1978, 1982 and 1988 (The Conservation Fund 1992). Its current authorization expires September 30, 1992 (16 U.S.C. § 1542 (a)). While in theory the ESA can be amended at any time, historically, Congress has used the reauthorization deadline as the opportunity to reexamine the law, assess its strengths and weaknesses, and make appropriate amendments.

The 1992 reauthorization debate is shaping up as the most contentious ever. The increased prominence of several endangered species controversies since the last reauthorization—including conflicts involving the northern spotted owl and the timber industry in the Pacific Northwest, sea turtles and shrimp fishing in the Southeast, and the Stephens' kangaroo rat and residential and commercial development in Southern California—has encouraged opponents of the ESA to openly challenge the law. In addition, ESA opponents have grown more sophisticated at working the political process, adopting many of the tactics previously used by the conservation community. Thus, organizations sporting such euphemistic names as the National Endangered Species Act Reform Coalition and the Alliance for America have formed. These groups purport to represent a nationwide "grassroots" backlash against the ESA, although they actually are comprised of longstanding opponents of the ESA, including water development, livestock, timber and mining special interests. Moreover, such mainstream business and development special interest groups as the U.S. Chamber of Commerce, the American Farm Bureau Federation and the National Association of Homebuilders have begun working under their own banners to significantly weaken the ESA (The Conservation Fund 1992).

This vigorous assault on the ESA has galvanized its supporters to unite in defense of the law. The Endangered Species Coalition, an umbrella organization, comprised of numerous conservation organizations from across the spectrum of the movement—including such groups as the Environmental Defense Fund, the National Audubon Society, the World Wildlife Fund, the Humane Society and Greenpeace—is working to strengthen the ESA. In addition, other major conservation organizations, including the National Wildlife Federation and The Nature Conservancy, though not members of the Endangered Species Coalition, share its basic goals for strengthening the ESA and are cooperating in those efforts.

The proliferating anti-ESA groups espouse common criticisms of the law. First, ESA opponents argue that the law hasn't worked, supporting their claim by pointing to the mere half-dozen species which have recovered and been delisted over the past two decades. Second, critics of the ESA charge that it exalts protection of animals and plants over human needs, failing to consider the economic and social costs imposed by endangered species conservation requirements (Irvin personal files: 1991). Third, anti-ESA groups portray the law as having brought development to a grinding halt in many areas of the country (Irvin personal files: 1992). To remedy these claimed defects, ESA opponents are seeking, among other things, amendments which would inject economic considerations into every stage of ESA implementation; restrict protection under the ESA to full species rather than treating species, subspecies and distinct vertebrate populations equally, as under the current law; and require the government to compensate property owners for alleged diminutions in value of their property or livelihoods due to ESA restrictions (Irvin personal files: 1991).

Supporters of the ESA refute each of the anti-ESA arguments. First, ESA proponents point out that measuring the success of the law by the number of species removed from the list uses the wrong yardstick; the more appropriate measure is the number of species whose condition has been stabilized or improved as a result of ESA protection. By that measure, the condition of 238 listed species, comprising 41 percent of the species listed in the U.S., is stable or improving. These include such prominent species as the bald eagle and red wolf, and such lesser known species as the Knowlton cactus. By contrast, the condition of 219 species, or about 38 percent, continues to decline (U.S. Fish and Wildlife Service 1990b). Given that the ESA is analogous to an emergency room which handles only the most dire cases, supporters of the law argue that it has been a success by getting hundreds of species off the operating table, though not yet out of the hospital.

Second, ESA supporters dispute the claim that the law is anti-human and ignores economic and other social considerations. ESA supporters point out that economic and social considerations are taken into account throughout the ESA. Indeed, only in listing determinations are non-biological considerations prohibited, since such considerations have no bearing on whether a species is endangered. On the other hand, ESA supporters note, in virtually every other provision of the law, economic and social concerns are balanced against the conservation needs of species. For example, the ESA expressly requires that economics be factored into decisions to designate critical habitat. Indeed, application of this requirement resulted in the exclusion of millions of acres from the recent designation of critical habitat for the spotted owl. ESA proponents also note that developers can obtain federal permits to harm and even kill endangered species on their property, provided that they develop a habitat conservation plan to minimize and mitigate impacts on the species. Similarly, if the FWS finds that a federal project will jeopardize an endangered species, it is required to propose available reasonable and prudent alternatives which, by law, must be economically and technologically feasible. Finally, the ESA's provision allowing a project developer to ask the God Committee for an exemption from the ESA, even at the cost of a species' extinction, allows the starkest balancing of economic and social consideration against a species' conservation needs (Irvin 1991).

Third, supporters of the ESA reject the contention that the law has brought development to a standstill. The National Wildlife Federation and the World Wildlife Fund have analyzed Section 7 consultations between 1979 and 1991. Of more than 120,000 federal activities reviewed by FWS during that time for impacts on listed species, more than 99 percent were found to pose no jeopardy to threatened or endangered species. Moreover, of the more than 5,000 projects on which the FWS was formally consulted during that period, only 34, or 0.7 percent, were cancelled due to conflicts with endangered species (Barry et al. 1992).

While ESA supporters can credibly refute opponents' claims of draconian impacts from the law, they recognize that the law is not perfect, as evidenced by the ever-growing number of threatened and endangered species. Thus, conservation groups have united behind a five-point agenda for strengthening the ESA. First, conservationists want to streamline the listing process, to ensure that the more than 3,500 species awaiting listing decisions do not become extinct before conservation efforts under the ESA can be undertaken. Second, in order to address the single greatest cause of extinction, habitat destruction, conservationists are seeking to improve the designation of critical habitat and to coordinate it with the development of recovery plans. Third, to accelerate the recovery and delisting of species, conservationists are working to impose deadlines for the completion and timely implementation of recovery plans. Fourth, to address the chronic underfunding of the ESA, conservationists want to dramatically increase the authorization levels for appropriations to implement the law. Fifth, conservationists want to strengthen various enforcement provisions in order to close loopholes remaining in the ESA (Irvin personal files: 1991).

The Outlook in Congress

While the battle lines have been drawn between opponents and supporters of the ESA, it is too soon to predict when the climactic cavalry charges in the halls of Congress will take place. Already, three bills have been introduced in the U.S. House of Representatives addressing the ESA. As of January 1992, however, no ESA reauthorization bill had been introduced in the Senate.

The leading measure in the House is H.R. 4045, the Endangered Species Act Amendments of 1992. It was introduced in November 1990 by 31 Members of Congress, led by Representative Gerry Studds of Massachusetts, who is chairman of the subcommittee with jurisdiction over ESA reauthorization. Supported by the conservation community, H.R. 4045 would reauthorize the ESA for five years and, in the process, double the funding authorization levels for ESA implementation. In addition, H.R. 4045 would require the completion of recovery plans within two years of a species' listing and give priority to the development of integrated multispecies recovery plans for ecosystems or ecological communities containing more than one listed or candidate species. The bill also would establish a revolving fund to finance development of habitat conservation plans for listed and candidate species. Furthermore, H.R. 4045 would enable citizens to file suit immediately in emergencies to enforce the ESA, and would help stem illegal international trade in endangered species by clarifying the authority of federal agencies to implement the Convention on International Trade in Endangered Species (The Conservation Fund 1992).

The other two bills—H.R. 3092, the Human Protection Act, introduced by Representative James Hansen of Utah, and H.R. 4058, the Balanced Economic and Environmental Priorities Act, introduced by Representative William Dannemeyer—offer some of the anti-ESA groups' proposals for weakening the ESA. Both measures would require that all actions to implement the ESA first pass a rigorous benefit/cost analysis. Both measures also would impose tacit restrictions on ESA implementation, ostensibly to protect private property rights (The Conservation Fund 1992).

Whether any of these measures will be enacted in 1992 remains to be seen. In the midst of what may be a close Presidential election race, and with other contentious environmental issues, such as pending reauthorization of the Clean Water Act, Congress may be reluctant to resolve what promises to be a volatile conflict. Nevertheless, supporters and opponents of the ESA are vowing to make 1992 a year of decision.

If Congress does not take action on the ESA this year, conservationists have the upper hand, for several reasons. First, while the authorization for appropriations expires this year, the substantive requirements of the ESA remain in place. If Congress fails to reauthorize the ESA this year and if anti-ESA groups succeed in blocking efforts to vote continuing appropriations for the law, then developers with endangered species on their property may suddenly find themselves prohibited from taking an endangered species, yet unable to obtain a permit to allow a lawful taking because of a lack of authorized appropriations for the FWS. Clearly, the prospect of such situations across the country militates in favor of a timely reauthorization.

Second, the record of the ESA in its two decades of existence is hardly the economic Armageddon its opponents portray. As Congress examines that record in more detail and finds there is more smoke than fire in the anti-ESA groups' assertions, it is unlikely to enact major retrenchments in the national commitment to endangered species conservation.

Third, and probably most important, there is widespread support for the ESA among the American people. A recent nationwide poll revealed that fully two-thirds of Americans, in all regions of the country, support the ESA. Moreover, 73 percent of the American electorate said they are more likely to vote for a Senator or Representative who supports the ESA (Greenberg/Lake et al. 1992). Congress is unlikely to ignore such strong indicators of public sentiment, particularly during an election year.

Conclusion

The Endangered Species Act is regarded by many as the crown jewel of America's environmental laws. While opposition to the ESA is better organized and more visible than in past reauthorization battles, efforts to weaken the ESA will meet with stiff resistance among its defenders in the conservation community. Moreover, the law continues to enjoy broad and strong support among the American people and their elected representatives in Congress. Consequently, while it is uncertain whether the ESA will be reauthorized on schedule in 1992, it will ultimately be reauthorized and, in all likelihood, strengthened. In so doing, Congress will reaffirm the Nation's commitment to future generations, embodied in the ESA, to leave them a world as rich in plants and wildlife as our own.

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References Cited

Barry, D., L. Harroun, and C. Halvorson. 1992. For conserving listed species, talk is cheaper than we think: The consultation process under the Endangered Species Act. World Wildlife Fund, Washington, D.C. 12 pp.

Greenberg/Lake, The Analysis Group, and The Tarrance Group. 1992. Bi-partisan poll results. National Audubon Society and The Nature Conservancy, Washington, D.C. 8 pp.

Irvin, W. R. 1991. Balancing economics and wildlife. *Star-Tribune*, Casper, Wyoming. Page A8 (September 12, 1991).

Jablonski, D. 1986. Mass extinctions: New answers, new questions. Pages 43–61 *in* L. Kaufman and K. Mallory, eds., The last extinction. The MIT Press, Cambridge, MA. 208 pp.

The Conservation Fund. 1992. The Endangered Species Act—controversial listings sharpen reauthorization debate. Land Letter 11(3). 8 pp.

U.S. Fish and Wildlife Service. 1990a. Service publishes revised plant notice. Endangered Species Technical Bulletin XV(3):6.

———. 1990b. Report to Congress: Endangered and threatened species recovery program. Page 15. U.S. Department of the Interior. 406 pp.

———. 1991. Box score—listings and recovery plans. Endangered Species Technical Bulletin XVI (7–8):16.

Conservation on a Grand Scale

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Introduction

In this election year, we hear a lot from the candidates about America's position in the global community. Whether we talk about trade, defense, or politics, it seems that each year the affairs of our country become more closely intertwined with those of our neighbors, both near and far. And in seeking solutions to the challenges that face America, the candidates recognize that this country's economic or environmental problems are so complex that there is no way we can solve them in isolation from the global community.

The candidates also talk about the need for fresh approaches to solving our problems. The old way of doing things not only isn't working, it threatens to undermine some of our greatest achievements. By treating symptoms, rather than causes, we remain locked in a cycle of spiraling costs and worsening problems.

The field of wildlife conservation is, in many ways, a microcosm of this much larger system. We also face challenges of increasing complexity. Global environmental changes, migratory fish and wildlife, and economic impacts of conservation all require cooperation on an international scale. And we, too, need fresh approaches to our problems. As human populations grow and wildlife habitats decrease, the friction between the two escalates, with crises rising at seemingly exponential rates. The old way of doing things isn't working, because it fails to promote biologically and economically viable strategies, and neglects to muster the political coalitions necessary for success. To continue business as usual may well mean losing our most important achievements, like the Endangered Species Act.

In this paper, we present a fresh approach to one of our most challenging problems: the conservation of migratory birds, particularly neotropical migratory land birds. This approach is not breathtaking in its ingenuity; it is a strategy that most conservationists have considered, and some have implemented, usually on a smaller scale. The beauty of this approach is that it is working. After less than 15 months, this program, popularly known as "Partners in Flight," has provided a framework for conservation of neotropical migratory birds on a "grand" scale.

Declines of Neotropical Migratory Birds

As defined by Rappole et al. (1983), neotropical migrants are those species ". . . all or part of whose populations breed north of the Tropic of Cancer and winter south of that line," with the Tropic of Cancer being the approximate dividing line between the Nearctic and Neotropical Faunal Regions (Mayr 1985). This includes approximately 355 species, 51 percent of all those recorded as breeding in the United States.

In 1989, an international symposium (Hagan and Johnston 1992), a popular book (*Where have all the birds gone?* [Terborgh 1989]), and a series of scientific papers (e.g., Robbins et al. 1989, Askins et al. 1990) forecast a rather bleak outlook for the future of neotropical migrants. Long-term monitoring programs, like the Breeding Bird Survey, indicated that populations of many neotropical migrants declined over the last one to two decades (Robbins et al. 1989, Terborgh 1989, Askins et al. 1990). In the eastern United States, for instance, 70 percent of the neotropical migrants monitored by the Breeding Bird Survey declined from 1978–1987, and 69 percent of prairie and prairie edge species that migrate to the neotropics declined during the same period (Robbins et al. 1989). Declines for some species have been gradual but significant. For example, populations of the Cerulean warbler declined an average of approximately 3.2 percent per year from 1966–1989 (Droege and Sauer 1990). Two primary explanations for these declines have been acknowledged: the deterioration of breeding habitat in the temperature zone through forest fragmentation, and the loss of nonbreeding habitat in the tropics. A number of associated factors, including predation and brown-headed cowbird parasitism, also are believed to be principal factors contributing to declines (Terborgh 1989).

A New Approach

Declines in neotropical migrant populations focussed the attention of the scientific community, conservationists, and the public on this diverse group. The declines also brought attention to existing conservation programs for neotropical migrants. In 1989 and 1990, the National Fish and Wildlife Foundation reviewed existing programs for neotropical migratory birds to identify opportunities for new conservation efforts. This assessment revealed that many groups, including federal agencies, nongovernmental organizations, and universities, were involved in dynamic and successful research, monitoring, management, and education programs benefitting neotropical migrants. In most cases, however, these efforts were limited in scope, addressing small geographic areas or single species. Communication among groups was limited and coordination often was lacking. Furthermore, increased interest in neotropical migrants was stimulating many new programs, but these were developing in the absence of an overall, coordinated framework. Under the present system, it was difficult to determine if the most critical questions and geographic areas were being covered, nor was there any assurance that studies were being designed to facilitate comparative data analysis.

The sheer complexity and geographic scope of the challenges facing neotropical migrants suggested that a more comprehensive and coordinated approach to their conservation was warranted. The conservation of neotropical migrants represents a daunting challenge: some 355 species, representing tens of millions of individuals that breed in, migrate through or winter in over a dozen countries, each with its own culture and conservation structure. Neotropical migrants are a diverse group, with representatives in 36 of the 62 families of North American birds, and they occupy a wide range of habitats during both the breeding and nonbreeding seasons. Although considerable information about the ecology of these species on breeding grounds is available, even the most basic data on distribution and abundance are lacking for many species during the nonbreeding season (Keast and Morton 1980).

Effective conservation programs for neotropical migrants clearly would require simultaneous action on the breeding and winter grounds, and on the migration routes. Given the vast geographic ranges of neotropical migrants, the diverse array of species, and the dearth of information on ecology during the nonbreeding season, it seemed clear that a major, international effort would be required for their conservation.

In 1990, the National Fish and Wildlife Foundation (1990) proposed a coordinated and comprehensive Neotropical Migratory Bird Conservation Program to meet these objectives. The proposal suggested marshalling the collective resources of all public and private entities with an interest in conservation of neotropical migrants and their habitats. The Program was modelled after other successful bird conservation efforts, such as the North American Waterfowl Management Plan and the Western Hemisphere Shorebird Reserve Network.

The proposal for a Neotropical Migratory Bird Conservation Program included:

1. Design for a comprehensive framework for conservation of neotropical migrants on both the breeding and nonbreeding grounds, with clearly specified roles and responsibilities for each participating organization;
2. Establishing a mechanism to ensure coordination among North American federal, state and private sector, and corporate organizations involved in research, monitoring, management and other related activities;
3. Developing linkages to ensure coordination among participants in North America, Latin America and the Caribbean;
4. Simultaneous implementation of research, monitoring and management practices in North America and the Neotropics; and
5. Providing consistent and adequate funding to support these efforts.

The Neotropical Migratory Bird Conservation Program offered many benefits. It called for a comprehensive approach, with activities implemented simultaneously on both the breeding and nonbreeding grounds, and keyed on the positive aspects of public and private joint efforts to improve habitat conditions in all partner countries. It also provided the mechanism for coordinated involvement and commitment of federal, private and corporate partners throughout the range of neotropical migrants.

In the United States, the Program was designed to stimulate the growth of existing programs of federal and state agencies, nongovernmental organizations, and other entities with an interest in migratory bird conservation. For example, the Program would stimulate expansion of the Breeding Bird Survey (BBS) and other monitoring programs coordinated by the U.S. Fish and Wildlife Service. Reliable monitoring programs are important as early warning systems to provide advance notice of population decreases, and also to monitor population recovery. The Neotropical Migratory Bird Conservation Program also would stimulate new monitoring programs for underrepresented groups, like nocturnal and colonial nesting species, and for roadless areas.

By fostering partnerships between federal agencies, philanthropic groups and the corporate community, the Program would enlarge the scope of state agency and nongovernmental organization efforts. For example, nearly a dozen states do not yet have Breeding Bird Atlas projects to provide baseline data on bird distribution and abundance. Most states have the expertise to organize atlases, but lack the financial resources. Partnerships with federal agencies, philanthropic groups and corporations could meet this need, allowing states to move forward with atlas projects and other conservation programs for neotropical migrants.

Similarly, many small nongovernmental organizations have excellent research, monitoring and education projects that could be greatly expanded with additional financial assistance. Nongovernmental organizations also have the expertise to train federal and state agency personnel and international colleagues in monitoring techniques and other skills. The Neotropical Migratory Bird Conservation Program would provide the framework necessary for this expansion to occur.

Implementation of the Neotropical Migratory Bird Conservation Program also would significantly improve the balance between nongame and game species programs within the U.S. federal agencies. It would provide a focus for incorporating migratory birds into existing agency efforts like the USDA Forest Service's "New Perspectives" and "Eyes on Wildlife" programs, the U.S. Fish and Wildlife Service's "Strategies for Conservation of Avian Diversity in North America," the Bureau of Land Management's "Fish and Wildlife 2000," and bolster the National Park Service's "Migratory Bird Watch" effort.

Reforestation efforts to benefit neotropical migrants would support the President's tree planting initiative, the Global Releaf Program of the American Forestry Association, and the Backyard Wildlife Program of the National Wildlife Federation. The Neotropical Migratory Bird Conservation Program also would provide for meaningful implementation of the Migratory Bird Treaty Act for forest and grassland neotropical migrants by supplementing ongoing efforts for waterbirds.

Implementation of the Program on the international front would be facilitated through existing agreements between key U.S. federal agencies, Canada, Mexico and other countries in the Neotropics. International coordination also would be greatly enhanced by the well-developed networks maintained by many nongovernmental organizations and universities. The Program would provide the link between conservation of neotropical migrants and other fundamental concerns in the Neotropics that included training of wildlife and natural resource managers, deforestation, sustainable resource development and conservation of nonmigratory and endemic species.

The Neotropical Migratory Bird Conservation Program also provides a flagship mechanism for an ecosystem level approach to conservation, while at the same time maintaining the option for single-species approaches, when necessary. Neotropical migrants occupy a wide variety of habitats on both the breeding and nonbreeding grounds, and groups of species often are associated with particular habitat types. A habitat based, ecosystem level approach is the most viable and effective option for neotropical migrant conservation. The traditional problems associated with marketing ecosystem level programs, conservation of biological diversity and nongame programs could be overcome by capitalizing on the popularity and appeal of neotropical migratory songbirds.

In 1985, it was estimated that 61,000,000 people in the United States observed birds closely, 115,000,000 observed birds as a secondary activity (e.g., while doing yard work), 82,000,000 fed wild birds and 25,000,000 took trips of greater than one mile to observe birds (U.S. Department of the Interior 1988). Kellert (1985) concluded that there are about 1,800,000 active or committed bird watchers represented in this group. Expenditures by the 61,000,000 birdwatchers were estimated at $20 billion in 1981. This group represents a well-educated, environmentally literate and economically influential group. If this vast constituency could be effectively mobilized, they could provide broad support for a new and non-traditional conservation program. The grassroots participation of amateur birdwatchers also would provide the skilled participants for enhancing bird population monitoring programs.

Finally, the Neotropical Migratory Bird Conservation Program offers the opportunity to "do conservation when it should be done," that is, before species become legally threatened or endangered. Although declines in populations of neotropical migrants are widespread, only 13 species or subspecies (4 percent) of neotropical migrants are classified as federally endangered (U.S. Fish and Wildlife Service 1990). The rest, to varying degrees, are still fairly common. By beginning an effective, ecosystem level program soon, it might be possible to prevent entire suites of species from being added to the Endangered Species List.

The scope of the proposed Neotropical Migratory Bird Conservation Program was clearly beyond the means of any one organization or country, and successful implementation would depend on the cooperation of a wide range of organizations and interests from throughout the species' ranges. Paramount to the success of such a coalition was the inclusion of entities with legal authority for migratory bird protection, expertise for research, management, training and education, land management responsibilities, grassroots public networks, and economic resources.

The Foundation's initial proposal called for a broad domestic coalition that included the principal land management federal agencies, the Smithsonian Institution, state agencies, nongovernmental organizations, professional societies, philanthropic groups, businesses and trade industry groups. Similar entities in Canada and the Neotropics were to be included once the Program became established in the United States. Establishment of joint ventures among these diverse groups were to be a primary means of implementing priority research, monitoring, management, education, and habitat acquisition projects.

Organizing and empowering such a coalition are at least as challenging, if not more so, than the actual conservation of neotropical migrants themselves. To facilitate communication among members of this coalition, the proposal called for establishing an interagency committee modelled after the Interagency Grizzly Bear and Spotted Owl Committees. This committee would have responsibility for coordinating the activities of the federal agencies and guiding development of the Neotropical Migratory Bird Conservation Program.

The proposal also included a series of specific steps for immediate Program implementation that included: establishing a restricted fund within the Foundation to begin immediate financial support of key projects; establishing an advisory group to guide Program development; arranging meetings with representatives of federal agencies and key Congressional staff to pursue funding requirements; developing long-term strategies for neotropical migrant conservation within the federal agencies; preparing a needs assessment of federal agency funding needed to implement the Neotropical Migratory Bird Conservation Program; and hosting a workshop for all potential participants to gather technical input for a long-term strategy document that would provide the framework for coordinated research, monitoring, and habitat conservation efforts on the breeding and nonbreeding areas.

The proposed workshop took place in December of 1990 in Atlanta, Georgia, and was sponsored by the U.S. Fish and Wildlife Service, the U.S. Forest Service and the National Fish and Wildlife Foundation, and was hosted by the National Wildlife Federation. This workshop provided the first structured opportunity for open exchange and discussion about the Neotropical Migratory Bird Conservation Program. Over 150 resource professionals, representing 6 federal agencies, 7 state wildlife departments, 17 nongovernmental conservation organizations, the forest products industry, and representatives from the governments of Canada and Mexico met to debate and develop a comprehensive plan for conservation of neotropical migrants. Many components of the Foundation's original proposal were modified, and new parts were added. Participants identified goals in the area of monitoring, management, research, education and outreach, and international cooperation, and outlined specific objectives that would lead to meeting these goals (Neotropical Migratory Bird Conservation Program 1990).

The Atlanta workshop also provided an opportunity to formalize the "framework for cooperation" for the program. An Interagency Committee, with an initial membership representing the U.S. Fish and Wildlife Service, U.S. Forest Service, National Park Service, Bureau of Land Management, and the Agency for International Development, was established. The Smithsonian Institution, which is not a federal agency, was represented on the committee in observer status.

Federal law governing advisory committees prevented nongovernmental organizations from participating on the interagency committee, so they formed a parallel planning and implementation committee. The membership of this committee includes those domestic and international organizations with an interest in conservation of neotropical migrants and with resources to contribute to the Program. The nongovernmental committee interacts closely with the federal agency committee, and functions with its federal counterpart in an oversight capacity for the whole program. Meetings of the two committees occur in conjunction at least twice yearly.

The Atlanta workshop participants also identified a number of program priorities that included research, monitoring, education and international needs, and represented the basis from which the Neotropical Migratory Bird Conservation Program would develop. At the workshop, the taxonomic scope of the Program also was narrowed. Although it was recognized that all migratory birds required conservation, the greatest need was for a program that specifically addressed the needs of forest and grassland species. By focussing on the approximately 240 species of forest and grassland species, the Neotropical Migratory Bird Conservation Program would complement existing programs for waterbirds, like the North American Waterfowl Management Plan and the Western Hemisphere Shorebird Reserve Network.

Perhaps the most important outcome of the Atlanta workshop was the establishment of technical Working Groups. Working Groups were established to represent the fields of research, monitoring, education and outreach, and international relations. Regional Working Groups, with a focus on management issues, were established for the Northeast, Southeast, Midwest and Western regions of the United States. Membership in the Working Groups is open to representatives from all federal agencies and nongovernmental organization participating in the oversight committees, and to any others who wanted to contribute. Working Groups were established to provide specific programmatic recommendations to the two oversight committees, and were viewed as the heart of the Neotropical Migratory Bird Conservation Program.

The Atlanta workshop also was the first opportunity for the many diverse participants in the program to discuss their individual roles, as well as how they would interact as partners. It was clear at the Atlanta workshop that building partnerships among many participants would be challenging, as there were many different ideas on how a conservation program should be developed. There also were some long-standing barriers between participants that had to be overcome if a truly cooperative program were to develop. The success of the Neotropical Migratory Bird Conservation Program would depend as much on the constructive participation of the organizations involved as on the quality of the conservation programs developed.

Progress following the Atlanta workshop was rapid. The Forest Service and the National Fish and Wildlife Foundation already had a neotropical migratory bird coordinator, and the U.S. Fish and Wildlife Service, International Association of Fish and Wildlife Agencies, International Council for Bird Preservation, National Fish and Wildlife Foundation and The Nature Conservancy soon followed suit. An official logo, depicting two male American redstarts, one migrating north and one south, was adopted. The fledgling Program was christened with a popular name, "Partners in Flight—Aves de las Americas," which stresses the importance of partnerships and the international nature of the resource. New research, management, monitoring, and education projects were launched by a number of different participants, and in FY 1991, the U.S. Fish and Wildlife Service and the USDA Forest Service received first ever appropriations specifically for neotropical migratory birds. Communication among participants was enhanced with a newsletter produced through the Information and Education Work Group and published by the National Fish and Wildlife Foundation. The most important achievement, however, was maturation of the Working Groups.

Each Working Group was assigned a federal agency and nongovernmental organization co-chair who assumed responsibility for organizing meetings, establishing communication networks, and recruiting members. Working Groups met as needed, and began immediately to establish subcommittees to address specific issues. The Research Working Group, for example, convened a committee of experts that were available to provide technical review for proposals and publications. They also created a species list, and began to identify priority research projects. Regional Working Groups determined priority species lists by habitat type, thereby enhancing opportunities to promote habitat and ecosystem level program. The Information and Education Working Group developed brochures, slide shows and the Partners in Flight Newsletter.

Hurdles

Fifteen months after the Atlanta workshop, the Partners in Flight Program has taken shape and is progressing rapidly. As with any program, however, there have been problems. Consensus decisions among such diverse participants are not easy, and have slowed progress on some specific issues. As the Working Groups mature, and the federal and nongovernmental organization oversight committees became established, this process will improve considerably. It has been challenging to develop a broad conceptual program in such a way as to allow individual organizations to retain and enhance their own identities, while at the same time, contributing to the overall Program goals. Travel funding to attend meetings has been a barrier, particularly for the state agencies and nongovernmental organizations, but increasingly Working Group and other meetings have taken place in conjunction with other planned events. Fund-raising from philanthropic groups and the corporate sector also presents a challenge to nongovernmental organizations; many different groups seeking funding for the same Program requires coordination and communication between organizations that often compete for the same funds.

Conclusion

Despite these hurdles, "Partners in Flight" represents a significant step forward in providing a framework for the conservation of neotropical migratory landbirds. The Program's success can be attributed to fortuitous circumstances, broad-based support and cooperation, strategic planning, immediate project implementation, and, of course, the efforts of a number of dedicated conservationists. Although it is too early to tell if the Program will result in stabilized or increased bird populations, success can be measured in terms of enthusiasm generated for the resource, and the millions of dollars of funds committed to the implementation of hundreds of new research, monitoring, training, education and management projects.

As a model for other conservation efforts, there are several components to the Partners in Flight Program worth reiterating. "Partners in Flight":

- promotes conservation on habitat and ecosystem levels;
- focuses on species that are declining but not yet threatened or endangered;
- capitalizes on and focuses broad public support;
- provides early participation and integration of private groups interested in neotropical migrants with federal and state agencies;
- provides a single, flexible framework for communication and cooperation;
- promotes conservation throughout the species' ranges by linking Northern and Southern Hemispheres through a shared resource; and
- capitalizes on joint ventures and partnerships to provide project support;

Many of the challenges facing wildlife conservation today stretch across political boundaries, and involve costly economic and political considerations. Solutions will require biological, financial and political ingenuity on a scale that can be met only with the pooled resources of public and private conservation groups. "Partners in Flight" is a model for international cooperation of this type.

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References

Askins, R. A., J. F. Lynch, and R. Greenberg. 1990. Population declines in migratory birds in eastern North America. Current Ornithology 7:1–57.

Droege, S. and J. R. Sauer. 1990. North American breeding bird survey annual summary, 1989. U.S. Fish and Wildl. Serv., Biol. Rept. 90(8). 22 pp.

Hagan, J. M. and D. W. Johnston, eds. 1992. Ecology and conservation of neotropical migrant land birds. Smithsonian Inst. Press, Washington, D.C.

Keast, A. and E. S. Morton, eds. 1980. Migrant birds in the neotropics: Ecology, behavior, distribution and conservation. Smithsonian Inst. Press, Washington, D.C.

Kellert, S. R. 1985. Birdwatching in American society. Leisure Sciences 7:343–360.

Mayr, E. 1985. Nearctic region, neotropical region. Pages 379–382 *in* B. Campbell and E. Lack, eds., A dictionary of birds. Buteo Books, Vermillion, SD.

National Fish and Wildlife Foundation. 1990. Proposal for a neotropical migratory bird conservation program. Washington, D.C.

Neotropical Migratory Bird Conservation Program. 1990. Atlanta, GA.

Rappole, J. H., E. S. Morton, T. E. Lovejoy, III, and J. L. Ruos. 1983. Nearctic avian migrants in the Neotropics. U.S. Dept. of Interior, U.S. Fish and Wildl. Serv. U.S. Govt. Print. Off., Washington, D.C.

Robbins, C. S., J. R. Sauer, R. S. Greenberg, and S. Droege. 1989. Population declines in North American birds that migrate to the neotropics. Proc. Natl. Acad. Sci. 86:7,658–7,662.

Terborgh, J. 1989. Where have all the birds gone? Princeton Univ. Press, Princeton, NJ.

United States Department of the Interior. 1988. The 1985 national survey of fishing, hunting, and wildlife-associated recreation. U.S. Fish and Wildl. Serv., Washington, D.C.

United States Fish and Wildlife Service. 1990. Report to Congress: Endangered and threatened species recovery program. U.S. Dept. of Interior, Washington, D.C. 406 pp.

Impacts on Private Forestry of Conservation Strategies for Threatened and Endangered Species

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Introduction

Natural resource management agencies, the forest products industry,environmental organizations, the courts and Congress seem grid-locked in debates about protecting threatened and endangered (T&E) species in managed forests. Conservation strategies developed in response to such debates exhibit increasing applications of emerging concepts in conservation biology and landscape ecology. For example, Thomas et al. (1990) and the U.S. Fish and Wildlife Service (Bart personal communication) employed such concepts in proposing a regional conservation strategy and recovery plan, respectively, for the northern spotted owl (*Strix occidentalis caurina*). Another example includes the management strategy for the red-cockaded woodpecker (*Picoides borealis*) that was proposed by the U.S. Forest Service (Meier 1991).

Implementing conservation strategies that apply at the landscape scale requires innovative approaches for encouraging participation. Private forests occupy about 72 percent of the forests in the United States (American Forest Council 1991), representing an enormous management opportunity relative to conservation strategies for T&E species. Therefore, success in recovering T&E wildlife may depend upon how well the associated conservation strategies integrate varying forest conditions and objectives among federal, state and private landowners.

Here, we explore effects on private forestry operations that stem from conservation strategies for federally listed T&E wildlife. Our goal was to identify potential technical, legislative and policy actions that might improve conservation planning as well as operating conditions for private forestry. We were especially interested in identifying cost-effective mechanisms for private forestland owners to participate voluntarily in landscape-scale strategies that apply emerging concepts in conservation biology and address concerns for biological diversity.

We gathered information by perusing literature on relationships between private landowners and the Endangered Species Act of 1973, and by surveying the perspectives of private industrial and non-industrial forestland owners across the United States. We sent questionnaires to 125 people engaged in private forestry activities, including 28 who have direct wildlife responsibilities; 49 who have administrative, policy or managerial responsibilities; and 48 who serve as state tree-farm chairpersons for non-industrial forestland owners. We requested information on: (1) direct and indirect impacts of federal listing and associated guidelines for protection; (2) appropriate roles and responsibilities of private owners for protecting and/or recovering T&E species; (3) extent of willingness to contribute to landscape-scale conservation strategies; and (4) suggestions for legislative policy or research activities that might improve stewardship.

Our intent was to identify a range of viewpoints that might suggest improvements. We did not randomly sample the timber industry's perspectives about the Endangered Species Act or conservation of T&E species. Also, we did not address conservation of T&E plants.

Direct and Indirect Impacts of Conservation Strategies

We received 42 responses to our questionnaire and unsolicited responses from five people who learned about our survey. Seven respondents indicated that they had no T&E species on their lands and currently were not influenced by conservation strategies. Three representatives of large landowners named over 20 federally-listed wildlife species that impacted their activities. The majority of the respondents protected one to five federally-listed species.

Direct Consequences

Nearly all respondents whose activities were influenced by conservation strategies for listed wildlife indicated that they experienced increased operating costs. For about 60 percent of the respondents, such costs were associated with seasonal or other constraints to harvests, as well as more costly methods of timber harvest, reforestation and road construction. Direct costs for about 50 percent of the respondents involved re-directed staff activities to include surveying for T&E species, marking leave areas, alerting contractors about leave areas, monitoring compliance and serving on local or regional conservation committees. In 1991 some large companies incurred substantial costs to survey their lands for northern spotted owls (more than $250,000 in two cases) or red-cockaded woodpeckers.

Several respondents mentioned increased administrative and legal costs of acquiring state-agency approval for timber-harvest permits. A few respondents indicated direct costs were absorbed in protecting leave areas from fire or upon finding a listed species after timber harvests were initiated, which required stopping operations and moving personnel and equipment.

Indirect Consequences

Most respondents incurred opportunity costs (foregoing profits) in setting aside leave areas, implementing longer rotations than desired or not realizing the growth potential for trees that were harvested. Also, profits were reduced as a result of timber harvests that were not completed at economically opportune times relative to market conditions. Some individuals noted reduced interest income caused by delays in selling timber. Also, timberland sales and trades have been affected, especially by wide-ranging species, such as northern spotted owls.

Indirect costs also might occur when private landowners seek federal permits, licenses or grants-in-aid, because they may be held liable for take of a listed species under Section 7 of the Endangered Species Act (Quarles et al. 1991). For example, establishing forests on non-industrial private lands may be aided by federal matching-funds grants through the Stewardship Incentive Program. Such private/federal agreements may trigger U.S. Fish and Wildlife Service consultations that result in stipulations or conditions associated with such actions. Some eligible owners have avoided requesting such matching funds, because they believed they might not realize a return on their investments if T&E species occur later on those or adjacent forests.

Additional indirect costs have included lost investments in existing developments, such as roads or bridges in forests that thereafter could not be used for economic return. Because few T&E species have been de-listed, several respondents expressed fear that their costs may rise in the future due to delays in de-listing species that might actually be recovered.

Opportunity costs also included preclusion of access to private lands across federal lands where roads or traffic may harm or harass listed species. Preclusion of access could result in double jeopardy: a private owner might be at risk to prosecution for taking a listed species if his/her inaction results in an avoidable natural event that destroys habitat (e.g., forest fire).

Several respondents from the Pacific Northwest pointed out that both direct and indirect costs have been associated with guidelines prepared by the U.S. Fish and Wildlife Service (1990) for avoiding incidental take of the northern spotted owl. The guidelines indicated that state officials would be held liable for taking prosecutions if their approval of private timber-harvest permits resulted in taking northern spotted owls. In effect, such guidelines enlisted the states as regulatory agents.

Perceived Role and Responsibility of Private Owners

Most respondents alluded to their role of managing for continued health of the forests under their care. Nearly all respondents indicated that protection of T&E wildlife constituted a proper role for private forestland owners. Such protection usually included providing habitat structures (e.g., nest trees, den sites, snags), setting aside limited leave areas, restricting operations seasonally where necessary or generally avoiding take of listed species. Most respondents did not agree with broad interpretations that take of listed species should be equated with habitat alteration.

Contributions to Landscape Conservation Plans

Under the Endangered Species Act, private parties have no duty to implement recovery plans, although they may be required to assist recovery under Section 10 of the Act (Quarles et al. 1991). Incidental-take permits that result from approval of habitat conservation plans (HCP) under Section 10 could prescribe tasks associated with recovery plans. A private party that continues activities that a recovery plan indicates or implies should not occur could be litigated, alleging that an unlawful taking has occurred (Quarles et al. 1991).

Most respondents supported landscape-scale conservation strategies, as long as such support is voluntary or implemented via modified take guidelines that provide flexibility for forestry operations. Past contributions most frequently included providing habitat conditions that were believed to facilitate travel by T&E species across private lands. Thus, about 25 percent of the respondents perceived that their primary role was to support conservation strategies by helping to maintain viable populations. A few respondents believed that private forestland owners should provide older-forest successional stages or otherwise contribute directly to recovery of species that find optimal habitat in such forests. Two respondents felt that private landowners should have the right to do nothing for conservation of T&E species, until they are repaid for their losses in protecting public resources.

Voluntary Contributions by Private Forest Owners

Numerous publications document the forest industry's record of voluntary contributions for wildlife in general, as well as for T&E species (e.g., Owen and Heissenbuttel 1990). Specific contributions have included limiting operations in buffer zones around bald eagle (*Halaieetus leucocephalus*) nests and providing alternate nest trees. Many private owners have controlled midstory vegetation and maintained optimum overstory conditions in red-cockaded woodpecker colony sites, and maintained adequate foraging habitat by lengthening rotations around such colonies. Some companies have removed up to 1,000 acres from their timber base to provide for red-cockaded woodpecker colonies, including providing connections between suitable habitats. Voluntary contributions also have included educating recreational users of private lands about the value of conserving T&E species.

Several companies have donated lands or sold lands at below-market prices for conservation purposes. Some companies have set aside parcels of old-growth forests, and others have voluntarily developed and implemented protection guidelines for state-listed species, as well as federally-listed T&E species. One company has taken a lead role in developing a conservation strategy at the landscape scale for biological diversity.

Additional contributions have included providing access to private forests in support of research that might improve compatibility between forestry and T&E species. On the other hand, several respondents expressed frustration in acquiring guidance from biologists who were skeptical that self-sustaining populations of listed species could be maintained in managed forests. Some private landowners have avoided wildlife/forestry research on their lands, because they feared the results might lead to increased regulatory constraints (e.g., broadening of critical habitat definitions and increased risk of prosecutions for take).

Technical, Regulatory or Legislative Suggestions

The topic of private rights and public good (in this case, conservation of T&E wildlife in private forests) is serious, confusing and confounded. The applicable laws and regulations seem to exacerbate the confusion. In 1990 alone, the federal government produced more than 60,000 pages of regulations on the use of private property. And there is evidence that the U.S. Fish and Wildlife Service and the courts increasingly consider any habitat modification as synonymous with destroying or harming T&E species (Quarles et al. 1991). Below, we discuss opportunities for improving conservation efforts by promoting stewardship on private forests.

Financial Incentives

Most respondents expressed a desire for financial relief from the burdens of taking private forest lands out of production on behalf of the public's interest in T&E species. Most frequently, such relief was suggested in the form of voluntary financial incentives for maintaining habitat for T&E species:

- promote the Stewardship Incentive Program concept (cost-sharing), allowing limited participation by industrial owners;
- provide tax credits for lands taken out of production and for approved actions for conservation of T&E species; and
- provide direct compensation by the government for lost opportunities, or easement of rights that are affected.

Environmental costs of doing business are not equally distributed, so some means of subsidizing the extra costs of protecting T&E species could help. In a region dominated by numerous small private owners, a comprehensive, voluntary incentive program could be difficult to administer. Perhaps coalitions that include state, federal and private interests might coordinate landscape-scale conservation strategies. Preliminary attempts at such coordination have been made, for example, in Maine, Michigan and Washington. The greatest opportunities may include tax-payer supported incentive programs (Hunter 1990), which might provide for creative involvement by various interest groups, while minimizing the need for additional regulations.

Habitat Conservation Plans

Non-federal parties can seek insulation from prosecution by seeking an incidental-take permit under Section 10 of the Endangered Species Act, which must include a HCP. The HCP would describe actions, funded by the applicant, that minimize or mitigate the impacts to listed species while conducting the described management activity. Very few private forestland owners have experience with HCPs, and some respondents were unaware of the HCP process. Those that were aware believed that the process is cumbersome (e.g., Quarles et al. 1991), unnecessarily expensive or involves unreasonable requirements. For example, one company wishing to convert a forest management plan to a HCP was presented with a list of requirements that included long-term commitments and oversight by environmentalists.

Small or non-industrial forest owners expect difficulty in getting HCPs approved for wide-ranging species on their lands, due to insufficient habitat for mitigation. And private landowners may be unable legally to join with neighboring landowners, due to anti-trust laws. Only a few HCPs have been developed, and perhaps 30 more are being developed at this time (Bean et al. 1991). The preparation and approval of HCPs has involved extended periods of time, which has caused most private forestland owners to seek other actions.

Respondents to our survey listed several topics that might improve the HCP process as it relates to private forestland owners:

- set limits to landowners costs;
- provide financial support for developing environmental assessments associated with HCPs;
- restrict the process to the agency and the landowners; and
- specify the time for agency completion and action.

In 1991, Congresswoman Jolene Unsoeld (D-WA) introduced the "Non-federal Landowners Protection and Resource Enhancement Act," to assist non-federal landowners with conservation of northern spotted owls. The act would require that, rather than individual HCPs, states would develop standards and guides for managing lands adjacent to owl nests and areas designated as critical habitats. The proposed Act relies heavily on "new forestry" practices and protection of riparian areas. Landowners that follow such guidelines would be deemed to comply with the Endangered

Species Act. Such legislative actions are encouraging, although respondents to our survey either rejected the principles of new forestry or indicated that such concepts should be tested and applied by federal agencies.

Some respondents suggested that the U.S. Fish and Wildlife Service and the public may believe that landowners seeking approval of their management activities through the HCP process actually intend to take a listed species. Such taking is frequently not the intention, especially where habitat is to be modified temporarily. Thus, some procedure for a "no-take" plan may be needed.

Incidental Take Guidelines

Incidental-take guidelines frequently apply across large regions, and often stem from administrative simplifications of complex ecological relationships. Thus, they may provide more protection than necessary in specific forest situations. Also, several respondents indicated frustration about agency withholding of information about locations of T&E species on their lands. Such secrecy precludes landowners from participating voluntarily in recovery efforts and results in unnecessary expenses in planning forestry operations in areas that should be protected. Moreover, most respondents suggested that the technical information used to support listing and subsequent conservation plans seemed "softer" than that required for de-listing, or for showing that listed species might be accommodated in managed forests. So, three important developments might include:

- secure anonymous, scientific peer-review for incidental-take guidelines;
- provide opportunities for landowners to demonstrate management capability in specific situations; and
- provide site-specific information so that landowners can protect T&E species through planning.

Discussion

In our opinion, the real issue is not whether T&E species in forests should or should not be protected. The debate is about how well we learn to integrate goals for a rich biotic future with increasing uses of forests for a variety of resources, including commodities and amenity values (Salwasser 1991). And the debate is about whether we seek such integration via empowering positive action versus compelling grudging compliance.

Simply protecting T&E species may constrain landscape-scale conservation strategies for wide-ranging species. We believe, for example, that many forests suffer from increasing probability of large wildfires, such that set-aside protection strategies are likely to fail in the long run. Thus, much is to be learned about managing for old-growth associated T&E wildlife, such as northern spotted owls (also recognized by Thomas et al. 1990) and red-cockaded woodpeckers. Lennartz and Lancia (1987) pointed out that not all old-growth associated wildlife require extensive, undisturbed stands. Some may require specific attributes of old-growth forests that might be identified and integrated within managed forests. Also, some old-growth associates may be more resilient than commonly believed.

Therefore, we believe that the optimal means of promoting private support for landscape-scale conservation strategies will include learning how to integrate managed and unmanaged forests across a mix of ownerships and land capabilities. We encourage cooperative processes that might answer such questions as, "What innovative silvicultural practices and landscape arrangement of stands can protect T&E species or contribute significantly to conservation strategies across a mix of managed and unmanaged forests?" Another question includes, "What positive roles can private landowners play in conservation strategies within the constraints of their objectives?" Providing reliable answers requires overcoming enormous technical and logistic challenges (Walters and Holling 1990), including the social barriers to linking scientists, wildlife biologists, foresters and private timberland owners in coordinated research and monitoring programs.

Private forestland owners and wildlife scientists may jointly hold keys that could help resolve the dilemma of judicious management versus preservation of forested landscapes for T&E species. Private landowners, perhaps in concert with federal owners, might be willing to provide necessary replicates for rigorously designed and monitored management experiments that include stand- and landscape treatments. Such landowners first must be convinced that wildlife biologists are committed to economic values from forests, just as wildlife biologists must be convinced of private commitment to wildlife conservation. The governing agencies, too, must recognize the possibility that innovative silvicultural practices may aid conservation of T&E species. Finally, the process requires commitment from the environmental community to allow such a process to work, knowing that some alternatives might fail in some locales.

This process, well known as adaptive management (Walters 1986), also could benefit from the extensive databases maintained by many private timberland owners, as well as their ability to effect experimental designs in the field. Simply described, adaptive management requires simultaneous implementation of more than one alternative, or operating hypothesis. Actively applying adaptive management principles might allow movement toward an experimental underpinning for conservation strategies, by examining ecological processes across gradients of managed and unmanaged forests.

Developing additional forest practice options that might protect and/or recover T&E species with minimal costs requires experimentation that applies at the landscape scale (Sinclair 1991). Such "intelligent tinkering" not only holds onto the ecological pieces, but also can expand options for future management, including concerns for biological diversity. Broad application of the adaptive process, in concert with coalitions and incentive programs, may promote greater support for wildlife conservation, because T&E wildlife might be considered as assets rather than liabilities for private landowners. Perhaps equally important, such processes might promote greater accountability among wildlife biologists for economic considerations.

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References

American Forest Council. 1991. The American forest: Facts and figures, 1991. Amer. For. Coun., Washington, D.C. 24 pp.

Bean, M. J., S. G. Fitzgerald, and M. A. O'Connell. 1991. Reconciling conflicts under the Endangered Species Act: The habitat conservation planning experience. World Wildlife Fund, Washington, D.C. 109 pp.

Hunter, M. L., Jr. 1990. Wildlife, forests, and forestry. Principles of managing forests for biological diversity. Prentice-Hall, Englewood Cliffs, NJ. 370 pp.

Lennartz, M. and R. Lancia. 1987. Old-growth wildlife in second-growth forests: Opportunities for creative silviculture. Pages 74–103 in Proc. National Silviculture Workshop: Silviculture for all resources. USDA For. Serv. Timber Manage., Washington, D.C.

Meier, M. C. 1991. Management direction for the red-cockaded woodpecker in the Southern Region. Fed. Reg. 56(209):55,656–55,657.

Owen, C. and J. Heissenbuttel. 1990. Wise use of the forest resource: The conservation record of the forest products industry. Am. For. Found., Washington, D.C. 40 pp.

Quarles, S. P., J. A. Macleod, T. R. Lundquist. 1991. The Endangered Species Act and its application to private lands. Am. For. Resource Alliance Tech. Bull. No. 91–06. Washington, D.C. 36 pp.

Sinclair, A. R. E. 1991. Science and the practice of wildlife management. J. Wildl. Manage. 55:767–773.

Salwasser, H. 1991. In search of an ecosystem approach to endangered species conservation. Pages 247–265 *in* K. A. Kohm, ed., Balancing on the brink of extinction. The Endangered Species Act and lessons for the future. Island Press, Washington, D.C. 318 pp.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. U.S. For. Serv., U.S. Bur. Land Manage., U.S. Fish and Wildl. Serv., and Nat. Park Serv., Portland, OR. 427 pp.

U.S. Fish and Wildlife Service. 1990. Procedures leading to Endangered Species Act compliance for the northern spotted owl. USDI Fish and Wildl. Serv., Reg. 1. 15 pp.

Walters, C. J. 1986. Adaptive management of renewable resources. MacMillan, New York, NY. 374 pp.

Walters, C. J. and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71:2,060–2,068.

Endangered Species Protection through Local Land-use Regulations

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Florida's Growth Management Act, adopted in 1985, required local governments to develop and implement comprehensive plans addressing growth management issues with associated land development regulations. As a result, local governments in Florida are answering the challenge of "restrict(ing) . . . activities known to adversely affect the survival of endangered and threatened wildlife" (Administrative Rule 9J–5.013.4.(c).5). Although the state requires listed species protection through local land-use regulation, it does not specify how this is to be accomplished.

During this period of regulation proliferation, many new ideas in protection of listed species through local land-use regulations have emerged to meld with the old. Basic templates include zoning regulations, subdivision regulations and building codes. New approaches use the basic templates but include variations that address the needs of listed species. The final result is an overall strategy to address listed species conservation.

Standard Local Regulations

Most local governments regulate land use through zoning, subdivision of land and building codes. Almost every incremental elimination of listed species habitat can be regulated at the local government level. The power of these regulations exceed those of regional, state and federal governments and their potential to protect listed species habitat is immense.

Zoning (land-use) regulations allow preservation areas to be identified early in the development permitting process. At this stage, basic transportation patterns are normally established, and areas of intense and low density development are identified. Listed species that are wide ranging or otherwise require large conservation areas are best addressed during zoning review. As an example, eagle nests, which may require approximately 40 acres (16 ha) of primary buffer, compel consideration during early planning.

Subdivision regulations control how property is to be divided. By dividing the habitat of a listed species among several property owners, habitat fragmentation may occur as the separate tracts of land are developed. Species that do not require large areas and have site location flexibility, such as little blue heron (*Egretta caerulea*) foraging habitat, can be addressed through subdivision platting procedures.

Building Codes normally pertain to structural integrity and setbacks. Communities such as the city of St. Augustine, Florida have used building codes to restrict building in listed species habitat. Permits are issued only for activities which "benefit the public as a whole" and have "no significant impact on natural systems individually or cumulatively" (Brookes 1991).

Bissell et al. (1987) believe that "programs of land use control, even if fairly radical in nature, will succeed if they are viewed as local programs, administered by people living close to the land . . . [and] probably will succeed if they remain under the jurisdiction of local government." Relatively small groups of involved citizens can significantly alter the specific language and the adoption of land-use regulations at the local level. Environmental citizen groups have enjoyed an effective voice in the development of listed species protection in some jurisdictions. The regulated public can provide valuable input that helps to develop forceful regulations. For example, clarity of the regulations protects the development community, but also protects listed species.

In some local jurisdictions, the presence of listed species habitat is not addressed and development permits are issued in areas that potentially harbor listed species. Consequently, the quality of local regulations that protect listed species habitat range from poor to outstanding and reflect the basic values of the community. The individuality of local governments also leads to many approaches and philosophies in addressing listed species habitat protection.

Approaches

At least three approaches exist to address listed species concerns through local regulations. These approaches require a foundation provided by the standard mechanisms of zoning, subdivision and building codes. They include single species regulations, likely habitat regulations, and known habitat regulations. Each approach has characteristic advantages and disadvantages.

Single Species Regulations

Single species regulations have the advantage of tailoring requirements to the species in question. There are two aspects to protection of species in this manner: unusual management requirements that cannot be addressed through general species protection measures and the level of affection for the species by the general public. Glamour species, such as West Indian manatee (*Tricherus manatus litirostris*) and bald eagle (*Haliaeetus leucocephalus*), are candidates for single species ordinances. It is difficult to establish regulations to protect species not embraced by the general public, such as Garber's spurge (*Euphorbia garberi*) or sand skink (*Neoseps reynoldsi*). Since only one species is considered, tremendous flexibility is inherent. One ordinance can address procedures to be followed in zoning, subdivision regulations and building codes. The disadvantage is only one species may be addressed, unless management requirements are similar for more than one species in a given region.

Likely Listed Species Habitat Regulations

Likely habitat protection regulations are those that protect vegetative communities typically associated with the presence of listed species. For example, Charlotte County, Florida is developing a Conservation Overlay which is based on vegetative communities that are known to harbor listed species. Land development regulations will be attached to the overlay (Elliot Kampert personal communication: 1991).

Likely listed species habitat regulations have the advantage of not relying on the results of surveys produced by the development applicant or by an over-committed permitting staff. Another advantage is the lack of reliance on species presence. This avoids the possible temptation of the property owner to illegally harass listed species.

There are two disadvantages with this approach. Special management requirements are not normally included for listed species, and cases exist where listed species exist in non-standard habitats, such as disturbed areas.

Known Listed Species Habitat Regulations

Regulating known listed species habitat requires knowing the species occur on the site. Unlike determining the land-use category of a parcel, identifying if there are listed species on a site requires site inspections. Because of typical time constraints of staff permit reviewers, these surveys are normally performed by representatives of the property owner. Regulating known habitat has the advantage of focusing conservation and management efforts where they are most needed.

Useful Tools

Many of the advantages and disadvantages of the various approaches relate to the tools required by each. As in almost any constructive endeavor, choosing the proper tool to accomplish the task will greatly affect the outcome.

Survey Methods

As survey methods vary, so will the results of those surveys. Survey characteristics, such as time of day, season of year, site coverage, amount of time per acre, driving animals away from survey locations, qualifications of surveyor, number of surveyors, mode of transportation (on foot, by car, by boat), all affect the results. When survey methods are unspecified, a windshield survey driving by the site is as legal as a thorough investigation performed at many different times of the day and seasons of the year. Without specified survey requirements, it is often in the property owner's interest to conduct the least intensive survey possible.

With specific survey requirements, data from the surveys have more scientific merit and can be used at the state and federal level for listed species inventories. As more information is gathered regarding listed species presence, better models of potential location can be developed and included to refine land-use regulations.

Habitat Mapping

Habitat mapping can be used to predict listed species habitat locations without the need for listed species survey. Many jurisdictions require vegetative community maps to be submitted by applicants for development permits. Moreover, many jurisdictions have produced general vegetative community maps for planning purposes. Through new technologies, such as LandSat, and old technologies, such as aerial photo interpretation, such maps are becoming more available. As simple as habitat mapping may appear, several variations can affect the accuracy and usefulness of the map. Issues include classification system utilized and scale of mapping.

Habitat community classification systems vary in adaptability to listed species protection regulations. The Florida Land Use, Vegetative and Cover Classification System (FLUCCS) is often used in Florida. When these classification systems are applied to actual site conditions, slightly unusual vegetation arrangement, broad ecotones and entire plant communities are sometimes difficult to classify.

Scale of the mapping is an important consideration. The expense of mapping increases with the amount of detail. In addition, mapping on a county-wide scale cannot usually be accurately applied to a development site.

Regulatory Incentives

Incentives are benefits that property owners may be able to utilize as a result of listed species protection. Cash payment for the preserve is an example of an incentive. Regulatory incentives are provided through the permitting process. Waiving of certain fees, additional site density allowances, lower open space requirements and reduction of other permit requirements are examples of regulatory incentives. With more diverse and strict land-use controls, the potential for regulatory incentives increases. Ironically, something has to be required from the property owner before it can be given back as a regulatory incentive.

Regulatory incentives can additionally protect listed species. When property owners perceive a loss of development potential because of listed species considerations, persecution of listed species and inaccurate surveys are more likely. With regulatory incentives, benefits derived from listed species habitat protection can off-set the loss of developable area.

Off-site Mitigation

On-site preservation of critical habitat encourages habitat to be fragmented by development, substantially reducing its function for listed species. When only small habitat areas are reserved, the adjacent development impacts the habitat and reduces species viability. ''Recent dissatisfaction with the biological results of this approach coupled with the prospect of reducing mitigation costs borne by the development community has led to the development of . . . Mitigation Park program(s)'' (Allen 1991). Allen (1991) identifies five common problems with on-site preservation, including economic costs of preserving large areas, management difficulty in small areas, human disturbance, large range species intolerance and lack of movement corridors. The use of mitigation parks solves several problems associated with mitigating the loss of listed species, particularly because the tracts would be larger and more likely to function as a system. Also, the most viable and diverse habitats could be selected for preservation.

Section 10 of the federal Endangered Species Act includes a provision for off-site mitigation through Habitat Conservation Plans. Local governments may function as the ''lead agency'' to implement Habitat Conservation Plans (Marsh and Lallas 1991). Off-site mitigation for impacts to listed species habitat may be accomplished through contribution of funds to purchase and manage large tracts of land, also known as mitigation parks.

Land Acquisition

Public acquisition of listed species habitat can be used strategically with development regulations. Where regionally-significant listed species populations are identified utilizing most or all of a parcel, acquisition of that parcel is warranted. By using acquisition as a supplement to land-use regulation, larger preserves can be established. In this way, the critical habitat of far ranging species and species which are less tolerant of land development can be conserved.

Compliance and Enforcement

Compliance and enforcement of any land-use regulation is essential to ensuring that the requirements of the regulation are met. Compliance investigations ensure that protected listed species habitats are not illegally impacted, through such activities as land clearing. When illegal activities are identified, enforcement action must be pursued to ensure that the violation is abated or fixed. Mechanisms, such as restoration standards, citation powers, fines, criminal penalties and responsible parties, should be outlined in land-use regulations for most effective enforcement. News articles reporting on successful criminal prosecutions lead to more respect of listed species habitat.

Synergy

Lee County, Florida has adopted all of the approaches and tools discussed. Over the last ten years, Lee County has adopted over a dozen regulations that address protection of listed species. Due to the evolution of such regulations, new regulations may render some relatively recent regulations antiquated, but still in effect. This leads to a regulatory structure that seems more complicated than it is.

Single Species Ordinances

Lee County has adopted two single species land-use ordinances. They include the Bald Eagle Nesting Habitat Protection Ordinance and the Sea Turtle Protection Ordinance.

The Bald Eagle Ordinance was adopted using zoning regulations, subdivision regulation and building codes as the base mechanisms. The ordinance established the Eagle Technical Advisory Committee (ETAC) to make recommendations regarding the biological requirements for each eagle nest as it is threatened with development. The decision-making body, the Board of County Commissioners, uses these recommendations and the proposals from the property owner to approve the type and size of buffers around the nest tree and a management plan for the entire site. Inadequate buffers occasionally ensue from compromise and can result in abandonment of the nest. Too often, the necessary minimal buffer would include the entire parcel. Lee County land-use law guarantees reasonable use of the property and allows infringement within the minimal buffer. The ordinance is at its best when used in concert with free simple acquisition. For example, the nest site and the majority of the buffer could be purchased, and additional buffer preserved through the development regulations.

Like many coastal counties in Florida, Lee County has adopted a Sea Turtle Protection Ordinance which limits the amount of artificial light that may be cast on the beach. Artificial illumination disorients sea turtle hatchlings which crawl to the lighter horizon. Lee County included lighting standards for sea turtles through its building codes. In addition, opaque shields are required for existing lights that burn into the night. Due in large part to a consistent enforcement effort, the number of disoriented hatchlings has been reduced since the adoption of the ordinance. Since the implementation of the ordinance, thousands of Lee County sea turtle hatchlings successfully entered the Gulf of Mexico.

Habitat Protection Ordinances

Through zoning and subdivision regulations, Lee County has addressed general habitat protection which also correlates with protection of likely listed species habitat. Both zoning and subdivision regulations require applicants to supply vegetative community maps.

The Zoning Ordinance includes provisions for "rare and unique uplands." These upland systems are all utilized by listed species. Through the zoning process for planned developments, consideration to setting these upland systems aside is required.

The Development Standards Ordinance (subdivision regulations) requires preservation of "indigenous vegetation" areas of up to 50 percent of required open space areas. Although some of these areas do not contain known listed species at the time of permitting, the eventual use by a listed species is possible, and by potentially rare species, likely. Such areas may contribute to averting the future listing of species.

It has been the experience of Lee County staff that setting aside habitat through these regulations is more difficult than preserving known listed species habitat. Once listed species are identified on site, harassment prohibitions of state and federal law become active. Lee County has succeeded in the civil and criminal prosecution of destruction of gopher tortoise habitat. However, prosecuting individuals that illegally clear "brush" is more difficult in the current legal climate.

Protection of Known Listed Species Habitat

The Protected Species Ordinance addresses most of Lee County's listed animal and plant species. It was adopted in 1989 and supplements other local regulations protecting listed species. Although the 1985 Zoning Ordinance amendments required identification and protection of listed species, this requirement was difficult to enforce. Without survey standards, few listed species were identified for protection. The lack of management standards resulted in little, if any, site management for identified listed species. Survey standards have been critical to identify listed species presence. The Protected Species Ordinance requires a variation on the Method of Diminishing Quarters with 80 percent site coverage. The County Administrator (or designee) may allow alternative methods if they are documented and meet the quality of the prescribed method. To date, three other methods have been approved. Success rates of these methods do not significantly differ from the approved method.

Two years of listed species surveys performed under the Zoning Ordinance language (n = 21) were compared to two years of Protected Species Ordinance surveys (n = 53) (Table 1). Only 24 percent of Zoning surveys revealed listed species, while over 79 percent of Protected Species surveys were successful in identifying at least

Table 1. Descriptive comparisons of listed species survey variables.

Variables	Zoning Ordinance	Protected Species Ordinance
Surveys that identify listed species	24 percent	79 percent
Mean acreage (hectares)	171.71 (69.49)	92.26 (37.33)
Mean vegetative community diversity	4.19	4.85
Mean number of listed species	0.57	2.06

one listed species. Other variables were considered, such as average project acreage and average number of vegetative communities. Because of the larger areas surveyed under the Zoning Ordinance, the greater chance of listed species presence could be predicted (Adams and Dove 1989). Even so, 0.57 listed species per site were found on average under the Zoning Ordinance and 2.06 listed species per site by the Protected Species Ordinance procedures. Listed plant species have been identified through the Protected Species Ordinance, but not the Zoning Ordinance.

A statistically significant difference exists for the number of species identified for listed species surveys conducted under the Zoning Ordinance and the Protected Species Ordinance (Table 2). Such differences are not present for vegetative community diversity. Although the difference is statistically significant for acreage, it is in the favor of the zoning ordinance which average much higher total acreage. Essentially, listed species were not as effectively identified under the Zoning Ordinance as under the Protected Species Ordinance. When species are not documented on a site, development of the habitat becomes more likely.

Further evaluations of the Protected Species Ordinance revealed no statistically significant difference of success between the consultants (chi-square of 22.10 and significance of 0.181) or the approved methods for surveys (chi-square of 3.78 and significance of 0.287).

Management plans developed through the Protected Species Ordinance have resulted in long-term protection of critical habitat for a diversity of listed species. The management plans also include examples of simple accommodation with little hope of continued existence of the species on site. The issues regarding the success with any given management plan vary.

The least effective management plan concerns a scrub jay (*Aphelocoma coerulescens coerulescens*) nesting area. The survey was submitted identifying gopher tortoises on the site, but not the scrub jay nest. The scrub jay was later discovered by the county wildlife biologist. The nest was in a wax myrtle (*Myrica cerifera*) bush, an unusual nesting location for scrub jays. Foraging areas were distributed throughout the site, including the fenceline by the nest for insects and an oak scrub area for acorns on the other side of the site. Wetlands on the site added to limited site planning flexibility. The property owner would not preserve any habitat beyond the minimum required by the regulations. The management plan included preservation of a small oak scrub area, a small buffer around the nest, an area associated with the fenceline, commitment to planting scrub oak on the residential lots and slow areas on the road that crossed the birds' flight path. Although every provision available by the ordinance was included in the management plan, the long-term prognosis for the nesting area is not good.

Table 2. Kruskal Wallis chi-square relationships of surveys performed under the Zoning Ordinance and Protected Species Ordinance.

Variables	Chi-square	Level of significance
Number of species	18.05	0.001
Species per acre	21.48	0.001
Acreage	7.74	0.005
Vegetative community diversity	0.94	0.333

Several outstanding management plans have been developed. One development was retitled ''The Preserve'' after numerous listed species were identified through survey. The Preserve provided for preservation of nearly all the gopher tortoise burrows, even though building densities were high. The listed species were used as a marketing amenity. Educational brochures and interpretive signage throughout the development were an important element of both the management plan and marketing approach. Another development, ''Andalusia Woods,'' preserves and manages mangrove fox squirrel (*Sciurus niger avecennia*) nests and wood stork (*Mycteria americana*) foraging areas. The continued use of the preserved areas by these species is likely, as these species are tolerant of proximity to development, for nesting and forage, in the case of mangrove fox squirrel, and forage, in the case of wood stork. Other management plans include combining on-site preserves and contributions to an off-site mitigation park.

The best management plans are developed by property owners and their consultants who are sympathetic to listed species and believe conservation of listed species in the context of private development has marketing advantages. Naturally, the larger sites with more tolerant listed species provide the best advantages for listed species conservation efforts.

An enforcement and compliance program ensures that preserve areas are managed correctly for the continued survival of listed populations. Data derived from compliance visits to preserve areas will demonstrate the ability to conserve listed species in the context of private development in Lee County.

Lee County's current listed species efforts include a Wildlife Corridor Plan to address habitat requirements of large listed mammals, such as the Florida panther and black bear. Conservation of far-ranging species may be addressed through a combination of acquisition, regulatory incentives and open space regulations.

Conservation or Accommodation?

Local government is the level at which the elimination of most listed species habitat is permitted. Much of the cumulative removal of critical habitat for listed species occurs in the United States through local government permitting processes, and without documentation of listed species presence. Local governments have the opportunity to have a more significant impact on protection of listed species by improvement of land use regulations. Developing regulations that simply accommodate listed species on development sites is not enough to protect populations in the long run.

No one regulation is the solution for all regions and all species. Because of different habitat area and management requirements of different listed species, problems emerge for any one regulation. Successful programs for listed species conservation require a diversity of regulatory, administrative and education techniques which are regionally specific. These techniques may be more successful if combined with other tools, such as regulatory incentives, off-site mitigation and land acquisition. The commitment and expertise of the review staff and consultants, combined with the cooperation of the property owner, are critical to the success of the program. Listed species conservation is ultimately an enterprise which demands a selection of tools in the right combination.

References

Adams, L. and L. Dove. 1989. Wildlife reserves and corridors in the urban environment. Nat. Instit. for Urban Wildl., Columbia, MD. 91 pp.

Allen, M. 1991. Mitigation parks. Pages 10.1–10.6 *in* Wildlife, habitat and land use law: Florida's developing zoo. February 8–9, 1991, The Florida Bar.

Bissell, S. J., K. Demarest, and D. L. Schrupp. 1987. The use of zoning ordinances in the protection and development of wildlife habitat. Pages 37–42 *in* L. W. Adams and D. L. Leedy, eds., Integrating man and nature in the metropolitan environment. Proc. Nat. Symp. Urban Wildl. Nat. Instit. for Urban Wildl., Columbia, MD.

Brookes, R. G. 1991. Habitat protection in comprehensive plans and land development regulations. Pages 12.1–12.50 *in* Wildlife, habitat and land use law: Florida's developing zoo. February 8–9, 1991, The Florida Bar.

Marsh, L. and P. Lallas. 1991. Commentary on recent developments in land use and environmental law. pages 5.1–5.33 *in* Wildlife, habitat and land use law: Florida's developing zoo. February 8–9, 1991, The Florida Bar.

Protection of Threatened and Endangered Species and Their Habitats by State Regulations: The Massachusetts Initiative

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Introduction

Threatened and endangered species have become a major issue attracting worldwide attention. The federal endangered species program of the United States and its enabling legislation, the Endangered Species Act (ESA), have generally been regarded as the most comprehensive species protection programs in the world. Since passage of the ESA in 1973, over 600 species have been added to the federal list of threatened and endangered species, and some 3,650 species have been identified as candidates for listing in the U.S. alone. Over 350 recovery plans for listed species have been approved (U.S. Department of Interior 1991), and over $700 million have been spent to support the program and land acquisitions since 1974 (Bean 1991). Yet, despite the program's best intentions, listed and non-listed U.S. species continue to go extinct and the list of threatened and endangered species continues to grow. From these trends, Scott et al. (1991:283) concluded that our endangered species programs "have become essentially efforts to document the loss of species through the listing process." Clearly, current regulatory and nonregulatory programs are inadequate for protecting threatened and endangered species and the broader issue of biological diversity. Thus, the objectives of this paper are to (1) examine the limitations of the federal endangered species program for threatened and endangered (T&E) species and candidate species, (2) review the status of state T&E programs and their potential to supplement the federal program, and (3) examine how Massachusetts, through its recently enacted (1992) Endangered Species Act, has expanded its protection for T&E species and their habitats.

Limitations of the Federal Endangered Species Program

The Endangered Species Act (ESA) is the primary federal law that provides protection for T&E species in the United States. The purpose of the act is to conserve T&E species and their physical environments. The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) are the two primary federal agencies responsible for administering the ESA; however, other federal and state agencies and private conservation organizations contribute resources to research and recovery plan preparation and implementation, and land acquisition. Further, many of the species protected under the ESA also are protected under the Marine Mammal Protection Act and migratory bird treaties.

In general, the FWS is responsible for T&E freshwater and land species, and NMFS is responsible for marine species, except for sea turtles for which both agencies share responsibility. These agencies are responsible for determining which species should be listed; enforcing the act's prohibitions against violations; reviewing, through mandatory consultations, the actions of other federal agencies that may affect listed species; and working to recover species until they no longer need protection of the ESA.

Despite increasing public support for the conservation of T&E species and increased efforts to list species, develop recovery plans and implement recovery efforts, a recent report from the General Accounting Office (GAO) (1988) to Congress concluded that the federal endangered species program has had relatively few measurable successes or failures since the act's passage. While there have been some successes in the recovery of several species, such as the whooping crane (*Grus americana*), bald eagle (*Haliaeetus leucocephalus*), peregrine falcon (*Falco peregrinus*) and others, Noss (1991:227) concluded that "most officially listed species are closer to extinction now than when they were originally listed."

A variety of factors, both internal and external to the program, have been identified as contributing to the limitations of the federal program to protect T&E species. Two recent government reports, the previously cited GAO report (U.S. General Accounting Office 1988) and one by the Office of Inspector General (OIG) (U.S. Department of Interior 1990) underscore some of the program's major limitations.

Limitations to Listing Species

The first step toward protecting and recovering species under the ESA is listing. The ESA requires that the Secretaries of the Interior and Commerce determine whether any animal or plant species are endangered or threatened, and that a published list of such species be maintained. Despite the listing of over 600 U.S. species as threatened and endangered and increased efforts to list species in recent years, there are still over 3,600 U.S. species that are either known or probably threatened or endangered that have not been listed (U.S. Department of Interior 1990). As of February 1991, these candidate species included 550 species for which there is substantial information to warrant immediate protection under the ESA (Category 1) and 3,100 species that are suspected to be threatened or endangered but insufficient information exists to make a determination (Category 2) (U.S. Department of Interior 1991).

Currently, the goal of the FWS is to list 50 species per year (U.S. Department of Interior 1990). Even if the FWS meets this goal, it will take 11 years to list the current Category 1 species, and an additional 26–36 years to list those Category 2 species (1,300–1,800 species) that FWS staff estimate will eventually qualify for full protection under the ESA (U.S. Department of Interior 1990).

Another limitation to the listing process is cost. According to FWS estimates, it spends approximately $60,000 to officially list a single species (U.S. Department of Interior 1990). Thus, it would cost $33 million to list the 550 current Category 1 species and an additional $78 to $108 million to list the remaining 1,300–1,800 candidate Category 2 species estimated to eventually merit listing. These estimates contrast sharply with the total listing budget for fiscal year 1991 of approximately $4.3 million (U.S. Department of Interior 1991).

Considering, the length of time (37–47 years) and cost ($111–$141 million) estimated to list just those species that are currently believed to qualify for listing, protection of these species is severely limited. The likelihood of protection is even more remote for the other 1,300–1,800 candidate Category 2 species currently listed for which there is insufficient information to make a determination. This lack of protection may well result in extinction for some. At least 33 species formerly classified as Category 1 or Category 2 candidate species, such as the Texas Henslow's sparrow (*Ammodramus henslowii houstoensis*) and wild spiderflowers (*Cleome spinosa*), are now considered extinct. In the meantime, many other species are declining and will undoubtedly be proposed for listing. Yet, the shortage of funds and personnel of the federal endangered species program, and the complicated listing and review process mandated by the ESA, will probably presage the loss of many species before they can be listed and potentially benefit from full protection under the ESA.

Limits to Recovery Plan Development and Implementation

After listing, development and implementation of recovery plans for all T&E species which can benefit from such a plan is the next essential step for the survival and recovery of listed species. Recovery plans are required to identify the problems threatening the species or groups of species and the actions needed to resolve these threats. Further, these actions are to be divided into specific, ranked assignments for each of the participating groups involved in the plan's implementation.

While FWS and NMFS have made substantial progress in developing recovery plans during the past decade, about 40 percent of listed species still do not have approved plans. Further, according to the 1988 GAO report, it has taken the FWS an average of 6.4 years before recovery plans are completed with periods ranging from 9 months to 13 years. The average time that U.S. species have been listed without recovery plans is even longer for species under the jurisdiction of NMFS, averaging 8.2 years (U.S. General Accounting Office 1988).

In recent years, the FWS has substantially reduced the time between listing and plan approval to an average of 3.4 years, and the agency believes that this time lag is acceptable and does not adversely affect species' recovery. This is because recovery actions are often initiated before plans are completed (U.S. General Accounting Office 1988). Yet, even with this increased efficiency, the ability of the FWS to reduce the backlog of uncompleted plans is hampered by the growing number of listed species while program funding has remained relatively stationary. Further, with increasing numbers of listed species, the number of mandatory consultations with federal agencies increases, thereby reducing the staff and resources for recovery plan preparation.

Limitations of Program Guidelines and Priority Systems

Considering the increasing workload of FWS and NMFS, in combination with relatively stationary endangered species program funding, it is essential that available funds be optimally used. Thus, Congress mandated development of priority systems to guide the expenditures of limited funds for developing and implementing recovery plans. Both agencies now have established guidelines and priority systems.

In 1988, prior to establishment of guidelines by NMFS, the GAO report concluded that the FWS was not adhering to their established guidelines. More specifically, the priority system was not being followed in deciding how to allocate funds among different species and determining which tasks to implement first. The heavy concentration of funds for relatively few species, of which only some are considered highly threatened and others classified as facing low threats, is one indicator that the priority system is not being utilized fully (U.S. Department of Interior 1990). Additionally, 50 percent of available recovery funds was spent on only 10 species, less than 2 percent of FWS-listed species. Further, the GAO review indicated that lower priority tasks of recovery plans often are initiated before all higher priority tasks (U.S. General Accounting Office 1988).

A variety of reasons have been identified contributing to the FWS not closely following their guidelines and priority systems. These include (1) congressional earmarking of funds to certain lower priority species and tasks, (2) FWS decisions to recover lower priority species that have high visibility or are on the threshold of recovery, (3) inflated task priority numbers in recovery plans, and (4) inadequate review and updating of recovery plans. Further, in prior years, the absence of a system for accurately tracking and reporting expenditures also contributed to the inability of the FWS to closely follow their guidelines and priority system (U.S. General Accounting Office 1988, U.S. Department of Interior 1990). In 1990, the FWS revised its guidelines for planning and coordinating recovery of T&E species, in part, in response to the 1988 GAO report.

Limitations for Protecting Habitats of Threatened and Endangered Species

Although the stated purpose of the ESA was to conserve the ecosystems upon which T&E species depend, the federal endangered species program primarily protects species, not ecosystems. Hunter (1991:268) characterizes the program as a "fine-filter approach" to conservation that is unable to effectively protect natural communities and multiple species in manageable groups. Although the ESA provides for the designation of critical habitat for listed species, such designation only applies to *federal* decisions or activities within the specified area. Although the ESA requires that critical habitats be designated concurrently or soon after listing of new species, critical habitat has been designated for less than 20 percent of species listed since 1979 (Bean et al. 1991). Further, nothing galvanizes opposition to endangered species as effectively as a proposed critical habitat designation. Bean et al. (1991) suggested that this is principally the reason that the FWS has largely abandoned new critical habitat designations.

The Land and Water Conservation Fund provides for the purchase of lands for T&E species. However, FWS guidelines require that all proposals to acquire land are appropriate only when other means of achieving recovery objectives are not available or effective (U.S. Department of the Interior 1989). Further, when property must be acquired, the minimum interest necessary to meet species recovery objectives is to be acquired or retained. Additionally, the Office of Management and Budget has imposed restrictions on the use of the fund for the purchase of lands identified only as essential habitat. In contrast to critical habitat, which is defined by regulation, essential habitat is to be identified in the recovery plan. These restrictions, in combination with increasing land costs and limited monies in the Land and Water Conservation Fund, place many constraints on the future acquisition of lands for T&E species.

Status of State Threatened and Endangered Species Programs

In the past two decades, most states have increased their role significantly in protection of T&E species and their habitats. We surveyed natural resources agencies in all 50 states and Puerto Rico during December 1991, requesting information on each state's current nongame/endangered species programs. We conducted the survey by mail with follow-up phone calls for non-respondents. The survey consisted of 14 questions (Table 1) and was designed to help evaluate the potential of various states to play a larger role in conserving T&E species. A 100 percent response rate was achieved.

Forty-six states indicated that their list of T&E species was part of statute or regulation; however, nine states did not list species other than those listed on the federal T&E species list. Mammals, birds, herptiles and fish were included on lists of rare species in 40 to 43 states. In contrast, rare plants and invertebrates were the taxa most frequently not protected, being listed in only 31 states each. Thirty-seven states had special penalties for taking/harming state-listed species that are different from penalties for illegally taking non-listed species.

We also attempted to identify which states protected rare species habitats. Forty-three states had land acquisition or conservation easement programs. However, in only 28 states did one of the state's natural resources agencies have the legal power of eminent domain for acquiring wildlife habitats. Thirty-four states had regulatory authority over activities that adversely impact rare species habitats on public lands

Table 1. Survey questions mailed to state natural resources agencies requesting information on their current nongame/endangered species programs. (A yes or no response was requested for each question.)

1. Does your state have an endangered/threatened/rare species list that is part of a statute or regulation?
2. Does your list include species other than those listed on the federal endangered and threatened species list?
3. Does your state list rare mammals?
4. Does your state list rare birds?
5. Does your state list rare herptiles?
6. Does your state list rare fish?
7. Does your state list rare invertebrates?
8. Does your state list rare plants?
9. Are there penalties for taking/harming state-listed species that are different from penalties for illegally taking non-listed species?
10. Does your state have land acquisition or conservation easement programs for the habitats of rare species?
11. Does your state have regulatory authority over activities that adversely impact rare species *habitats* on *public* lands?
12. Does your state have regulatory authority over activities that adversely impact rare species *habitats* on *private* lands?
13. Does one of your state's natural resources agencies have the legal power of eminent domain for acquiring wildlife habitats?
14. Do you consider your state to have a comprehensive rare species protection program?

However, only 22 states had such regulatory authority over rare species habitats on private lands.

Slightly less than half of the states (n = 24) considered their state to have a comprehensive rare species protection program. We further evaluated the comprehensiveness of state programs by examining their responses to five of the 14 questions (1, 9, 10, and 11 and 12 combined) (Table 1). In our evaluation, we considered a state to have a comprehensive T&E species program if four criteria were present, including: (1) their list was part of statute or regulation, (2) there were special penalties for taking/harming listed species, (3) the state had land acquisition or conservation easement programs for listed species, and (4) there was regulatory authority over activities that adversely affected rare species habitats on both private and public lands. Of the 24 states that considered their T&E species programs to be comprehensive, all four of the above criteria were present in only 12 states (Figure 1). Whereas, the other 12 states had at least one or more of the four criteria absent.

Our survey results indicate that although state involvement in T&E species protection is variable, many states have strong regulatory authority to protect T&E species and their habitats. Most significantly, states collectively provide protection for a wider array of species than the federal program, thereby potentially providing protection for candidate or regionally declining species. Additionally, a number of states extend their authority over activities that may impact rare species habitats on private lands. This is especially important in the northeastern United States where there are relatively few federal lands that are subject to Section 7 review under the federal program. Thus, many state T&E species programs can and do play a critically important role in protecting rare species and their habitats.

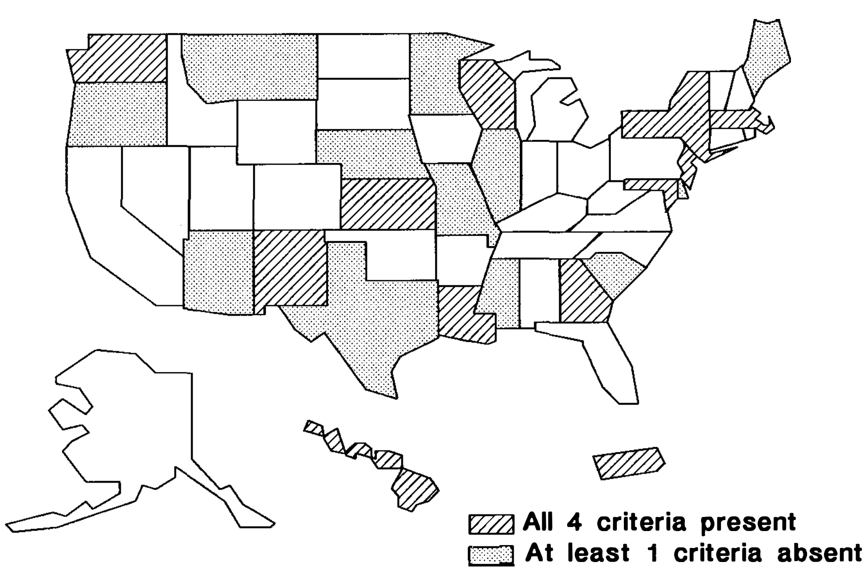

Figure 1. States considered to have comprehensive rare species protection programs.

The Massachusetts Initiative

The Massachusetts Endangered Species Act (MGL 131A), passed in 1990, and its supporting regulations (321 CMR 10.00), promulgated in January 1992, provide Massachusetts with one of the strongest and most comprehensive state laws by which to protect its rare native species. Although the Massachusetts Wetlands Protection Act provides strong protection for the habitats of all rare wetland vertebrate and invertebrate species listed by the state (Griffin 1989), the new state Endangered Species Act now provides the primary regulatory and enforcement authority for protecting all rare species statewide. The Massachusetts Division of Fisheries and Wildlife (MDFW) is the primary regulatory agency for the act. This segment of the paper briefly summarizes the regulations, including species listing and protection, habitat protection, and environmental review.

Species Listing and Protection

The listing process and the protection it provides recognizes vertebrates, invertebrates and plants equally, and categorizes them into three levels of rarity and vulnerability, including endangered, threatened and species of special concern. The listing process begins either by investigation of a species' status by MDFW personnel or by proposals from the public. These public initiated proposals must be reviewed within 21 days and the Director of the MDFW must determine whether sufficient evidence has been submitted to warrant full review. A public hearing is required as part of the review process, and the Director must make available a summary of the biological data upon which the listing proposal is based. The Director is required to review the list of endangered, threatened and species of special concern at least once every five years.

Unless specifically authorized, it is unlawful to take, possess, transport, export, process, sell or buy an individual of any listed species, regardless of its origin. No permits are required for the propagation of listed plants, but no stock may be taken from the wild in Massachusetts. Penalties for the unlawful taking or possession of a listed species begin at $500 for the first offense and increase to not less than $5,000 for subsequent offenses, and with each individual taken constituting a seperate offense and with the added option of imprisonment for periods ranging up to 180 days.

Habitat Protection

The primary provision for protecting habitat is through the designation of "significant habitat." Significant habitats are specific sites that contain physical or biological features important to the conservation of one or more endangered or threatened species populations, and that may require special management consideration or protection. This form of habitat protection is not extended to species of special concern.

The designation of a significant habitat is initiated by the Director of the MDFW based on an annual review of records maintained by the Division's Natural Heritage and Endangered Species program. Designation is done through a public hearing held within 25 miles (40 km) of the site to be designated and requires a public notice at least 21 days prior to the hearing. It also requires that a special notice of the hearing be sent to all affected land owners and to a variety of town officials and agencies at least 30 days prior to the hearing. Prior to designation, the Director must review the information presented at the public hearing, any written comments submitted, and take into consideration the size of the threatened or endangered species population.

Additionally, the Director must consider the current and forseeable uses of the land, the current and forseeable threats to the population or its habitat, the potential benefits of designation to the population, and the status and welfare of the species generally. Based on the best scientific evidence available, the Director must make a final decision within 60 days of the public hearing.

Once a final decision is made to designate a site, this designation becomes part of state regulation (321 CMR 10.70). Within the regulation that designates a specific site as a significant habitat, certain activities that may or may not alter the significant habitat may be specified. Elsewhere in the main body of the regulations (321 CMR 10.33) is a list of activities that can always be considered to be alterations, other activities that are never considered to be alterations and exempted activities. In addition to the promulgation of a specific regulation which identifies the formal designation of a significant habitat, a ''designation document'' is published in the Massachusetts Register which includes a general description of the area, a summary of reasons for designating the site and a map showing the boundaries of the site. A record of the designation identifying its location and its owners is then filed with the appropriate registry of deeds. The designation of a significant habitat may be appealed through a hearing process but may only be reversed if it is found that there is no credible scientific information to support the designation. Sites also may be undesignated through the previous public hearing process if at some later time they no longer warrant designation.

Once designated, a significant habitat may not be altered without a permit, and a permit may only be issued if the action will not reduce the viability of the habitat to support the resident population of the listed species. Penalties range from $1,000–$10,000 for the first offense and $10,000–$20,000 for subsequent offenses, with the additional option of imprisonment ranging up to 180 days.

Environmental Review

Another provision, that resembles Section 7 of the federal ESA, requires that all state agencies utilize their authorities to further the purposes of the Massachusetts Endangered Species Act and its regulations. State agencies must review, evaluate and determine the impact on state listed species or their habitats, all projects or activities that they conduct, and they must use all practicable means to avoid or minimize any damage to listed species or their habitats. This responsibility extends to any activity directly undertaken by an agency, as well as any project that an agency funds or permits.

Conclusions

State endangered species acts fulfill a necessary ''first line of defense'' role that the federal ESA was never designed to fulfill. As such, they are essential companions to the federal ESA but are not a substitute. The Massachusetts Endangered Species Act, and those of most other states, list species that are locally and regionally declining but do not yet qualify for federal listing. In theory, the recovery of these species can be initiated long before their status has deteriorated rangewide and while management solutions are more varied and far less expensive than last ditch efforts that are sometimes required for federally listed species. In practice, however, the budgets of most state endangered species programs, that usually rely heavily on voluntary public contributions, are too small to undertake more than just a few core restoration efforts.

The listing process in Massachusetts, and in most other states, is far more responsive and timely than the federal process. In Massachusetts, there is no backlog of species waiting to be listed, and the listing cycle from the time a species is proposed for listing until the final decision is made rarely exceeds 12 months. By contrast, over 3,600 candidate species are currently awaiting review for inclusion on the federal list of T&E species. For most species, this listing process takes years, and inevitablly, some species will become extinct while awaiting formal listing and protection.

Unfortunately, the designation of significant habitat under the Massachusetts law, that requires publication of a detailed site map and a description of the rare species found at the site, could result in greater harm to some species than the benefit resulting from protection of their habitat. In Massachusetts, this would be particularly true for the bog turtle (*Clemmys muhlenbergii*) and timber rattlesnake (*Crotalus horridus*), which are two of the state's most endangered species, but also are highly sensitive to directed collection and, in the case of the rattlesnake, persecution. However, the designation of critical habitat under the federal ESA also creates the same dilemma. Further, in contrast to the federal designation of critical habitat that affects only federal agency involvement in undertaking, funding or permitting a threatening activity, significant habitat under the state law can be protected from adverse activities undertaken by any entity, including a private land owner.

In conclusion, the limitations of the federal endangered species program make it imperative that states begin assuming a larger role in the protection of T&E species. Although a number of states currently have comprehensive T&E species programs, there is substantial opportunity for states to more fully develop their programs and regulations to protect rare species and their habitats. This would provide a much needed supplement to the federal program and provide additional protection for a wider variety of rare species and their habitats.

Acknowledgments

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References

Bean, M. J. 1991. Issues and controversies in the forthcoming reauthorization battle. Endangered Species Update 9(1 and 2):1–4.

Bean, M. J., S. G. Fitzgerald, and M. A. O'Connell. 1991. Reconciling conflicts under the Endangered Species Act: The habitat conservation planning experience. World Wildlife Fund, Baltimore, MD. 109 pp.

Griffin, C. R. 1989. Protection of wildlife habitat by state wetland regulations: The Massachusetts initiative. Trans. N. Am. Wildl. and Nat. Resour. Conf. 54:22–31.

Hunter, M. L. 1991. Coping with ignorance: The coarse-filter strategy for maintaining biodiversity. Pages 266–281 *in* K. A. Kohm, ed., Balancing on the brink of extinction: The Endangered Species Act and lessons for the future. Island Press, Washington, D.C. 318 pp.

Noss, R. F. 1991. Endangered species to biodiversity. Pages 227–246 *in* K. A. Kohm, ed., Balancing on the brink of extinction: The Endangered Species Act and lessons for the future. Island Press, Washington, D.C. 318 pp.

Scott, J. M., B. Csuti, K. Smith, J. E. Estes, and S. Caicco. 1991. Gap analysis of species richness and vegetation cover: An integrated biodiversity conservation strategy. Pages 282–298 *in* K. A. Kohm, ed., Balancing on the brink of extinction: The Endangered Species Act and lessons for the future. Island Press, Washington, D.C. 318 pp.

U.S. Department of Interior. 1989. Draft guidelines for planning and coordinating recovery of endangered and threatened species. U.S. Fish and Wildl. Serv., Washington, D.C. 19 pp.

———. 1990. Audit report: The endangered species program. U.S. Fish and Wildlife Service. Rept. No. 90–98, Office of Inspector General, Washington, D.C. 39 pp.

———. 1991. Endangered species: A summary of the Act and Service activities. February 22, 1991, Unpubl. rept., U.S. Fish and Wildl. Serv., Washington, D.C. 16 pp.

U.S. General Accounting Office. 1988. Endangered species: Management improvements could enhance recovery program. GAO/RCED–89–5. Washington, D.C. 100 pp.

Economic Values of Threatened and Endangered Wildlife: A Case Study of Coastal Nongame Wildlife[1]

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Introduction

Policy makers must make decisions concerning nongame wildlife protection and management activities in a world of scarcity where tradeoffs must be made. For example, economic development often destroys nongame wildlife habitat which causes wildlife populations to become more scarce. Whenever nongame wildlife populations are managed and protected, however, society loses the value of the foregone economic development. A benefit-cost analysis, which can be used to identify whether development or preservation is socially preferred, requires that all economic benefits and costs of nongame wildlife preservation, including the benefits to users and nonusers of nongame wildlife, be monetized and incorporated in the policy decision. Without explicit measurement and consideration of the economic value (benefits) of nongame wildlife, benefits may be underestimated and resources devoted to nongame wildlife protection may be underallocated. With this in mind, this paper summarizes recent research which sought to provide a monetary measure of the economic value of nongame wildlife preservation programs under conditions of demand and supply uncertainty in coastal North Carolina (Whitehead 1991).

Nongame Wildlife Values

Theory of Economic Value

The economic value of nongame wildlife can be defined with the concept of willingness to pay (Loomis et al. 1984). Nongame wildlife economic value is the amount of money an individual would be willing to pay, over and above current expenditures, in order to reduce the risk of wildlife extinction. Total willingness to pay (WTP) includes wildlife use and nonuse values. On-site use of nongame wildlife includes participation in wildlife-related outdoor recreation. Nonconsumptive use economic values arise from recreation activities in which the wildlife resource is not harvested or extracted, such as wildlife observation or photography. Off-site use of

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The Survey Research Laboratory at ECU's Regional Development Institute implemented the mail survey. The author would like to thank Tom Henson, N.C. Nongame Wildlife Program for help with the loggerhead sea turtle contingent market; Wendy Creasy, Michele McIntyre, and Scott Wallace for graduate research assistance; Skip Kirby, Planning and Institutional Research, ECU, for developing the graphical presentation of theory and results; and David Guynn for suggestions on an earlier draft of this paper.

nongame wildlife occurs when people read magazines, newspapers (and other literature), and watch television programs about nongame wildlife. Nonuse values may accrue to a potentially large portion of the population who feel better off by simply knowing that nongame wildlife is preserved, even if they never travel to the wildlife habitat area to pursue nonconsumptive recreation (Krutilla 1967).

Figure 1 shows the demand for reductions in wildlife extinction risk, or the marginal willingness to pay (WTP (π_1^D)) curve, where π_1^D is the probability of on-site use of nongame wildlife. Extinction risk ranges from a high of one (definitely will become extinct) to a low of zero (definitely will not become extinct). The reduction in risk is the change in perceived probability of wildlife supply, $\Delta\pi^s$, where π_i^S is the status quo perceived wildlife supply probability and π_*^S is an exogenous, increased supply probability (reduced risk), i = 1, . . . , n individual perceptions. The value of risk reduction, total willingness to pay (WTP) for the reduced extinction risk, is the area under the marginal WTP curve, outlined by the points d, c, π_*^S, and π_i^S.

Future demand for wildlife recreation (on-site use) may be uncertain due to uncertainty about such things as tastes, travel costs and income. Past users and nonusers of the wildlife resource may have a positive probability of participating in recreation in the future. In Figure 1, an increase in the subjective recreation demand probability (represented by $\pi_2^D > \pi_1^D$) shifts the marginal WTP curve upward and to the right (WTP (π_2^D)>WTP (π_1^D)). The shift increases total WTP to the area under the WTP (π_2^D) curve outlined by the points a, b, π_*^S and π_i^S. The increase in total WTP due to the demand probability increase is the area outlined by the points a, b, c and d.

Measurement of Economic Value

Measuring the demand for nongame wildlife resources is not as straightforward as estimating the demand for ordinary market goods, such as candy bars or automobiles. In contrast to ordinary market goods, nongame wildlife preservation has

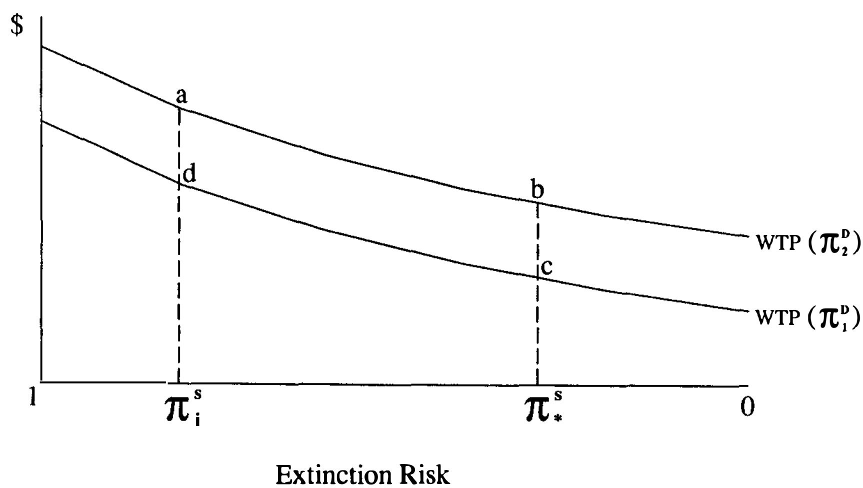

Figure 1. Theoretical model: The demand (marginal willingness to pay) for reductions in wildlife extinction risk.

resource amenity aspects which can be collectively consumed by many people at the same time. Nonmarket valuation techniques are necessary to measure the economic value of nongame wildlife resources. The contingent valuation (CV) method is a survey approach to the valuation of nonmarket goods.

The emergence of the CV method has allowed empirical measurement of total, use and nonuse values for wildlife resources. Nonconsumptive use and nonuse values measured by contingent valuation are significantly greater than zero, indicating that nongame wildlife resources are scarce economic goods. Benefit estimates range from about $1 to $75 per household/individual, depending on the wildlife species, characteristics of the preservation policy and type of survey (*see* Loomis and Walsh 1986, Boyle and Bishop 1987, Stoll and Johnson 1984).

The CV method requires that a contingent market be presented to survey respondents using mail, in-person or telephone survey instruments. A contingent market for nongame wildlife preservation must contain (1) a detailed description of the proposed preservation policy; (2) the baseline preservation level of nongame wildlife and proposed increments in preservation of nongame wildlife; (3) market institutions such as the payment rule and policy implementation rule; and (4) a value elicitation question in order to generate reliable and valid measures of economic value (Mitchell and Carson 1989).

Contingent Market Design

In this study, survey respondents are presented with two contingent markets. The first, and more detailed, contingent market presents a preservation policy for the loggerhead sea turtle (*Caretta caretta*). Respondents are informed about the current status of and threats to loggerhead sea turtle nesting habitat in North Carolina (*see* Henson and Beasley 1992, Thompson 1988). Following this description, questions concerning attitudes about extinction of the species, including risk, are asked.

Next, respondents are introduced to a hypothetical preservation program designed to manage loggerhead sea turtle nesting habitat. One-half of the respondents are asked to assume that with the management program the loggerhead sea turtle will definitely not become extinct within the next 25 years. The other half are asked to assume that with the management program the loggerhead sea turtle will probably not become extinct within the next 25 years.

Following the description of the preservation policy, respondents are presented with the contingent market valuation question and asked if they would be willing to donate money to preserve loggerhead sea turtles: ''Suppose that a $A contribution from each North Carolina household each year would be needed to support and fund the loggerhead sea turtle program. Would you be willing to contribute $A each year to the 'Loggerhead Sea Turtle Preservation Trust Fund' in order to support the loggerhead sea turtle program?''

Each respondent is randomly assigned one of the following dollar values: $A = 1, 5, 10, 25, 50 or 100. Respondents answer ''yes'' or ''no'' to the dichotomous choice question based on the $A presented to them and partially reveal their values for loggerhead sea turtle preservation. If total WTP is greater than the dollar amount the respondent will answer yes to the dichotomous choice. If the dollar amount is less than or equal to total WTP the household respondent will answer no to the dichotomous choice. A follow-up question contains categories of reasons for the response to the contingent market.

The second contingent market presents a preservation policy for the coastal component of the North Carolina Nongame Wildlife Program. Respondents are informed that wetlands, forests and beaches are nongame wildlife habitat areas that support populations of the Dismal Swamp Southeastern shrew (*Sorex longirostric fisheri*), red-cockaded woodpecker (*Picoides borealis*), Southeastern bald eagle (*Haliaeetus leucocephalus*), American alligator (*Alligator mississippiensis*), Carolina salt marsh snake (*Nerodia sipedon williamengelsi*), Cape Fear shiner (*Notropis mekistocholas*), Outer Banks kingsnake (*Lampropettis getutus sticticeps*), piping plover (*Charadrius meldus*) and loggerhead sea turtle. These are listed by the North Carolina Nongame Wildlife Program (1990) as state threatened or endangered species. The contingent market makes clear that the representative species mentioned for protection are only a few of those found in coastal North Carolina that would be affected by the management program.

After several existing threats to coastal nongame wildlife are mentioned, a "Coastal Nongame Wildlife Preservation Fund" and program is described. Money from the Fund would be used to manage nongame wildlife habitat along the North Carolina coast. Respondents are asked to assume that with the management program nongame wildlife will not become extinct within the next 25 years. A dichotomous choice valuation question follows: "Suppose that a $A contribution from each North Carolina household each year would be needed to support and fund the nongame wildlife management program. Would you be willing to contribute $A each year to the 'Coastal Nongame Wildlife Preservation Trust Fund' in order to support the nongame wildlife management program?" Respondents again answer "yes" or "no" based on the randomly assigned $A value and partially reveal their values for coastal nongame wildlife.

In both contingent markets the dollar amount variable ($A) is the same. The voluntary contribution payment rule is similar to the North Carolina Nongame and Endangered Wildlife Fund which should be familiar to survey respondents. The implicit policy decision rule is that if a sufficient amount of contributions are received the management programs will be implemented.

Survey and Empirical Methods

The population is North Carolina households. A random sample of household names was drawn from telephone directories of N.C. cities and rural areas in all three regions of North Carolina: the mountain, piedmont and coastal regions. More cities in coastal North Carolina were sampled to weight the sample toward those households. The mail survey was conducted following procedures described in Dillman (1978) during the Winter of 1991. A response rate of 35 percent was achieved.[2]

Since a yes or no response to the dichotomous choice question is a discrete (yes = 1, no = 0) variable, econometric estimation of the contingent market response requires use of qualitative response models, such as logistic regression (Amemiya 1981).

[2]Contingent valuation mail surveys assessing wildlife resources tend to achieve response rates lower than the typical 40–60 percent (i.e., *see* Stoll and Johnson (1984)). Of five mail surveys reviewed, the only exception to this observation is the study by Boyle and Bishop (1987).

Logistic regression parameter estimates are converted to the total WTP equation using the Cameron (1988) method. Willingness to pay estimates are found by predicting each sampled households' WTP value. Mean WTP is found according to the formula presented in Mitchell and Carson (1989) for a log normal distribution.

Population economic values for each program are found by aggregating across the appropriate regional population and then summing the regional benefit estimate. The appropriate populations for each region are found by first calculating the number of households in the region (regional population divided by the average regional household size). Next, an estimate of the number of households with prior knowledge that nongame threatened and endangered species were found in coastal North Carolina is determined. Willingness to pay for households with no prior knowledge is set equal to zero, as suggested by Whitehead and Blomquist (1991). To account for any self-selection bias or nonresponse bias, WTP for households who did not respond to the survey is set equal to zero, as suggested by Mitchell and Carson (1989), to generate conservative population value estimates.

Data Summary

Socioeconomic characteristics loosely conform to typical census data summaries. Household size is in the two to three range, with the number of children less than one. Age of the respondent is lower than average, assuming the head of the household is the respondent. Average education of the respondent, high school + 2.5 years beyond, is higher than average. Annual household income is lower than average. Education and income results suggest that sample bias may be present.

Survey respondents are familiar with endangered and threatened wildlife in coastal North Carolina. Seventy-eight percent of respondents know that nongame wildlife occurs in coastal North Carolina. Ninety-four percent of the sample has read literature or watched television about nongame wildlife in coastal North Carolina. Forty-four percent has actually seen a nongame wildlife species in its natural habitat. Respondents, on average, feel that there is a 50 percent chance that they will visit coastal North Carolina in the future to observe or photograph nongame wildlife in natural wildlife habitat. These results seem high and also suggest that sample bias may be present.

Contingent Market Results

Thirty-two percent of respondents (37) answered yes to the sea turtle (coastal habitat) dichotomous choice valuation question. The most important reasons given for the yes response to the sea turtle dichotomous choice valuation question was ''survival of endangered species is important for the environment.'' Few respondents value sea turtles for their outdoor recreation experiences. This result suggests that almost all of the values expressed in the contingent markets are nonuse values.

The most important reason for a no response to the sea turtle question is ''I can't afford to contribute to the Trust Fund.'' Seventeen percent of respondents needed more information. Nine percent of respondents felt they ''should not have to contribute to the Trust Fund'' which, when combined with ''no'' responses, identifies ''protest no'' responses. It is standard practice to delete protests from contingent valuation data analysis and WTP aggregation (Mitchell and Carson 1989).

The natural log of the dollar amount variable, subjective recreation demand and supply (extinction risk) probabilities, and socioeconomic characteristics are expected to influence "yes" responses. What follows is a brief summary of the empirical results for both contingent markets.[3]

Loggerhead Sea Turtle Results

Two hundred and seven observations are available for empirical analysis, after deleting protest responses and nonresponses to the contingent market. Logistic regression equations in the sea turtle preservation market are statistically significant according to the model chi-square statistic at the 99 percent confidence level. The most important result is that the coefficient estimates for the dollar amount variable are negative and significant at the 99 percent confidence level. As the cost of the preservation program increases, the probability of a yes response decreases. This result increases theoretical validity of the contingent market response, since survey respondents answered the valuation question in a rational manner.

Coefficients for subjective probability variables, extinction risk probability change and demand probability are of the expected sign and significantly different from zero at the 95 percent level. The larger the extinction risk probability change, the greater the effect of the management program.[4] As the extinction risk probability change variable increases, the probability of a yes response increases.

The demand probability variable measures respondents' subjective probability that they will travel to the North Carolina coast in the future to experience nongame wildlife recreation. As this variable increases respondents have a larger stake in the preservation program. Accordingly, as the respondents' stake in the program increases they are more likely to respond yes.

None of the socioeconomic characteristic variables, gender, age, number of children, education or income, are significantly different from zero at the 90 percent confidence level. The level of respondent education is positively related to the probability of a yes response at the 85 percent confidence level.

Coastal Nongame Wildlife Results

The estimated regression model for the coastal nongame wildlife preservation program is statistically significant according to the model chi-square statistic at the 99 percent confidence level. As with the sea turtle market, the most important result is that the coefficient estimate for the dollar amount variable is negative and significant at the 99 percent confidence level, increasing theoretical validity.

The coefficient on the demand probability variable is positive and significantly different from zero at the 99 percent confidence level.[5] Socioeconomic characteristics do influence a yes response in the coastal nongame wildlife market. The age and

[3]For a full discussion and tabular presentation *see* Whitehead (1991).

[4]The loggerhead sea turtle preservation program description includes the assurance that the risk of sea turtle extinction would fall with implementation of the program. The extinction risk change variable is constructed by subtracting the extinction risk with the management program (definitely = 0, probably = 0.25) from the respondent's prior subjective probability of extinction without the management program (mean = 0.55).

[5]Elicitation of subjective probabilities of extinction risk for all coastal nongame wildlife was not feasible for the coastal nongame market. Comprehendible questions for individual species would have been too bulky and space consuming for the survey.

number of children of the respondent decreases the probability of a yes response. The level of education increases the probability of a yes response. Gender and income were insignificant determinants of a yes response.

Contingent Market Valuation

The loggerhead sea turtle preservation program is a component of the coastal nongame wildlife program. The increased number of species protected in the coastal nongame wildlife program should generate higher WTP estimates. Mean WTP for the loggerhead sea turtle ($12.99) is lower than mean WTP for all coastal nongame wildlife ($38.41).[6] This result further suggests theoretical validity of the WTP estimates.

Figure 2 shows how total WTP increases with the probability of recreation demand for all coastal wildlife and the loggerhead sea turtle. The difference in total WTP for the two programs is $0.70 at a zero probability, $2.59 at a 25 percent probability, $8.49 at a 50 percent probability, $26.06 at a 75 percent probability and $76.86 at a 100 percent probability. Total WTP ranges from $1 to $30 ($2 to $106) for the

[6]The sample over-represents households in coastal North Carolina, higher education and lower income households. A weighting approach is used to correct for the stratified sample and also to minimize potential sample bias. Mean WTP is weighted with cross tabular demographic information from a recent statewide survey which obtained a much higher response rate. This approach departs from Whitehead (1991) where the most conservative WTP estimates are presented.

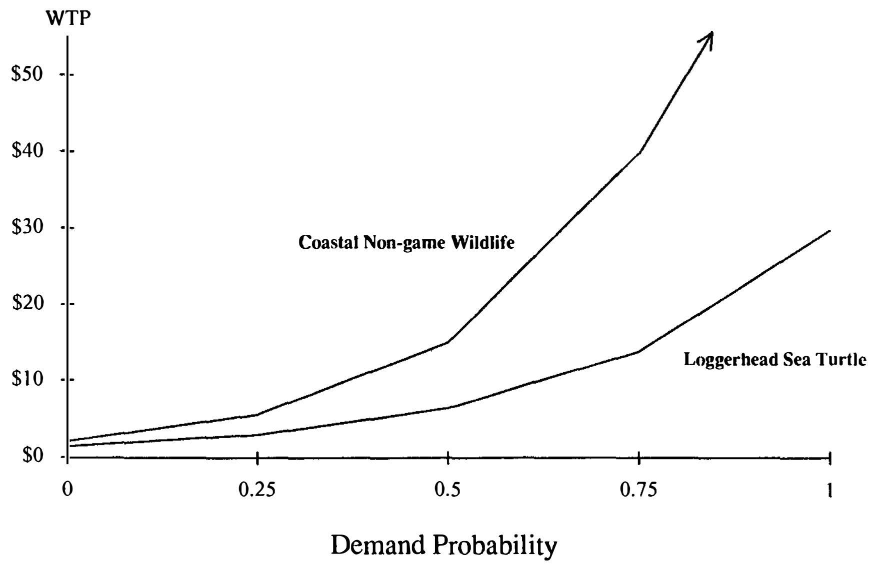

Figure 2. Empirical results: The effect of nonconsumptive recreation demand probability on total willingness to pay for wildlife preservation.

loggerhead sea turtle (Coastal nongame wildlife) program as the probability rises from zero to 100 percent.

Figure 3 shows how total WTP increases with the perceived effectiveness of the loggerhead sea turtle management program. Perceived effectiveness of the program is measured by the perceived change in extinction risk with the management program. The larger the management induced reduction in extinction risk the higher the total WTP. Total WTP ranges from about $1 for a zero change to over $62 for a 100 percent change.

North Carolina population economic values for the two programs are found by summing regional population estimates and multiplying by mean WTP for the loggerhead sea turtle and coastal nongame wildlife programs. The loggerhead sea turtle program would be worth about $8.75 million to North Carolina households. The coastal nongame wildlife program would be worth about $25.87 million. These estimates should be considered the point estimates of the mean of the population value distribution.

Conclusions

A benefit-cost analysis requires that all economic benefits of nongame wildlife preservation be monetized for comparison with the costs of preservation. Without explicit measurement and consideration of the economic benefits of nongame wildlife, benefits may be underestimated and resources devoted to nongame wildlife protection may be underallocated. This research sought to provide a monetary measure of the

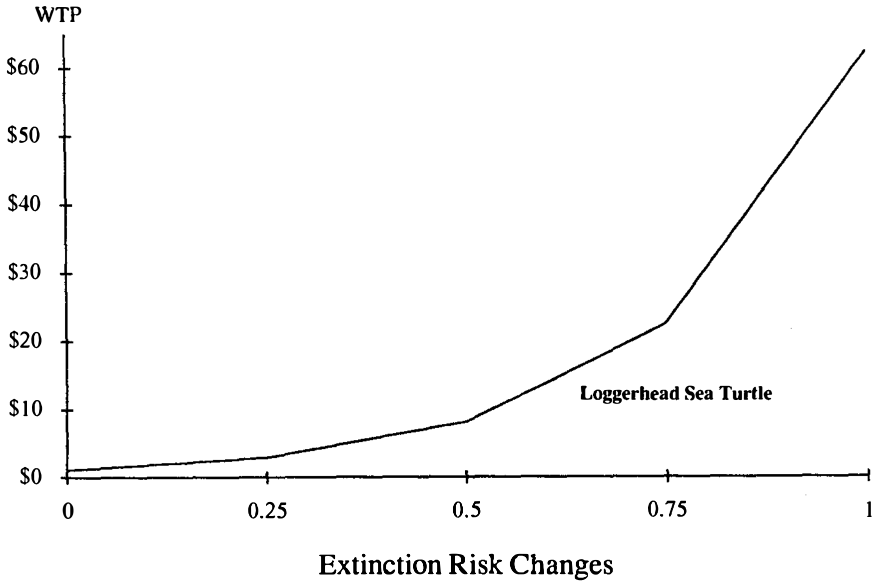

Figure 3. Empirical results: The effect of perceived program effectiveness on total willingness to pay for wildlife preservation.

economic value of nongame wildlife preservation programs in coastal North Carolina under conditions of demand and supply uncertainty.

Using the CV method, household mean WTP is $12.99 for a loggerhead sea turtle management program and $38.41 for a coastal nongame wildlife program. Much of the total WTP is comprised of nonuse values. Total WTP increases with the subjective probability of nonconsumptive recreation and the perceived effectiveness of the management program. The loggerhead sea turtle and the coastal nongame wildlife programs are found to be worth $8.75 million and $25.87 million per year, respectively, to North Carolina households. These estimates can be used for comparison to wildlife management program costs to indicate the economic efficiency and social desirability of these programs.

References

Amemiya, T. 1981. Qualitative response models: A survey. J. Economic Literature 19:1493–1536.

Boyle, Kevin J. and Richard C. Bishop. 1987. Valuing wildlife in benefit-cost analyses: A case study involving endangered species. Water Resources Research 23:943–950.

Cameron, Trudy Ann. 1988. A new paradigm for valuing non-market goods using referendum data: Maximum likelihood estimation by censored logistic regression. J. Environ. Economics and Manage. 15:355–379.

Dillman, Don A. 1978. Mail and telephone surveys: The total design method. John Wiley and Sons, NY.

Henson, Tom and Karen Beasley. 1992. Saving sea turtles. Wildlife in North Carolina. 56:14–19, January.

Krutilla, John V. 1967. Conservation reconsidered. American Economic Review 57:777–786.

Loomis, John B. and Richard G. Walsh. 1986. Assessing wildlife and environmental values in cost-benefit analysis: State of the art. J. Environ. Manage. 22:125–131.

Loomis, John B., George Peterson, and Cindy Sorg. 1984. A field guide to wildlife economic analyses. Trans. N. Am. Wildl. and Nat. Resour. Conf. 49:315–324.

Mitchell, Robert Cameron and Richard T. Carson. 1989. Using surveys to value public goods. Resources for the future, Washington, D.C.

North Carolina Nongame Wildlife Program. 1990. Endangered wildlife of North Carolina. Mimeo, February 22, Raleigh, NC.

Stoll, John R. and Lee Ann Johnson. 1984. Concepts of value, nonmarket valuation, and the case of the whooping crane. Trans. N. Am. Wildl. and Nat. Resour. Conf. 49:382–393.

Thompson, Nancy B. 1988. The status of loggerhead, *Caretta caretta*; Kemp's ridley, *Lepidochelys kempi*; and green, *Chelonia mydas*, sea turtles in U.S. waters. Marine Fisheries Review 50:16–23.

Whitehead, John C. 1991. Measuring public benefits of nongame wildlife in eastern North Carolina. Final rept., North Carolina Wildl. Resour. Commiss., nongame and endangered wildlife program, Raleigh.

Whitehead, John C. and Glenn C. Blomquist. 1991. A link between behavior, information, and existence value. Leisure Sciences 13:97–109.

Red-cockaded Woodpeckers and Hydric Slash Pine Flatwoods

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Introduction

The red-cockaded woodpecker (*Picoides borealis*) is listed as threatened by the Florida Game and Fresh Water Fish Commission (FGFWFC) and as endangered by the U.S. Fish and Wildlife Service (USFWS) (Wood 1991). A pronounced concern in southwest Florida endangered species conservation is the continued loss of red-cockaded woodpecker habitat to development. Current habitat protection and species recovery plans for the red-cockaded woodpecker do not address the habitat requirements of the south Florida populations (Beever and Dryden 1992, Patterson and Robertson 1981). This study demonstrates that hydric slash pine (*Pinus elliotti* var. *densa*) flatwoods are the critical foraging and nesting habitat utilized by red-cockaded woodpecker populations in southwest Florida.

Study Area and Methods

This project involved the compilation of survey data for red-cockaded woodpeckers in the slash pine flatwoods (xeric, mesic and hydric) of Charlotte, Collier, Glades, Hendry and Lee counties, Florida. FGFWFC staff spent approximately 1,883 hours in the field. Survey information is supplemented by field logs, site reviews of proposed development, and the resource inventory of the Charlotte Harbor Flatwoods and State Reserves (1988–1991).

Hydric Slash Pine Flatwoods

Definition of the Hydric Slash Pine Flatwood

The hydric pine flatwoods habitat is dominated by a slash pine overstory with an understory consisting of several wetland plant community types. Mid-story plants of hydric pine flatwoods include ubiquitous natives, exotic invaders, and the shrub species characteristic of the mixed hardwood swamp forest and cypress forest of south Florida.

The hydric pine flatwoods association of southwest Florida has been recognized in the plant community literature by various names. Long (1974) was the first to recognize hydric pine flatwoods as a separate habitat type, wet pineland. The zone characterized by Ewel et al. (1976) and Myers (1984) as the ecotonal habitat in which both cypress and pine can grow, but in which neither does especially well, is hydric pine flatwoods. Klein et al. (1970) and Wharton (1977) map hydric pine flatwoods in their hydro-geologic cross sections of plant communities of the Big Cypress and south Florida successional stages. Duever et al. (1986) distinguished wet pine flatwoods from dry pine flatwoods by differences in understory. The Florida

Natural Areas Inventory (FNAI) (1989) recognizes hydric pine flatwoods as wet flatwoods. Most recently, Abrahamson and Hartnett (1990) define the wet flatwoods as seasonally inundated flatlands with sand substrates, canopies of pine and/or cabbage palm, and understories of mixed hydrophytic shrubs, grasses and forbs, that vary in accordance with fire frequency.

South Florida Slash Pine in the Hydric Slash Pine Flatwood

South Florida slash pine is the dominant tree of the hydric pine flatwoods canopy in southwest Florida. The taxonomy of var. *densa* has been a matter of significant debate (Little and Dorman 1954, Squillace 1966, McMinn and McNab 1971). *Pinus elliottii* var. *densa* is more flood- and drought-tolerant than is var. *elliottii* (McNab 1965). Squillace (1966) concluded that the phenotypic plasticity that allows *densa* to accommodate both upland and wetland conditions, fire, and flood is the result of its evolution under the severe environmental factors of south Florida flood and drought that vary from year to year and fluctuate widely over longer time periods.

Pine densities in hydric pine flatwoods are typically sparse. Canopy coverage of mature hydric pine flatwoods is only 10 to 20 percent in unlogged stands. Logged stands have typically less than 5 percent canopy coverage. Slash pine are usually abundant enough to dominate the apparent landscape view and canopy, but ground cover receives nearly full sunlight. The pine canopy is highly aggregated and leaf area index ranges from 3.0 to 6.5 in natural forests (Wade et al. 1980). Mature south Florida slash pine can attain a height of 110 feet (33.5 m) , with a dbh (diameter at breast height) of 16 inches (41 cm) (Langdon 1963). In our review of undisturbed southwest Florida hydric pine flatwoods, mature trees typically attained 10 to 12 inches (25.6 to 30.8 cm) dbh with 60 to 75 feet (18.3 to 22.9 m) of height. The early diameter at breast height (dbh) growth rate of south Florida slash pine has been measured in the Corkscrew area of Collier County at an 0.45 inches (1.15 cm) per year with an annual height increase of 2 feet (61 cm) per year (Duever et al. 1976).

South Florida slash pine growing in normal hydric pine flatwoods conditions typically display some buttressing of the lower trunk. Other characteristics include fire darkened or fire scarred lower trunks, a high frequency of double crowning from the same trunk, and a sparse canopy with twisted axillary branches. If viewed from a distance, this crowned growth form gives the pine tree the appearance of a tree grown under bonsai culture. In 10 to 15 percent of the trees, abnormalities occur in apical growth that cause the tree to grow in a twisted form.

Conflicts in the Recognition of Hydric Slash Pine Flatwoods

The initial mapping of plant communities in south Florida by Davis (1943) characterized the vegetative communities by aerial photography, which does not distinguish between dry and wet pine flatwoods, particularly if the aerial photography is flown in winter to spring (dry season) months. Aerial photography is typically unable to distinguish hydric pine flatwoods from drier pine flatwoods when canopy cover is dense, or from wet prairie when canopy cover is sparse. As a result, any mapping system that depends upon aerial photography for plant community delineation cannot distinguish hydric pine flatwoods. This lack of aerial photographic distinction, coupled with interest in the hydric slash pine flatwoods only as ecotonal or seral stages in successional models, has contributed to undervaluing hydric slash pine flatwoods as an ephemeral, transitional state, or ignoring its existence completely.

The Florida Land Use Classification and Cover System (FLUCCS) does not have a specific categorization for hydric slash pine flatwood. The hydric pine flatwoods could be mapped as any of six separate FLUCCS codes. The U.S. Soil Conservation Service (1986) combines hydric slash pine flatwoods with mesic and xeric pine flatwoods in a "South Florida Flatwoods" category.

The U.S. Army Corps of Engineers (1990 jurisdiction), the USFWS, the South Florida Water Management District (SFWMD), the South Florida field offices of the Florida Department of Natural Resources, the Fort Myers U.S. Soil Conservation Service office, the Fort Myers U.S. Geological Service office and the FGFWFC recognize hydric pine flatwoods as a separate wetland habitat type in southwest Florida. However, the Florida Department of Environmental Regulation does not consider hydric pine flatwoods to be a wetland unless the pine canopy and mid-story pine canopy coverage is sufficiently sparse to render jurisdictional determination at the groundcover level. This conflict in jurisdictional claims between the principal state of Florida wetland regulatory agency and the principal federal wetland regulatory agencies renders hydric pine flatwoods subject to differential regulation with subsequent conflicts in resource protection and management.

Red-Cockaded Woodpecker in Hydric Slash Pine Flatwoods

The red-cockaded woodpecker of southwest Florida utilizes nesting and roosting cavities in live slash pine. The smallest cavity tree diameter we observed in southwest Florida is approximately 6 inches (15.4 cm) dbh. We found a common cavity tree size is 8 to 12 inches (20.5 to 30.8 cm) dbh. The largest measured tree to date had a 14 inch (35.9 cm) dbh and was aged, by coring after lightning death, at 153 years (L. Campbell personal communication: 1991).

The red-cockaded woodpecker in southwest Florida utilizes slash pine hydric flatwoods as nesting and foraging habitat (Beever and Dryden 1992, Duever et al. 1986, D. Jansen personal communication: 1991). This situation contrasts with the distribution and habitat preference of the red-cockaded woodpecker with upland mesic and xeric longleaf pine (*Pinus palustris*) forest in north Florida and the remainder of the southeastern United States (Baker 1978, Bradshaw 1990, Crosby 1971, Henry 1989). The territories of red-cockaded woodpeckers in hydric slash pine flatwoods are documented to be larger, on average 356.7 acres (144.4 h), than reported for northern birds, which ranged from 172.4 to 233.2 acres (69.8 to 94.4 h) (Nesbitt et al. 1983, Patterson and Robertson 1981). This habitat difference is demonstrated by a survey of the known red-cockaded woodpecker colonies in southwest Florida.

Of the 29 active and inactive red-cockaded woodpecker colonies in Charlotte County, 20 colonies are located in hydric pine flatwoods and all 25 of the active clans forage in hydric pine flatwoods habitat. Those colonies in mesic pine flatwoods are on islands surrounded by hydric pine flatwoods. Of the 5 red-cockaded woodpecker colonies in Lee County, all are located in hydric pine flatwoods and forage in this habitat. Of the 39 active and inactive red-cockaded woodpecker colonies located west of the Big Cypress National Preserve in Collier County, 26 colony sites are in hydric pine flatwoods and all 23 of the active clans forage in hydric pine flatwoods habitat. The remaining 13 inactive colony sites are primarily located in relatively degraded hydric pine flatwoods drained by the large canals of Golden Gate and the Cocohatcheee River drainage. Of the 37 active red-cockaded woodpecker colonies located in the Big Cypress National preserve in Collier County, all are located in hydric pine flatwoods and all forage in this habitat (D. Jansen personal communication: 1991). Two recently discovered active red-cockaded woodpecker colonies are located in Glades County. One is in hydric slash pine flatwoods. No red-cockaded woodpecker colonies have been documented in Hendry County.

In summary, of the 112 known red-cockaded woodpecker colonies in southwest Florida, 89 colonies are located in healthy hydric slash pine flatwoods and 91 of the 92 active clans forage in hydric slash pine flatwoods. If the degraded hydric slash pine flatwoods of Collier County are included, then 102 of 112 colonies are found in hydric slash pine flatwoods.

The hydric slash pine flatwoods provide preferred habitat for red-cockaded woodpeckers of southwest Florida for several reasons. Red-cockaded woodpeckers are documented to avoid areas of dense midstory. Xeric and mesic slash pine flatwoods of southwest Florida typically possess dense midstory vegetation. The dynamics of fire and flood maintain an open understory under the hydric slash pine canopy that is not inhabited by saw palmetto, hardwoods and associated shrubs. Insect attack on slash pine trees stressed by fire, lightning and flood provides abundant forage for red-cockaded woodpeckers. Mature trees stressed by the conditions of hydric pine flatwoods may also prove more suitable for the creation of start holes and cavity trees.

Historic forestry, agricultural and land clearing practices in southwest Florida concentrated on mesic and xeric pine flatwoods. These practices tended to avoid the hydric pine flatwoods, which were physically difficult to access because of inundation, had a higher percentage of malformed trees and had a lower tree density. Following logging, southern slash pine recovery is enhanced in wetland areas, around seasonal ponds and in the topographically depressed hydric slash pine flatwoods (Wade et al. 1980). Two factors contribute to this pattern. Slash pine grows quicker and, during its early life stage, has fire protection in hydric conditions. The absence of a thick cover of saw palmetto also enhances slash pine seedling growth and survival in fires. All these factors resulted in the retention of mature pine in hydric slash pine flatwoods, thus enhancing their use by red-cockaded woodpeckers.

Inadequacies of Existing Guidelines in Southwest Florida

The existing USFWS, Southeast Region (Henry 1989) guidelines for preparation of biological assessments and evaluations for the red-cockaded woodpecker are generally designed to address the habitat requirements in the longleaf pine forests subject to forestry management. These guidelines do not address the habitat requirements of the southwest Florida red-cockaded woodpecker populations.

Procedure part I of the guideline for determining whether suitable red-cockaded woodpecker habitat exists requires the identification of pine and pine-hardwood stands through aerial photographs (IA), landowner information (IB) or onsite visit (IC). Following onsite inspection, aging of the stand is performed to determine if the pines are 30 years of age or older. The method presumes that trees 9 inches (23.1 cm) or larger in dbh constitute suitable habitat.

Procedure part II for determining whether red-cockaded woodpecker colony sites are present involves identifying pine or pine-hardwood stands over 60 years of age, or younger stands containing scattered or clumped old-growth trees.

Assuming that procedures I and II are passed, a survey is performed, a red-cockaded woodpecker colony is found, and a colony site is delineated; the guidelines for colony protection are implemented. Procedure III assumes that foraging habitat consists only of pine and pine-hardwood stands of over 30 years, as identified by a presumption of 9 inches (23.1 cm) dbh. Procedure IIIA states that a red-cockaded woodpecker colony requires 8,490 square feet (789 square meters) of pine basal area, 6,350 pine stems 10 inches (25.6 cm) or larger in dbh, and a total of 21,250 pine stems. From procedure IIIB3, the guideline generally considers 125 acres of longleaf pine, at least 30 years of age with at least 50 acres (20.2 h) of pine 60 years or older, 70 square feet (6.5 square meters) of basal area per acre, and at least 24 pines per acre with 10 inches (25.6 cm) or greater dbh to be acceptable habitat preservation.

Most landowners and administering land agency staff either dispute the existence of or have difficulty identifying hydric slash pine flatwoods. We have received wildlife surveys stating that red-cockaded woodpeckers are not present, and that no red-cockaded woodpecker surveys were performed because suitable upland slash pine forests were not indicated by aerial photographs and FLUCCS maps. Follow-up surveys required by the FGFWFC typically revealed hydric slash pine flatwoods and red-cockaded woodpeckers on these sites. For southwest Florida, only onsite inspection by a trained biologist (method IC of the federal guideline) will determine the presence of the critical hydric slash pine flatwoods habitat.

Given that 30-year-old slash pine will have an average dbh of 7.1 inches (18.2 cm) (Henry 1989), that southwest Florida red-cockaded woodpecker cavity trees can be found in slash pine as small as 6 inches (15.4 cm) dbh, and 8 to 9 inches (20.5 to 23.1 cm) dbh is a common cavity tree size, at least half of the southwest Florida red-cockaded woodpecker habitats would fail to meet the 9 inch (23.1 cm) dbh criteria of procedure I. Subsequently, a No Effect determination under the federal guideline would be made. We have consistently received verbal and written reports that red-cockaded woodpeckers are not present and no surveys were performed because the slash pine trees on the site are too young, based upon dbh measures. Subsequent surveys required by the FGFWFC found red-cockaded woodpecker colonies on these sites.

Review of the stocking tables in the federal guideline indicate that a 60-year-old slash pine forest, required by Part II, will have an average dbh of 11 inches (28.2 cm). This is on the upper range of common cavity tree size in hydric south Florida slash pines. More than half of the colony sites we surveyed fall below this standard.

Stocking tables in the federal guideline also indicate that a slash pine forest 60 years of age typically has 470 trees per acre (1161 trees/h), 162 trees 10 inches (25.6 cm) or larger dbh per acre (400/h), and 158 square feet per acre (36.3 m/h) basal area. Using the guideline tables and procedure III, good quality slash pine flatwoods foraging habitat per clan would be estimated at 45.2 acres (18.3 h) based on total pine stems, 39.2 acres (15.9 h) based on pine stems 10 inches or larger in dbh, and 53.7 acres (21.7 h) based on basal area. These estimates are low compared to documented territory sizes, which average approximately 356 acres (144 h) for south Florida red-cockaded woodpeckers (Nesbitt et al. 1983, Shapiro 1983).

It is our experience that very good quality 65-foot-tall canopy, hydric slash pine flatwoods have approximately 54 trees per acre (133 trees/h), approximately 5 to 8 pine stems of 10 inches (25.8 cm) or larger in dbh (12 to 20 trees/h) and a basal area of approximately 20 square feet per acre (4.6 square meters/h). Utilizing these parameters and the procedure III federal guideline criteria, foraging habitat per clan would be estimated at 115.5 acres (46.8 h) based on total pine stems, 453.6 acres (183.6 h) based on pine stems 10 inches (25.8 cm) or larger in dbh, and 424.5 acres (171.9 h) based on basal area.

Essentially, procedures I, II, and III of the federal guideline eliminate the majority of hydric slash pine flatwoods foraging habitat in which we have observed red-cockaded woodpeckers. By definition, the guidelines consider all the red-cockaded woodpecker foraging habitat in southwest Florida to be poor quality or non-existent habitat.

The Florida Game and Fresh Water Fish Commission currently lacks a formal guideline addressing the habitat needs of the red-cockaded woodpecker in southwest Florida. Under current habitat review processes, hydric slash pine flatwoods, and, subsequently, red-cockaded woodpecker habitat, continue to decline. At best, only isolated fragments of these habitats have been preserved, under dubious management commitments. For example, in 10 recent large southwest Florida development projects with hydric slash pine flatwoods occupied by red-cockaded woodpecker clans, only 12 percent (839 acres) of the documented habitat is being preserved. It is improbable that long-term protection of regional populations of red-cockaded woodpeckers and long-term viability of hydric slash pine flatwoods will occur under the current federal and state management and regulatory procedures.

Accommodation or Conservation?

Slash pine flatwoods were reduced to approximately 50 percent of their historic extent in south Florida by 1970 (Birnhak and Crowder 1974), as a result of agricultural activities, speculative real estate clearing and urban development. Wade et al. (1980) reported that slash pine flatwoods occupied more area in south Florida than any other plant community except the Everglades marsh. By 1989, FGFWFC mapping (Elert 1989, Kautz 1989) of southwest Florida indicated that the slash pine flatwoods community has dropped to fifth in areal extent behind grasslands, cypress swamp, dry prairies and freshwater marsh. This study indicated that, for the first time, urban areas occupied more acreage in southwest Florida than did slash pine flatwoods.

Regionally, the hydric slash pine flatwoods habitats of Charlotte, Collier and Lee counties are critical for the survival of red-cockaded woodpeckers in southwest Florida. Large scale development, conversion to citrus cultivation, pulpwood production and construction of new roadways in hydric pine flatwoods pose serious threats to habitat quality and quantity, and, subsequently, the long-term survival of the red-cockaded woodpecker in south Florida.

Conservation

The inadequacies of the current federal guidelines for red-cockaded woodpecker protection and the proposed federal wetland jurisdiction changes serve to accommodate the development interests of southwest Florida rather than the red-cockaded woodpecker. We recommend that the conservation of the southwest Florida red-cockaded woodpecker requires identification, purchase and management of regional wildlife conservation areas that incorporate both wetland and upland habitat protection, and hydric slash pine flatwoods in particular. These wildlife conservation areas should be specifically managed for the red-cockaded woodpecker and other listed species that are being impacted by regional development. Conservation lands should be bought with monies provided by development interests, in lieu of fragmented, minimal, on-site habitat protection within developed areas. The off-site mitigation should not be subject to development interest preference or general permit. The extent to which the off-site option is made available to the developer would be based on an evaluation by qualified biologists in state and federal wildlife and wetlands protection resource agencies.

The conservation areas should be located adjacent to existing publicly-owned conservation lands or land slated for public acquisition that contain red-cockaded woodpecker colonies. Each conservation area should be at least 1,000 acres (405 ha) in size, benefit a diversity of listed and unlisted wildlife and plant species, and not include any lands currently identified for public acquisition (Allen 1990).

Lands identified for acquisition must be type-for-type replacement for lost habitat. Where the loss of habitat of a specific listed species such as the red-cockaded woodpecker is of issue, the listed species of concern must be documented on the conservation purchase area or be within documented reasonable dispersal distance of the conservation purchase area.

Red-cockaded woodpeckers of the hydric pine flatwoods of southwest Florida require significant tracts of land. Only by providing what the listed species need for long-term survival will conservation be achieved. Anything less accommodates the path to extinction.

References

Abrahamson, W. G. and D. C. Hartnett. 1990. Pine flatwoods and dry prairies. Pages 103–149 *in* R. L. Myers and J. J. Ewel, eds., Ecosystems of Florida. Univ. Central Florida Press.

Allen, M. 1990. Off-site habitat mitigation: A regional approach for resolving conflicts between land development and habitat protection. Off. Environ. Services, Florida Game and Fresh Water Fish Commiss. 5 pp.

Baker, W. W. 1978. Red-cockaded woodpecker. Pages 11–13 *in* H. W. Kale II, ed., Rare and endangered biota of Florida. Vol. II. Birds. Univ. Presses Florida, Gainesville.

Beever, J. W., III and K. A. Dryden 1992. The Hydric Pine Flatwoods of Southwest Florida: A community profile. Florida Game and Fresh Water Fish Commiss. In press. 118 pp.

Birnhak, B. I. and J. P. Crowder. 1974. An evaluation of the extent of vegetative habitat alteration in south Florida 1943–1970. South Florida Environ. Proj. Ecol. Rep. DI-SFEP-74-22. USDI 26 pp.

Bradshaw, D. S. 1990. Habitat quality and seasonal foraging patterns of the red-cockaded woodpecker (*Picoides borealis*) in southeastern Virginia. M.S. thesis, The Coll. William and Mary in Virginia. 82 pp.

Crosby, G. T. 1971. Home range characteristics of the red-cockaded woodpecker in north-central Florida. Pages 60–73 *in* R. L. Thompson, ed., Symposium on the red-cockaded woodpecker. Bur. Sport Fisheries Wild., USDI and Tall Timbers Res. Sta., Tallahassee, FL.

Davis, J. H. 1943. The natural features of southern Florida, especially the vegetation and the Everglades. FL. U.S. Geol. Surv. Bull. 25, 333 pp.

Duever, M. J., J. E. Carlson, L. H. Gunderson, and L. C. Duever. 1976. Corkscrew Swamp, a virgin strand, ecosystems analysis at Corkscrew Swamp. Pages 707–737 *in* H. T. Odum, ed., Cypress wetlands. 3rd Ann. Rept. on Research Projects. Nov. 1875–Dec. 1976. Center for Wetlands, Univ. Florida, Gainesville.

Duever, M. J., J. E. Carlson, J. F. Meeder, L. C. Duever, L. H. Gunderson, L. A. Riopelle, T. R. Alexander, R. F. Myers, and D. P. Spangler. 1986. The Big Cypress National Preserve. Res. Rept. No. 8 of the Nat. Audubon Soc. Naples, FL. 444 pp.

Elert, J. 1989. Southwest Florida regional planning council prints and memorandum. 3 pp.
Ewel, J., R. Myers, L. Conde, and B. Sedlik. 1976. Studies of vegetation changes in south Florida. Univ. Florida, Gainesville, and U.S. Forest Service, Research Agreement No. 18–492:72–82.
Florida Natural Areas Inventory. 1989. Guide to the Natural Communities of Florida. 111 pp.
Henry, V. G. 1989. Guidelines for preparation of biological assessments and evaluations for the red-cockaded woodpecker. U.S. Fish and Wildlife Service, Southeast Region, Atlanta, GA. 195 pp.
Kautz, R. 1989. A comprehensive statewide wildlife habitat system for Florida, Florida Game and Fresh Water Fish Commiss. 6 pp.
Klein, H., W. J. Schneider, B. F. McPherson, and T. J. Buchanan. 1970. Some hydrologic and biologic aspects of the Big Cypress Swamp drainage area. USGS Open-File rept. 70003. 94 pp.
Langdon, O. G. 1963. Growth patterns of *Pinus elliottii* var. *densa*. Ecology 44:825–827.
Little, E. L. Jr. and K. N. Dorman. 1954. Slash pine (*Pinus elliottii*) including South Florida slash pine, nomenclature and description. U.S. For. Serv. Southeast For. Exp. Sta. Pap. 36. 82 pp.
Long, R. W. 1974. The vegetation of southern Florida. Florida Scientist 37(1):33–45.
McMinn, J. W. and W. H. McNab. 1971. Early growth and development of slash pine under drought and flooding. U.S. Dept. Agric. For. Serv. Res. Note SE–89, Southeast For. Exp. Stn., Ashville, NC. 10 pp.
McNab, W. H. 1965. Response to drought and flooding of two varieties of slash pine in south Florida. M.S. thesis, Univ. Florida, Gainesville. 61 pp.
Myers, R. L. 1984. Ecological compression of *Taxodium distichum* var. *nutans* by *Melaleuca quinquinervia* in southern Florida. Pages 358–364 *in* Cypress Swamps, K. C. Ewel and H. T. Odum, eds., Univ. Press. Florida.
Nesbitt, S. T., A. E. Jerauld, and B. A. Harris. 1983. Red-cockaded woodpecker summer range sizes in southwest Florida. Pages 68–71 *in* Proceedings of the Red-cockaded Woodpecker Symposium II, Florida Game and Fresh Water Fish Commiss.
Patterson, G. A. and W. B. Robertson, Jr. 1981. Distribution and habitat of the red-cockaded woodpecker in Big Cypress National Preserve. South Florida Res. Ctr. Rept. T–613. 137 pp.
Shapiro, A. E. 1983. Characteristics of red-cockaded woodpecker cavity trees and colony areas in south Florida. Florida Scientist 46(2):89–95.
Squillace, A. E. 1966. Geographic variation in the slash pine. For. Sic. Monogr. 10, 56 pp.
U.S. Soil Conservation Service. 1986. 26 ecological communities of Florida. 146 pp.
Wade, D., J. Ewel, and R. Hofstetter. 1980. Fire in South Florida Ecosystems. U.S.D.A. Forest Service General Tech. Rept. SE–17, 125 pp.
Wharton, C. H. 1977. Forested wetlands of Florida—their management and use. Final rept. to Div. St. Planning. Ctr. for Wetlands, Univ. Florida, Gainesville. DSP–B CP–19–77. 421 pp.
Wood, D. 1991. Official lists of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commiss., April 1, 1991. 23 pp.

Special Symposium.
Wildlife and American Wildlife History: Insights from the Past

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Gazing Across the Gulf: Environmental History and American Wildlife Ecology

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Why a symposium on environmental history? The reasons are many, not the least of which is the excitement of uncovering little-known or long-forgotten circumstances that enlighten our attitudes toward current events. President Thomas Jefferson's scientific probes into the West two centuries ago represent America's earliest example of federally sponsored science—events that were arguably as significant to the discovery of the continent's wildlife as they were to claims of empire. Moreover, with Lewis and Clark, as well as two lesser-known Jeffersonian explorations, led by William Dunbar and Thomas Freeman (Flores 1984a), lie the kindred beginnings of the research branches of the U.S. Fish and Wildlife Service and the USDA Forest Service, to say nothing of the National Science Foundation, NASA or a host of other federal agencies dedicated to scientific inquiry.

In a more applied sense, the historical record often serves to establish an ecological baseline, an early template against which subsequent changes may be evaluated (Malin 1984, Flores 1984b). Historical data carefully used in this way provide key insights into many interesting debates about wildlife. A variety of historical sources, for example, suggest that bison herds in the American West were seriously diminished by a confluence of drought, exotic bovine diseases and the response of Native American hunters to market forces, perhaps a quarter century or more before the infamous hide-hunting slaughter of the 1870s (Flores 1991). Similarly, the historical record—employed at times almost like some New World biblical scripture—is central to those arguments concerning the past and present status of ungulate populations in Yellowstone National Park (Chase 1987). Moreover, history sketches more fully the roles that fire and predators may have played—and might still play—in regulating ungulate populations throughout the West.

History, in other ways, often explains the "hows" and "whys" of contemporary biological and management phenomena. For example, the change from Native American to Euroamerican land use explains the contracted ranges of many species and the altered composition of the flora in such regions as New England (Cronon 1983). In a related example, it was the combined historical events of the Dust Bowl and the Great Depression that established some 19,900 miles (32,000 km) of shelterbelts in the American plains, and thereafter led to significant changes in the distribution and abundance of such species as the Mississippi kite (*Ictinia mississippiensis*), Swainson's hawk (*Buteo swainsoni*) and merlin (*Falco columbarius*) (Smith 1977, Love and Knopf 1978, Gilmer and Stewart 1984, Fox 1971). Hence, as the original plantings of the Civilian Conservation Corps age and die without replacement, we note the potential for history repeating itself, with a period of catastrophic soil loss—as well as diminished raptor habitat—in the decades ahead (Bolen and Flores 1989).

A close search of the historical record also may disclose those insights of our professional forefathers that augured management activities today. The "father" of American ornithology, Alexander Wilson, in 1813, wrote of the intimate biological relationship between horseshoe crabs (*Limulus polyphemus*) and shorebirds, especially ruddy turnstones (*Arenaria interpres*): "This spawn [of what Wilson called the 'horsefoot' crab] may sometimes be seen lying in hollows and eddies in bushels; while the Snipes and Sandpipers, particularly the Turn-stone, are hovering about, feasting on the delicious fare." Wilson actually understated what is a biological ritual of immense proportions. In May, millions of horseshoe crabs spawn on the beaches of Delaware Bay, laying billions of eggs along the shoreline at high tide; one female may lay 80,000 eggs each year and there may be 50 clutches in a square mile of beach. In close synchrony with this event, a million or more migrating shorebirds stop at Delaware Bay, where they gorge on the bounty of horseshoe crab eggs. Starved by the rigors of the long flight from South America, the birds rapidly add fat to their lean bodies, some literally doubling their weight in two weeks. Myers (1986), in recounting these events, estimated that a single bird must consume nearly 135,000 eggs in 14 days to account for such a gain in weight, and a flock of 50,000 birds would devour no less than 27 tons of eggs during the same period.

What is so important about this chain of events? Simply that turnstones and other shorebirds inexorably depend on this and other staging areas along their migratory route. There are no substitutes, and without Delaware Bay and the vital spawn of its horseshoe crabs, most of North America's shorebird's could no longer complete their migrations. About 60–80 percent of the turnstones and other species of shorebirds stop at Delaware Bay each year. Fortunately, the governors of Delaware and New Jersey have declared this important a conservation area for shorebirds, and a network of this and similar sites forms the basis of a conservation strategy for the management of shorebirds (Myers et al. 1987). Alexander Wilson, no doubt, would be most pleased, and we propose that this unique site be named in his honor.

A century earlier, John Lawson (1709) published *A New Voyage to Carolina*, acknowledged as the first significant treatise to describe in any detail the natural history of the New World. Little was known about Lawson until recently (*see* Holloman 1991). Nonetheless, his travel "of a thousand miles" through the Carolinas remains a triumph of observation and, for the day, scientific inquiry (although some chimeric notions crept into his book). Initially, Lawson and his party canoed up the coast from Charleston, South Carolina, wandering through the tidal creeks of the coastal marshes to Bull's Island, where he found "Plenty of fowl, as Curleus, Gulls, Gannets,and Pellicans, besides Duck, and Mallard, Geese, Swans, Teal, Widgeon, etc." Unknowingly, Lawson had described the very resources that more that two centuries later led to the formation of Cape Romain National Wildlife Refuge at the same spot.

Lawson's observations of the feeding ecology of bald eagles (*Haliaeetus leucocephalus*) presaged later difficulties concerning their contamination with lead shot in the carcasses of waterfowl (*see* Pattee and Hennes 1983, Feierabend and Myers 1984). He wrote, "The bald Eagle attends the Gunners in Winter . . . and when he shoots and kill any Fowl, the Eagle surely comes in for his Bird; and besides, those that are wounded, and escape the Fowler, fall to the Eagle's share." Ironically, the recent and long-overdue requirement that waterfowl hunters use nontoxic shot stemmed more from the secondary poisoning of bald eagles than from the direct effect of lead poisoning on waterfowl themselves. Lawson also was the first to report the relationship between fire and the feeding ecology of snow geese (*Chen caerulescens*) overwintering on coastal wetlands. Great flocks of these "white Brant," he noted, sought the "Roots of Sedge and Grass" on freshly burned marshes, thereby heralding by nearly 250 years the now widely practiced management of winter habitat for geese (Lynch 1941, Hindman and Stotts 1989).

Perhaps one very significant contribution that environmental history can make to wildlife management lies in the humanities' necessary focus on people, their desires, motivations and visions. Works such as *The Columbian Exchange* and *Ecological Imperialism: The Biological Expansion of Europe, 900 to 1900* (Crosby 1972, 1986) proffer new insights into how Europeans desired to remake the New World into a facsimile of their homeland—desires that affected not only Native peoples, but wildlife. Ecological introductions, both intended (domestic animals and plants) and unintended (Old World diseases) made possible the "conquest" of the New World far more effectively than did superior technology or military might (Fausz 1979). Similarly, the image of wild nature as the face of God—a metaphor that resonated for Americans during the Romantic Age of the 19th century—and Frederick Jackson Turner's 1893 essay, "The Significance of the Frontier in American History," together cast the United States as the world's leader in wilderness protection (Nash 1983, Novak 1980). And that vision of wilderness has forged a lasting impact on American environmentalism and wildlife management strategies, one that is unique in world history.

As several of the papers in this session will attest, one of the contributions that this historical focus on human culture can provide is a reassessment of the origins of conservation. Those origins, long considered as "crusades" or "triumphs" of enlightened thinking, either by early sportmen's organizations (Trefethen 1975, Reiger 1975) or by government elites in search of "efficiency" (Hays 1969), may have murkier and more socially driven beginnings than we have thought. In a mirror of contemporary human/wildlife interactions in Africa, Alaska or the Pacific Northwest (Anderson and Grove 1987, McEvoy 1986), management that at first glance seemed to reflect a triumph of modern scientific thinking toward wildlife actually may have contained the seeds of class or social conflict.

In North American history, for example, colonial and even 19th-century laws protecting wildlife were in fact always strategies aimed at regulating people, and oftentimes specific groups of local people who used wildlife in ways that other groups deemed either undemocratic, unsporting or not scientifically grounded. Rural, local, Native, or ethnic Americans usually lost these battles to more politically astute urban elites who had science and/or government on their side; the interesting exception concerns Western stockraisers and the predator issue in the 20th century (Dunlap 1983). William T. Hornaday's (1913) assertion that Italian immigrants were responsible, in part, for declining populations of wildlife in early 20th century America represents only the iceberg tip of this perception. In a classic example of historicism, since most of the histories of wildlife management have been written by members of the "winning" side in these conflicts, the victories have been hailed as triumphs. In fact, what the story more readily demonstrates is just how anthropocentric early environmental laws were. Wildlife certainly may have benefitted, but the external and centralized approach (i.e., wildlife as a public resource managed by state bureaus) also may have left us poorer and less diverse in our knowledge of how local or indigenous groups worked out ways of interaction with the natural world.

As interdisciplinary scholars, environmental historians have profited much from reading works in ecology and wildlife management. Perhaps that flow of information should not be exclusively one-directional. As those who literally hold the tiller of the modern natural world, ecologists and wildlife managers ought to remain aware that the management tactics they follow are grounded as much in culture as in science. Science, in any case, is a cultural artifact. And history has always had something to say about the directions and underlying motivations of culture.

References

Anderson, D. and R. Grove, eds. 1987. Conservation in Africa: People, policies and practice. Cambridge Univ. Press, NY.

Bolen, E. G. and D. L. Flores. 1989. The Mississippi kite in the environmental history of the southern Great Plains. Prairie Nat. 21:65–74.

Chase, A. 1987. Playing God in Yellowstone: The destruction of America's first national park. Harcourt, Brace and Jovanovich, NY.

Crosby, A. 1972. The Columbian exchange: Biological consequences of 1492. Greenwood Press, Westport, CT.

———. 1986. Ecological imperialism: The biological expansion of Europe, 900–1900. Cambridge Univ. Press, NY.

Cronon, W. 1983. Charges in the land: Indians, colonists and the ecology of New England. Hill and Wang, NY.

Dunlap, T. R. 1983. The coyote itself: Ecologists and the value of predators, 1900–1972. Environ. Rev. 7:54–70.

Fausz, J. F. 1979. Fighting fire with firearms: The Anglo-Powhatan arms race in early Virginia. Am. Indian Cult. and Res. J. 3:33–50.

Feierabend, J. S. and O. Myers. 1984. A national summary of lead poisoning in bald eagles and waterfowl. Natl. Wildl. Federation, Washington, D.C.

Flores, D. L., ed. 1984a. Jefferson and southwestern exploration, the Freeman and Custis accounts of the Red River expedition of 1806. Univ. Oklahoma Press, Norman.
———. 1984b. The ecology of the Red River in 1806: Peter Custis and early southwestern natural history. Southwest. Hist. Quart. 88:1–42.
———. 1991. Bison ecology and bison diplomacy: The southern plains from 1800 to 1850. J. Am. Hist. 78:465–485.
Fox, G. H. 1971. Recent changes in the reproductive success of the pigeon hawk. J. Wildl. Manage. 35:122–128.
Gilmer, D. S. and R. E. Stewart. 1984. Swainson's hawk nesting ecology in North Dakota. Condor 85:12–18.
Hays, S. P. 1969. Conservation and the gospel of efficiency: The progressive conservation movement, 1890–1920. Cambridge Univ. Press, NY.
Hindman, L. J. and V. D. Stotts. 1989. Chesapeake Bay and North Carolina sounds. Pages 27–55 *in* Smith, L. M., R. L. Pederson, and R. M. Kaminski, eds, Habitat management for migrating and wintering waterfowl in North America. Texas Tech Univ. Press, Lubbock.
Holloman, C. R. 1991. Lawson, John. Pages 34–36 *in* W. S. Powell, ed., Dictionary of North Carolina biography. Vol 4. Univ. North Carolina Press, Chapel Hill.
Hornaday, W. T. 1913. Our vanishing wild life, its extermination and preservaton. New York Zool. Soc., NY.
Lawson, J. 1709. A new voyage to Carolina. H. T. Lefler, ed. Univ. North Carolina Press, Chapel Hill.
Love, D. and F. L. Knopf. 1978. The utilization of tree plantings by Mississippi kites in Oklahoma and Kansas. Pages 70–74 *in* Trees, a valuable Great Plains multiple use resource. Proc. 13th Annual Meeting. Forestry Comm., Great Plains Agric. Council Publ. No. 87. Lincoln, NE.
Lynch, J. J. 1941. The place of burning in management of the Gulf Coast wildlife refuges. J. Wildl. Manage. 5:454–457.
Malin, J. C. 1984. History and ecology, studies of the grassland. R. P. Swierenga, ed. Univ. Nebraska Press, Lincoln.
McEvoy, A. 1986. The fisherman's problem: Ecology and law in the California fisheries. Cambridge Univ. Press, NY.
Myers, J. P. 1986. Sex and gluttony on Delaware Bay. Nat. Hist. 95(5):86–77.
Myers, J. P., R. I.G. Morrison, P.Z. Antas, B. A. Harrington, T. E. Lovejoy, M. Sallaberry, S. E. Senner, and A. Trarak. 1987. Conservation strategy for migratory species. Am. Scientist 75:19–26.
Nash, R. 1982. Wilderness and the American mind. Yale Univ. Press, New Haven, CT.
Novak, B. 1980. Nature and culture: American landscape and painting, 1825–1875. Oxford Univ. Press, NY.
Pattee, O. H. and S. K. Hennes. 1983. Bald eagles and waterfowl: The lead shot connection. Trans. N. Am. Wildl. and Nat. Resour. Conf. 48:230–237.
Reiger, J. 1975. American sportsman and the origins of conservation. Winchester Press, NY.
Smith, L. 1977. No shelterbelts, no shelter, for the Great Plains. Conserv. News 42:10–13.
Trefethen, J. 1975. An American crusade for wildlife. Winchester Press, NY.
Wilson, A. 1813. American ornithology. Vol. 7. Bradford and Inskeep, Philadelphia, PA.

Outlaw Gunners and Hunting Law in the English Colonial South

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Introduction

Traveling along the Roanoke River in the 1720s, Virginia planter and surveyor William Byrd II came upon a colonist named Epaphroditus Bainton. Bainton was one of the early residents of the Piedmont, a region settlers in the east knew as "back parts," "back settlements" or "the backcountry." Having come from the more populous Tidewater region, Byrd took brief but careful note of Bainton's way of life. Bainton was "young enough at 60 years of age to keep a concubine, & to walk 25 miles a day." Indeed Bainton always walked; he had once been thrown from a horse and had nearly broken his neck. He spent "most of his time in hunting and ranging the Woods, killing generally more than 100 Deer in a year" (Byrd 1967:157).

Most Americans and many historians would regard Bainton as a typical colonial frontiersman, roaming the woods at will with his gun and indiscriminately killing as many deer as possible. But in the eyes of the colonial government, Bainton was probably an outlaw. Almost 30 years earlier, in 1699, Virginia legislators had made it unlawful to kill white-tailed deer between February 1 and July 1 (Hening 1819–23 [3]:180). In the first half of the eighteenth century, most of England's other southern colonies followed suit, creating some of the first closed hunting seasons on the American continent.

Recent Scholarship

For years, most scholars paid scant attention to such legislation. Instead, the colonial period has more often been depicted as a time when settlers were bent on "transforming the wild into the rural," driving out predators and killing any other animal that could provide a tasty meal or well-dressed pelt (Nash 1967:31). Not until the 1980s did environmental historians begin to recognize the deer laws, noting in the words of Albert E. Cowdrey (1983:57) that the "myth of abundance" had become "badly tarnished" by the eighteenth century. But that has proved no more than a passing acknowledgment. In what purports to be a scholarly reassessment of Columbus and his legacy, Kirkpatrick Sale (1990:286) has once again called attention to "the blindness, the insensitivity, the disconnectedness, the exploitation, the destruction—and above all the obsessive need [of early settlers] to try 'subduing' nature." In the popular mind, wildlife conservation seems unthinkable for people intent on taming a wilderness. English colonists have become historical scapegoats for many modern ecological problems, including extinction.

But is this really an appropriate image? Some of the most recent scholarship concerning the colonial South now allows historians to offer a more complete picture of the changing world of animals (especially deer) and their human antagonists. It is a scenario in which outlaw hunters, like Bainton, figure prominently and one which may surprise those who still think of early America as settled by colonists who believed "wilderness was waste; [and] the proper behavior toward it exploitation" (Nash 1967:31).

The Ecological Context of Early Southern Wildlife Law

By the end of the seventeenth century, the natural world of the white-tailed deer had undergone extensive change for more than 100 years. The earliest European explorers in the South quickly recognized the economic potential of deerskins. Stripped of hair, the hides could be turned into beautiful buff-colored leather, which Europeans favored for gloves and bookbinding. Hunters like Bainton sold deerskins from the animals they killed, but most colonial merchants depended on trade with Indians to supply the hides. Although the natives managed to maintain a remarkable degree of control over the ways in which the trade was conducted, their eventual dependence on European items (including guns and liquor) led Indians to hunt vast numbers of deer for the European market. Under such pressure, the herds began to decline (Crane 1964, White 1983, Silver 1990).

Both Indians and settlers also relied on whitetails for food. Acquired either by hunting or in trade with the natives, venison was a common meat at colonial tables. In 1666, George Alsop, a Maryland indentured servant, observed that his master once had some 80 deer stored to feed his household. As Alsop described it, "before this Venison was brought to a period by eating, it so nauseated our appetites and stomachs that plain bread was rather courted and desired than it" (Hall 1946:345).

Humans hunting for skins and meat were not the only ecological threats to deer. Because colonists rarely fenced their livestock, cattle, horses, hogs and goats all competed with deer for browse and mast. In areas where large herds of stock used the open range, as in the eastern Carolinas and Virginia, deer may have been driven away by domestic animals. Any whitetails that did survive alongside cattle and hogs may have been small and malnourished, hardly the sort of animals that were valuable for venison and skins (Hahn 1982).

The decline of the southern deer herd from livestock and hunting pressure was not a steady slide to the brink of extinction. When Indians went to war against colonists or other Indians—a frequent enough occurrence amid the political turmoil of the eighteenth century—deer populations faced fewer hunters and had time to recover. This ebb and flow of hunting and warfare meant that deer became scarce in different areas at different times (White 1983). By 1700, deer were disappearing from northeastern North Carolina and southeastern Virginia (Lawson 1967). By 1710, the animals were scarce along the South Carolina coastal plain (Hahn 1982). In 1728, when William Byrd made his first trip to the interior (the journey on which he met Bainton), it took 10 days travel to reach an area where deer and other game still abounded (Byrd 1967).

Such changes in the deer population make it easier to understand the basic premise of early southern wildlife law. With the animals periodically disappearing from the coastal settlements, the backcountry herds became crucial to the future trade in leather and venison. The rhetoric of the laws themselves clearly reflects concern for ensuring survival of enough young deer to replace those taken for meat and skins. Virginia justified its initial closed spring season on the basis of "the unseasonable killing" of deer ''when poor and of Does bigg with young'' (Hening 1819–23 [3]:180). By 1769, South Carolina instituted a closed season on does and fawns from January through July and prohibited killing bucks in September, October, March and April (Cooper and McCord 1836–1839[4]:310–11).

Aimed directly at commercial hunting, the laws frequently allowed friendly Indians and all colonists to hunt for food, but not trade. Possession of out-of-season skins (often identifiable by their rusty hue) was *prima facie* evidence of a violation. Those caught in the act or with illegal skins usually faced a fine for each animal unlawfully shot. Maryland's 1730 law, for example, levied a fine of 400 pounds of tobacco for every illegal deer (Kilty 1800).

The Social Context of Early Southern Wildlife Law

Over the course of the century, however, it became evident that wildlife laws were intended to do more than simply guarantee the future of the deer herds and the attendant trade. The legislation was also designed to alter the outlaw gunner's way of life.

Between 1720 and 1770, more and more farming colonists moved into the southern Piedmont. Scotch-Irish, Germans, Welsh, Swiss, English Quakers, and other groups carved out small, ethnically homogenous neighborhoods in the upland forests. They kept livestock, grew corn and other subsistence crops, and also may have tended small plots of wheat, tobacco and indigo (Hooker 1953). And they soon came into conflict with the regions's deer hunters.

As the recent work of historian Rachel N. Klein (1990:51) demonstrates, the backcountry became the scene of ''a deeply rooted social conflict between those [colonists] who relied primarily on hunting for a subsistence and those who did not.'' Unable or unwilling to settle into a life of farming, many backcountry hunters, like Bainton, became vagrants who squatted briefly on unowned land or wandered the countryside in search of deer. Indian wars, particularly the Cherokee War of 1760–61, increased the number of restless hunters in the Carolinas as militia men deserted to a life in the woods (Klein 1990).

At the heart of the problem were the tactics used by the wandering woodsmen. In 1770, William Eddis, the recently appointed governor of Maryland, noted that in the backcountry certain people ''were dexterous, during the winter season, in tracing the deer's path through the snow; and from the animal's incapacity to exert speed under such circumstances, great multitudes of them were annually slaughtered and their carcasses left in the woods'' (Eddis 1969:32). When deer could not be slowed by snow, hunters surrounded the animals with fire, driving them into a confined area where they might be easily slaughtered. Throughout the colonies, it was common practice to pursue deer at night with torches fashioned from pine limbs. Like the modern poacher's trick of jacklighting or shining deer, the torches temporarily blinded and paralyzed the animals so that they became easy targets (Klein 1990, Silver 1990).

Settlers who farmed the backcountry complained loudly and often about such practices. The colonists were not only concerned about the ongoing slaughter of deer, but also about the threats hunters posed to farms and livestock. Legislators took care to answer such complaints when they wrote wildlife law. A North Carolina statute levied fines on those who left deer carcasses in the woods, explaining that the rotting meat attracted ''wolves, bears, and other vermin which destroy the stocks of the inhabitants of this province'' (Iredell 1804:70). South Carolina found it necessary to impose a fine for night hunting because hunters who fired only at a pair of eyes glowing in the dark frequently killed as many cattle and horses as deer. Striking directly at vagrants, South Carolina also made it illegal for colonists to hunt more than seven miles from their homes (Cooper and McCord 1836–39 [4]:310–11, 410–13, 719, [5]:124).

Environmental and Social Implications of the Deer Laws

The exact impact of such measures remains difficult to assess. Colonial legislators found it necessary to renew and refine the game laws throughout the course of the century. Indeed, Virginia imposed a four-year moratorium on commercial deer hunting in 1772. Some scholars believe that the very renewal of such laws suggests their ineffectiveness (Cowdrey 1983).

Yet, the deer never were extirpated from the southern colonies. A decline in natural predators might have aided the whitetail's survival. For, while colonists and Indians slaughtered hundreds of thousands of deer, settlers (with some assistance from Indians) waged a war of equal intensity on wolves and other carnivores that threatened both deer and livestock. In conjunction with the disappearance of predators, the ebb and flow of hunting and warfare, and the deer's capacity for reproduction, restrictions on backcountry hunting might well have helped save whitetails from oblivion (Silver 1990).

If deer endured, outlaw gunners did not. They increasingly became targets of the regulators, bands of vigilantes who sought to rid the southern backcountry of undesirables in the late 1760s. As the backcountry became more like the settled coastal plain, farming triumphed over hunting, and the hunters like Bainton found their way of life destroyed by the emerging plantation society (Klein 1990).

Insights from History

Although vagrant hunters eventually disappeared from the southern backcountry, the lessons of their time should not be lost on modern Americans. One of the simplest of these lessons is that sensitivity and concern for disappearing wildlife began early in the country's history. For lawmakers, that initial concern was economically motivated, spawned from fears of losing a lucrative trade in leather and venison. Even so, early wildlife legislation should not be dismissed only as a half-hearted and unsuccessful attempt at wildlife management. As Cowdrey (1983:56) explains, colonial authorities clearly understood ''the concepts of an endangered species and of extinction.'' Controlling the most destructive backcountry hunters was one way to help ensure that such an abstract concept did not become stark reality.

Moreover, it seems that wildlife conservation was not necessarily incompatible with taming nature. Most of the complaints about southern hunters seem to have come from farmers—those who were most influential in reshaping the colonial countryside. Like lawmakers, backcountry farmers worried about more than the survival of the deer. Free-roaming, fire-setting hunters also threatened crops and livestock. But in a curious sort of way, wildlife became the beneficiary of laws designed to control social tensions on the colonial frontier, legislation intended to make the region fit to farm.

Given such a serious concern for the deer's survival and the changing ecological and social conditions from which it sprang, maybe it is time to offer a more balanced view of colonists and their attitudes toward wildlife. English settlers *were* sometimes guilty of wanton despoilation. The vanquished voices of Carolina parakeets, passenger pigeons and wolves offer silent testimony to colonial carelessness. But as the deer laws suggest, European settlers were also capable of understanding and curbing detrimental practices. Modern Americans can take some solace in that. For, if we are the cultural heirs of an acquisitive and destructive people, perhaps we also have the ability to recognize a crisis in our relationship with wildlife and generate an appropriate response. Certainly outlaw gunners who felt the sting of eighteenth-century law would not disagree.

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References

Byrd, W. 1967. Histories of the dividing line betwixt Virginia and North Carolina. W. K. Boyd, ed., Dover Publications, Mineola, N.Y. 340 pp.

Cooper, T. and D. J. McCord. 1836–39. The statutes at large of South Carolina. A. S. Johnston, Columbia, S.C. 10 vol.

Cowdrey, A. 1983. This land, this South: An environmental history. Univ. Press Kentucky, Lexington. 236 pp.

Crane, V. W. 1964. The southern frontier, 1670–1732. Univ. Michigan Press, Ann Arbor, 359 pp.

Eddis, W. 1969. Letters from America. A. C. Land, ed., Harvard Univ. Press, Cambridge, MA. 237 pp.

Hahn, R. L. 1982. "The trade do's not flourish as formerly:" The ecological origins of the Yamasee War of 1715. Ethnohistory 28:340–58.

Hening W. W. 1819–23. The statutes at large: Being a collection of all the laws of Virginia, from the first session of the legislature, in the year 1619. R. & W. G. Bartow, N.Y. 13 vol.

Hooker, R. 1953. The Carolina backcountry on the eve of the revolution: The journal and other writings of Charles Woodmason, Anglican itinerant. Univ. North Carolina Press, Chapel Hill. 305 pp.

Iredell, J. 1804. The public acts of the general assembly of North Carolina. 305 pp.

Kilty, W. 1800. Laws of Maryland. Research Publications Microfilm, Annapolis, MD.

Klein, R. N. 1990. Unification of a slave state: The rise of the planter class in the South Carolina backcountry, 1760–1808. Univ. North Carolina Press, Chapel Hill. 331 pp.

Lawson, J. 1967. A new voyage to Carolina. H. T. Lefler, ed., Univ. North Carolina Press, Chapel Hill. 305 pp.

Nash, R. 1967. Wilderness and the American mind. Yale Univ. Press, New Haven, CT. 256 pp.

Sale, K. 1990. The conquest of paradise: Christopher Columbus and the Columbian legacy. Alfred A. Knopf, New York, N.Y. 453 pp.

Silver, T. 1990. A new face on the countryside: Indians colonists, and slaves in south Atlantic forests, 1500–1800. Cambridge Univ. Press, New York, N.Y. 204 pp.

White, R. 1983. The roots of dependency: Subsistence. environment, and social change among the Choctaws, Pawnees, and Navajos. Univ. Nebraska Press, Lincoln. 433 pp.

Poachers, Conservationists, and Ecosystems: Local Struggles over American Wildlife

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Introduction

Historians are inevitably story tellers, whose task is to make sense of the past by telling factual stories about it. Environmental historians consider connections between human beings and the natural world, and how they change over time. One such connection between American society and the natural environment is embodied in the practice of wildlife conservation and management.

Today, the wildlife of America is public property, access to which is regulated by federal and state authorities (Bean 1983). Insofar as rights of access are exclusive to a defined group of people (for example, only license holders may hunt) among whom such rights are shared equally (each license-holder has the same rights to wildlife access as any other), American wildlife is a commons resource (McCay and Acheson 1987, Ciriacy-Wantrup 1975). The history of common users and their conflicting claims to commons resources provides useful insights into social and environmental history (McCay and Acheson 1987). We may separate opposing claimants to the American wildlife commons into two categories. On the one hand are local communities, who often claim rights of access to local game on the grounds of particular historical and customary precedent; on the other hand are government authorities and their allies, whose job it has become to administer the wildlife commons from centers of state power, indifferent to local custom. The issue of local response to the imposition of state control over wildlife lies at the heart of wildlife conservation history.

But appreciating the implications of wildlife conservation and its past requires a broader scope. Wild animals exist in a given locale by virtue of particular sets of local environmental conditions; their appearance or disappearance signal important environmental changes. Beyond ecological dynamics, wildlife can also signify radically different things to different people. A bear or a herd of deer can be a prized asset to tourists, but they can also be a nuisance and a threat to locals concerned for their livestock or crops, and some combination of both asset and nuisance to a more ambivalent public. Moreover, while their roles in human society are multifarious, the fact that wildlife populations are prone to seemingly sudden and often unforeseen changes makes their status in human society even more complex.

The history of the wildlife commons concerns the interactions of three historical actors: the state, local people and local ecosystems, of which wild game is a particular extension. The interactions of each actor with the others—always varying with local conditions and local history—have produced individual chapters which intertwine to describe the larger development of wildlife conservation. The ultimate narrative reveals the contentiousness of conservationist attempts to alter human interactions with wildlife, struggles complicated by local environments which are themselves changing in response to human activity.

Trespassers, Poachers and Conservationists: Local People and the State

Until the late nineteenth century, notions of proper humans/wildlife interaction were left to local communities, and their strictures were often more social (hunting was restricted to men, for example) than legal. Some have attributed the gathering of local wildlife into state-administered commons regimes to the large numbers of recreational hunters who became conservationists. Such a character was the Pittsburgh industrialist, John M. Phillips, who became an advocate of game conservation after a hunting trip to Pennsylvania's northern mountains in the 1890s. The forests were heavily cut-over, the game populations reeling from the combined blows of poor habitat and heavy hunting pressure. When he finally tracked a lone deer for some miles and killed it, Phillips reportedly told his friends that he feared he had "killed the last deer in Pennsylvania." He swore never to kill another. Phillips became a prominent advocate of game conservation, eventually serving on the Pennsylvania Game Commission, which he helped create (Sajna 1990, Schultz 1953).

The story of John Phillips and his hunting trip culminates with the removal of wildlife access from the realm of local prerogative, and its transfer to the protective cover of the state's administrative and law enforcement apparatus. Other regions of the country saw similar developments (Reiger 1986, Tober 1981). Early New Mexico conservationists included many ranchers who called for stronger game law enforcement, and some who lobbied for laws allowing them to create private hunting parks containing thousands of acres on their estates (Barker 1970).

As sportsmen/conservationists utilized state authority to resolve questions of wildlife access, local communities were obliged to relinquish control over game resources. Local subsistence and market hunters in rural America faced off against elite recreational hunters like John Phillips, many of them from distant urban centers, who demanded increased state regulation of hunting.

Local response could be violent. In 1906, Pennsylvania game warden Seely Houk was killed and his weighted body dumped in a river, where it remained for weeks. Upon its discovery, the Game Commission ordered an investigation. Pinkerton detectives were dispatched to infiltrate Hillsville, a small Italian immigrant settlement. A two-year investigation yielded a conviction, and in 1909, a local man, the former leader of the town's Black Hand society, was hanged for the murder (Warren 1992).

While it may at first seem extraneous to the larger story of wildlife conservation, this bloody turn of events has a direct connection to the story of the Phillips hunting trip. Both stories highlight the changing place of state authority in the hunting grounds, and together they illustrate how conservationists and local hunters could maintain distinctive relationships with the state. John Phillips and his colleagues joined forces with the state. Local communities, on the other hand, were often unprepared for the state's assumption of control over wildlife access.

Towns, villages, even entire regions were commonly of distinctive social and ethnic composition, and possessed distinctive, culturally-derived tools for regulating their interaction with the local landscape and its resources, including game. In Hillsville, Black Hand leaders were extra-legal civic authorities, prone to violence in defense of their own positions. Seely Houk enforced game laws which severely restricted customary hunting practices such as the killing of song birds, an important food source for the local populace. Between 1903 and 1906, tension in the Hillsville area rose as local English-speaking farmers joined forces with Houk to enforce the new laws against immigrant poachers, who frequently trespassed on farm lands as they violated game laws. Many immigrant hunters threatened Seely Houk's life. Finally, a Black Hand faction murdered Houk, partly to stop his hated anti-poaching patrols and partly because his presence as a state officer threatened Black Hand control over the community (Warren 1992).

The Hillsville case was a particularly hostile exchange in a noisy and sometimes violent confrontation over state game laws which often pitted local communities against state authorities. The extreme violence of the Hillsville story is not typical, though neither is it without parallel. In 1906, the year Seely Houk was killed, poachers in Pennsylvania (many of them Italian immigrants) fired on fourteen game wardens, killing four (Pennsylvania Game Commission 1906). Poachers killed game wardens in Maine in the 1880s and in Florida in 1905 (Ives 1988, Runte 1979). More often, local resistance to conservation manifested itself as poaching, which in many locales is, by now, something of a tradition in itself. In New Mexico, a succession of state game wardens complained for almost two decades about widespread poaching by Indians (New Mexico Department of Game and Fish 1911, Barker 1970). In Montana, Blackfeet Indians continued to hunt game on lands guaranteed to them by treaty well after those lands became part of Glacier National Park (Regan 1983). Whether for food or to maintain customary hunting relationships with animals, but probably out of some complex combination of motives, Indian resistance to state authority demonstrated a preference for the continuance of a local commons, a zone of Indian hunting prerogative beyond the reach of state authority.

Other disputes over wildlife access could also evolve as part of larger disagreements over land rights. In northeastern New Mexico, home to the state's largest private game parks, local for decades objected to being denied access to game in favor of out-of-state hunters who paid landowners for hunting privileges (Barker 1970). In the Hispanic heartland of the state's Sangre de Cristo Mountains, hunting rights on traditional village commons areas became one of a host of issues which led to violence against state authorities. Facing increased enclosure of old common lands by new Anglo landowners, a party of Hispanic villagers attempted to seize their old commons and evict the newcomers in the 1960s. Their grievances were many, including the loss of free, communal grazing to new, individual landowners (Gardner 1970). But in part their action was an effort to seize control of the lucrative local hunting business, largely controlled by the state and the same Anglo landowners they were trying to evict. The rebels announced they would not honor state hunting or fishing licenses on the re-claimed commons, but would sell their own instead (New Mexico Department of Game and Fish 1964). The struggle for control of wildlife access thus became an integral part of larger struggles between local community and extra-local agency.

Wildlife and Ecosystems as Historical Actors

As dynamic as any other actors, local ecosystems have played a crucial role in wildlife conservation disputes. Because of changes in human activities, including hunting, local landscapes change, sometimes in ways so fundamental that certain forms of human interaction with them become impossible.

Within a decade of the Seely Houk murder, farmers were appealing doe-shooting convictions on the grounds that there were too many deer (Commonwealth v. Carbaugh, 45 Pa. C. 67). Into the 1920s, defense lawyers in doe-shooting cases claimed that deer, "if allowed to continue their maraudings," would turn cultivated fields to "thistles, thorns, and briars" (Commonwealth v. Gilbert, 5 Pa. D. & C.:445.). The attorneys in these cases may have been exaggerating conditions to secure their clients' verdicts. But by the 1920s, the Game Commission was concurring with these local critics.

The causes of this shift in human/wildlife interaction and state wildlife policy lay in the dynamics of Pennsylvania's local ecosystems between 1890 and 1920. In this time the cut-over districts—those gameless lands which John Phillips set out to repopulate with deer—had become prime deer habitat by virtue of the secondary succession which covered them with deer forage (Harlow 1984, Pennsylvania Game Commission no date).

But the growth of succession species was co-eval with the growth of state game protection laws. To rural residents such as Clarence Seely of Tioga County, the changing landscape rendered laws banning the killing of does redundant. "All the state could or ever would do in the way of legislation," he remarked in 1908, "is not a drop in the bucket compared to the protection the deer have from the blackberry briars" (Seely 1908). The combination of obliging local ecosystems and the state's strictures against doe hunting led to a rapid increase in deer populations, until by 1911 authorities reported the expansion of deer populations into "territory where no deer have been found in a wild state for many years" (Pennsylvania Game Commission 1911).

As the state grappled to adjust the commons regime to this rapidly expanding pool of resources, they faced new opponents. The commission organized its first doe hunting season in 1923. But loud condemnation by sportsmen—once the state's staunchest allies in conservation matters—resulted in the hunt's cancellation. It took several years of bitter fighting before the commission held a doe hunt. Ultimately the better health of the deer and the support of local farmers brought a new consensus on the doe hunts, which became a standard, if somewhat controversial, game management tool by 1930 (Gordon 1937).

Ecosystem dynamics played a large role in conservation debates elsewhere, but sometimes in very different ways. Complaints of deer overpopulation and range deterioration in the Black Range of southwestern New Mexico led the state to open a twelve-day, either-sex special season in 1931. As in Pennsylvania, the outrage of sportsmen's groups divided the game commission's customary constituency.

The hunt proceeded, but only on 1 percent of the available deer range, and it left a lasting and bitter legacy because of ecosystem dynamics unique to the area. Rather than recuperating after the 1931 special season, the herd declined, shrinking between 65–90 percent in the years from 1927 to 1960. The reasons are obscure, but include a series of drought years, the sharing of range with cattle and heavy pressure on forage from the large deer population which remained after 1931, since a short season on so small an area could not reduce the herd enough to stabilize it. Primary deer forage in the area were mountain mahogany and oak, which were deteriorating in the 1930s and had all but disappeared by 1960. The deer population followed forage availability downward (Stewart 1962).

Ironically, the declining deer population was partly a function of the sportsmen's desire to protect the game. Many local recreational hunters were outraged at the hunt; as the herd continued to decline, their mistrust of the state game authorities grew. Local protests seriously hampered any subsequent doe hunts in Black Canyon, and as late as 1962, state officials reported that either-sex deer hunts in this area "are met with extremely strong opposition," because of local lore which claimed that the deer herd was "exterminated" in the 1931 hunt (Stewart 1962).

Insights from History

In Pennsylvania, New Mexico and elsewhere, local and extra-local contestants to wildlife access discoursed not only with one another, but with the land. Changing patterns of human interaction with the landscape could alter the local ecosystem, often in unpredictable ways. As the landscape altered its appearance and production, the terms of discourse over rights of access to it would also change, even driving wedges between one-time conservationist allies.

Changing local landscapes and battles over access to them brought home time and again in local communities that America was being "de-localized." Towns and communities which ordered their own relationships to the land were becoming parts of national networks, connected to strands in a growing web of market and state power. The processes have continued not only in America, but around the world. We see its occurrence with respect to wildlife in numerous examples in Africa, Latin America and Asia. In more general terms, the increasing integration of rural resources into market economies and government networks implies that rural communities will surrender much of their control over those resources to external authorities. The local relationship to the land and its products thus becomes vulnerable to re-shaping by external forces. What propels and directs that re-shaping, and the re-shaping of local landscape which is part of it, is a fundamental lesson of wildlife conservation history.

References

Barker, Elliott. 1970. A history of the New Mexico Department of Game and Fish. Unpubl. manuscript. New Mexico Dept. Game and Fish, Sante Fe, NM. 111 pp.

Bean, Michael J. 1983. The evolution of national wildlife law. Praeger, NY. 431 pp.

Ciriacy-Wantrup, S. V. and Richard C. Bishop. 1975. "Common property" as a concept in natural resources policy. Natural Res. J. 15(4): 713–727.

Gardner, Richard M. 1970. Grito! Reies Tijerina and the New Mexico land grant war of 1967. Bobbs-Merrill, Indianpaolis, IN. 202 pp.

Gordon, Seth. 1937. Conservation madness. New Mexico Magazine. XV(8): 32.

Harlow, Richard F. 1984. Habitat evaluation. Pages 601–628 *in* Lowell K. Halls, ed., White-tailed deer: Ecology and management. Stackpole Books, Harrisburg, PA. 870 pp.

Ives, Edward D. 1988. George Magoon and the down east game war: History, folklore, and the law. Univ. Illinois Press, Champaign. 352 pp.

McCay, Bonnie J. and James M. Acheson. 1987. Human ecology of the commons. Pages 1–34 *in* Bonnie J. McCay and James M. Acheson, eds., The question of the common: The culture and ecology of communal resources. Univ. Arizona Press, Tucson. 439 pp.

New Mexico Department of Game and Fish, 1911. Rep. game and fish warden. Santa Fe, New Mexico.

———. 1964. Tierra Amarilla land grant dispute. Unpubl. folder. New Mexico St. Records Center and Archives, Sante Fe.
Pennsylvania Game Commission. 1906. Ann. Rep. Board of Game Comm. Harrisburg, PA.
———. 1911. Ann. Rep. Board of Game Comm. Harrisburg, PA.
———. No date. Our deer problem. Pennsylvania Game News. Special issue No. 1.
Regan, Ann. 1983. The Blackfeet, the bureaucrats, and Glacier National Park. Unpubl. paper, Western Historical Assoc. Conf. Billings, MT.
Reiger, John. 1986. American sportsmen and the origins of conservation. Univ. Oklahoma Press, Norman. 316 pp.
Runte, Alfred. 1979. National parks: The American experience. Univ. Nebraska Press. Lincoln. 240 pp.
Sajna, Michael. 1990. The forgotten savior . . . John M. Phillips. Pennsylvania Game News 61(3):11–15.
Schultz, William Frederick. 1953. Conservation law and administration: A case study of law and resource use in Pennsylvania Ronald Press, NY. 607 pp.
Seely, Clarence, 1908. Letter to the editor. Hunter-Trader-Trapper XVI(1): 113.
Stewart, Robert H. 1962. Investigations of big game and ranges: Historical background of the Black Range. New Mexico Dept. Game and Fish, St. Records Center and Archives, Sante Fe.
Tober, James A. 1981. Who owns the wildlife? The political economy of conservation in nineteenth-century America. Greenwood Press, Westport, CT. 330 pp.
Warren, Louis S. 1992 [in press]. The killing of Seely Houk: Immigrants, conservationists, and the black hand in western Pennsylvania. Pittsburgh History: A magazine of the city and its region.

Searching for the Roots of the Conservation Movement: Fish Protection in New England 1865–1900

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In a 1937 address before the Agricultural History Society, Gifford Pinchot, often considered the father of American conservation, explained his perception of the origin of the movement. While riding his horse in Rock Creek Park one day in 1907, it occurred to him that the various resource problems of the day "actually constituted one united problem. That problem was the use of the earth for the permanent good of man." Pinchot discussed his idea with a group of Roosevelt administration insiders, and Overton Price suggested they call this new approach conservation. ". . . the President said 'O.K.,' " Pinchot continued, "So we called it the conservation movement" (Pinchot 1937).

Pinchot's reflections are at once facile and penetrating. Certainly, viewing resources as an integrated science is a profound idea, but Pinchot was far from the first to discover it. Tracing the origins of the conservation movement has been one of the great quests of environmental history, and, although scholars still disagree on the matter, one thing is clear: it did not spring full-blown from the minds of men like Gifford Pinchot. Rather, I would argue, the movement emerged out of the changing social circumstances of a class of Americans who were most involved with use and abuse of the land. The roots of this movement reach deep into the fertile soil of mid-nineteenth-century rural politics.

I would like to illustrate this by describing fish protection efforts in northern New England between 1865 and 1900. Here, conservation began officially with the founding of state fish commissions within the various state boards of agriculture. By the 1890s, however, the agricultural constituency for conservation began to dissipate, and the torch passed to a new class of sporting enthusiasts. This transition was not an easy one, but it was an important step in protecting wildlife.

Located, for the most part, on the margins of the market economy, the farm households of northern New England typically combined nonspecialized agricultural production with a variety of supplemental wage, handicraft and forage incomes. As diversified petty producers working in intimate contact with nature in a variety of circumstances, New England farmers took an active interest in the landscape around them, a landscape they invariably viewed with a commercial eye.

When settlers first moved into the region in the 1770s, hunting, fowling and fishing had played a key role in maintaining this mix of activities. Forests and meadows provided berries, herbs, roots, wood and other resources for a variety of purposes, and lakes and rivers offered a staggering bounty of fish. These forage items supplemented meager agricultural returns, and pioneer families relied heavily on this resource while they prepared the land for agriculture (Weeks 1860, Bell 1888, Moore 1893, Somers 1899). Although a maturing farm economy, and local extinction of many game and fish species reduced this dependency, hunting and fishing retained powerful symbolic associations with a mythical pioneer past.

To enhance the bounty of this landscape, townspeople began transplanting bass, trout, pickerel and eels into local waters and petitioning their state legislatures for local control over close times and fishing equipment. Those in Greene, Wales and Webster, Maine, for instance, informed the legislature that they had stocked a nearby pond with pickerel, and "but for the wanton, and improper destruction of them at the season of spawning, there is no doubt an abundant supply of this delicious and wholesome fish might be had at all proper seasons." The petitioners asked for a closed season between October and June for five years (Ham 1850). Hundreds of similar petitions in Maine, Vermont and New Hampshire attest to the popularity of experimental stocking and protecting local waters. The object was to recreate this important forage component of traditional farming—to insure, as one petitioner put it, that "at most times a man might get himself a decent mess of fish with little pains" (Anonymous 1828).

In the mid-nineteenth century, these experiments were absorbed into a regional agricultural reform movement aimed at improving the landscape for commercial extraction. This spirit of improvement—a conviction that every rock and rill of the New England landscape could be made to "pay" in some way or another—was triggered by a wave of uncertainty in upland New England brought by market changes, western produce competition, soil exhaustion and outmigration (Wilson 1936, Bassett 1952). Farm journals, farmers' clubs, agricultural boards and, later, grange leaders advanced a variety of panaceas. While opinions differed, they all shared an underlying premise: farmers should use their resources more intensely (New Hampshire Board of Agriculture 1873).

The New England legislatures expressed this faith in more intensive land use by funding a series of geological surveys. The Maine Board of Agriculture hoped, for instance, to expose the state's "soils, its muck beds, its marine manures, its rocks, its minerals, its . . . quarries . . . its forest lands, [to] . . . the scrutinizing eye of the minerologist, the chemist, and the geologist" (Maine Board of Agriculture 1859). Locally, farmers experimented with new uses for salt marshes, mucks, woodlands and exhausted pastures. In this atmosphere, unused farm property was a moral blight. Wetlands, "those repulsive . . . little swamps and marshes. . .promiscuously seen in the midst of fertile lands . . .," J.W. Seely (1845) wrote in the New York *Cultivator*, "baffle the industry . . . of the agriculturist . . . ."

With the same "improving eye," rural reformers turned to fish breeding to generate another "crop" from these unproductive wetlands. "I beg to call your attention . . . to a comparatively new kind of farming," W.W. Fletcher (1872) told the New Hampshire Board of Agriculture, "which we will call aquaeculture, or a judicious farming of our water surface." Ezekiel Holmes (1862), editor of the *Maine Farmer*, traveled across the state visiting farmers who experimented with fish ponds and reported that Maine's waters could be made as productive as the land, if farmers would plant fish. Seth Green (1889), who pioneered fish culture in New York, claimed that an acre of water would "produce as much as five acres of land, if it were tilled with equal intelligence."

Farm leaders also advocated restocking New England's public waters to supply food and recreation for farm families. Most favored species that would multiply quickly and complement traditional forage practices. Trout, the "gentlemen's fish," Ezekiel Holmes advised, required unconscionable pampering and could be stocked only in small, potentially exclusive locations. The fish for the masses, he suggested, was smelt or Great Lakes white fish—both hardy, common breeds that would proliferate quickly, provide good fun for local populations and yield abundant commercial harvests (Maine Farmer, March 23, 1865).

Interest in fish cultivation led to the creation of state fish commissions in New Hampshire (1864), Vermont and Massachusetts (1865), Connecticut and Pennsylvania (1866), and Maine (1867), all as departments within existing state agricultural boards. Using minuscule appropriations and private contributions, the new commissioners pioneered fish culture, drawing upon the experiences of their farmer predecessors. These experiments began the slow transformation from folk wisdom and local observation to a new science of ''aquaeculture.'' Speculations about fish conservation broadened as fish culturists transplanted various species and observed the relation between deforestation and declining fish stocks in local streams and rivers (Marsh 1857).

Yet, the rationale for fish conservation remained rooted in the traditional natural philosophy of New England farmers. Farmers viewed their own activities in the context of devine or natural rhythms, a teleological viewpoint in which natural forces operated to serve human needs. Nature ''humbles herself'' to serve the farmer, one journalist explained: rocks wasted away to renew the soil; rain and snow fertilized the ground; lightning purified the atmosphere; and frost broke up the hardened soil. ''All nature, from the rolling sun . . . to the crawling insect . . . are his, and operate for weal or woe, in aiding him in his designs'' (Bacon 1840). Anadromous fish runs illustrated this grand design. Seasonal spawning runs brought fresh salmon and shad, loaded with the fat of the ocean, into the rural interior when stores of protein were low on the farms. (Commissioners of Fisheries of the State of Maine 1879).

Nature was not only divinely ordained to meet human needs, but it was superabundant: spawning runs produced millions of eggs regularly that were simply wasted. Impressed with the natural fecundity of fish, the commissioners were universally optimistic: ''The spawn from half a dozen pair of trout per annum would furnish young fry enough to make good fishing in any brook in the State,'' Vermont's commissioners proclaimed (Vermont commission on restoration of seafish 1866). In time, the science of aquaeculture would become so exact that fish breeders, like farmers, would need only to ascertain the level of demand in a particular river, stock the appropriate number of eggs, and protect the crop as it matured.

Such unbounded optimism disappeared from the fish commission reports almost immediately. In the late 1860s, commissioners began a long and frustrating legal battle to force dam owners on New England's great rivers to install fishways. They succeeded, but faced new challenges from an ever-increasing number of dams, hostile commercial fishermen and poachers, and rising levels of pollution. By the late 1880s, long lines of dead perch, chub and other small fish were appearing below the new pulp and paper mills with unnerving regularity. Penobscot salmon, the last viable run on the Atlantic coast, struggled through a formidable gauntlet of weirs, nets, polluted waters, dams, spears and gaffs each season. The catch dropped from 25,000 fish to 2,000 between the 1850s and 1890s.

By the 1890s, frustrations with dams, overfishing and pollution made two things clear: first, natural propagation alone could never sustain the levels of fishing that had developed by this time; fish populations were dependent locally on artificial stocking. Second, fish were not replaceable at virtually any level demand, as commissioners originally thought (Fish Commissioners of New Hampshire 1883). Rising pressure from sport and commercial fishermen meant that fish stocks would have to be rationed carefully. Fish were an increasingly scarce commodity generated by the state commissions—no longer the natural resource farmers had harvested as part of a forage economy in the first half of the century.

These two lessons altered fish conservation strategies profoundly. As fish stocks became an artificial resource, state agencies assumed a stronger proprietary interest. Hatchery fish, a Maine report explained, were "the commission's spawn . . . not nature's bounty" (Commissioners of Fisheries of the State of Maine 1882). In fact, by the 1890s, all Maine's hatcheries were privately run by angling associations. This policy saved the state money, but it pitted sportsmen and the commissioners against forage-fishermen, whose assumptions about harvesting this open-access resource dated back to colonial times.

The 1890s brought other changes in the philosophy of fish conservation. On one hand, trout and salmon were coming into vogue among wealthy metropolitan anglers. On the other, interest in fish breeding declined among farmers as they abandoned traditional mixed husbandry for specialized commercial crops. Increasingly dependent on urban markets for their produce, farmers were more likely to welcome local industries and the dams that blocked migratory runs of fish. Commissioners noted that rural New Englanders were less willing to tax themselves or the local industrial order for the "sole end that a few 'city gentry,' as they express it, may go out and catch the fish" (Commissioners of Fisheries of the State of Maine 1877).

Searching for a stable constituency in this changing world, fish commissioners discovered a new class ally in their fight to protect the fish. New England's growing tourist industry represented substantial political power, and fish and game were essential ingredients in the bid for the tourist dollar. Tourism offered a strong rationale for fish protection, but the concerns of this powerful industry would shift the conservation movement far from its roots in the rural communities of New England.

New restrictions on fish and game in the 1890s brought these two groups into conflict. Farmers had long complained about city anglers who left fires in the woods, disturbed the livestock and trampled meadows (Goldsmith 1857). Writing to a local editor in 1883, one farmer registered his disgust at the perennial talk of fish conservation in Vermont. Despite years of agitation, fish still formed "no very prominent article of food," he observed: "If we are not to have fish, let us have less talk . . . less law, . . . less jealousy of spears, nets, pounds and other devices. . . . Let us protect the farmer's crops from tramping and not worry about the fish" (Vermont Watchman and State Journal January 10, 1883).

Underlying this tension was a disagreement about the philosophy of fishing. Agricultural editors recognized the legitimacy of recreational fishing, but still saw it as a forage activity, unburdened by complicated "sporting" rituals. The *Maine Farmer*, for instance, extolled the virtues of the lowly white perch, which offered "fine sport" for the amateur angler most typical among the paper's readership. A "plain, old-fashioned democratic fish," perch took the bait readily and offered "rare sport to those who love to catch a great many fish in a short time, without any special outlay of skill or labor" (Maine Farmer August 4, 1864). As a philosophy of fishing, this was not exactly Isaac Walton, but most rural New Englanders would have agreed with it.

In previous decades, fish commissioners had endorsed this approach to fishing, but as pressure on fish stocks mounted, their attitude toward traditional forms of recreation changed. Violators—often the type of forage-fishermen who initiated the conservation movement—were termed "a class of vagabonds too lazy to work, too cowardly to steal, who will spear and net the fish upon their spawning beds . . . so long as they can realize the price of a glass of whiskey from their spoil." Few rural citizens shared this sense of outrage; apparently, they lacked "the moral . . . courage to enter complaints or furnish evidence to bring [violators] to justice. . ." (Commissioners of Fisheries of the State of Maine 1872). The growing class distinctions between local fishermen and gentlemen-anglers set the stage for a series of confrontations at the turn of the century.

One of the most prominent was in Maine's Rangeley Lakes district, where, in 1891, a journalist noted a "warm discussion" taking place between bait and fly fishermen. The lakes had become a mecca for genteel anglers anxious to test their skills against the nationally renowned Rangeley trout. Local families, on the other hand, had used the lakes for generations to lay in a supply of fish for the winter. The tensions between these two groups were not subtle; "Some pretty rough titles are given to the bait fishermen," a newspaper correspondent noted, by those who chose the fly as a lure (Industrial Journal May 8, 1891). A group of visiting Boston anglers described the reigning local method: the fisherman "tolled" the waters with refuse and then, using a "jib-boom to bring the fish aboard," he would "derrick [the trout] over his head into the bushes where another would wrestle it into a barrel." Admonished to "play the fish," the local, boosting a fifteen-pound lake trout over his head, retorted: "Play your grandmother!. . . . I ain't here to play, I'm here to fish" (Industrial Journal June 31, 1898).

Maine's fish commissioner, backed by gentlemen-anglers and resort interests, launched a campaign to limit all trout fishing to fly-casting. The proposal drew strong opposition from rural lawmakers who defended the rights of "scores of men, women, and children who enjoy fishing, but had no idea of handling a fly or trolling" (Maine Woods February 24, 1905). Responding to these cross pressures, the Legislature instead limited bait-fishers to four trout or salmon per day, a compromise that acknowledged the conflicting traditions of gentlemen anglers and locals, and still managed some protection for the resource (Judd 1988).

Similar tensions were evident throughout northern New England. Legislative appeals from angling clubs and resort owners for special restrictions were often successful, and a proliferating body of laws pertaining to each lake, species and method of fishing generated great confusion and hostility. Locals opposed the laws pertaining to nearby waters, a commissioner reasoned, "not [so much] that they want to fish, "but because 'Their natural and inalienable rights' have been interfered with, as they think" (Maine Commissioners of Inland Fisheries and Game 1900). In some regions, it was impossible to recruit wardens locally, since enforcement brought reprisals against person and property, or at the least social ostracism (Commissioners of Fisheries of the State of Maine 1877).

The stalemate between farmers and sportsmen was relieved after the turn of the century through a combination of better laws, wardens and publicity. Parties interested in the tourist trade argued before Grange meetings and the agricultural press that tourists left millions of dollars yearly in rural districts and helped support rail passenger service so important upland farmers. Professionalization also helped mitigate this tension. After the turn of the century, license fees funded a better class of wardens and ended the notorious "half-fee" system—the practice of allowing wardens a portion of the fines they collected. Codification of the laws, making them appear less arbitrary and confusing, helped to break down barriers to wildlife conservation. The years after 1910 brought a growing realization that wildlife protection served both rural and metropolitan needs. The tradition of unobstructed rights to fish and game continued in more isolated areas, but conservationists enjoyed stronger support from legislatures and state agricultural institutions. The public duty to protect game and fish, in the interest of all citizens, achieved a firmer foundation (Judd 1988).

Insights from History

This paper suggests that conservation was not an abstract science, born in the minds of men like Gifford Pinchot, but rather a movement that emerged out of the social development of eastern land-use practices and the give-and-take of competing classes of resource users. Understanding the origins of fish conservation in New England brings an important point into focus: it demonstrates that modern wildlife management is grounded in the experiences, traditions and compulsions of nineteenth-century rural America. Fish conservation was a blend of everyday, practical observation and dogged traditionalism, molded by wrenching changes in New England agriculture. In short, it was a grass-roots phenomenon.

In an age when even organizations like the Sierra Club and Audubon Society have lost touch with their grass-roots constituents, it is important to remember that environmental thought receives its power and direction, not only from its scientific and legal "correctness," but from the way it resonates with popular impulses. As this paper suggests, these impulses change radically over time. Resource agents, arbitrating between contending classes of resource users, manage people as much as they manage nature and, subsequently, they must be keen observers of the changing political and social situation. What fish symbolized in the popular mind was as important as the dynamics of fish populations themselves. To some extent, wildlife is a social science. In this sense, it is almost impossible to imagine a "universal" or "abstract" approach to managing the resource.

References

Anonymous. 1828. Petition, May 31, 1828. Box 18, 1828–1830, New Hampshire Records Management and Archives, Concord.

Bacon, W. 1849. Study of the natural sciences. Cultivator. 6 (July): 200–09.

Bassett, T. D. S. 1952. Urban penetration of rural Vermont, 1840–80. Ph.D. dissertation, Harvard Univ., Cambridge, MA.

Bell, C. H. 1888. History of the town of Exeter, New Hampshire. J. E. Farwell and Company, Boston, MA.

Commissioners of Fisheries of the State of Maine. 1867–1888. Ann. reports. Sprague, Owen and Nash, Augusta, ME.

Davies, R. S. 1972. History of the Penobscot River: Its use and abuse. M.A. thesis, Univ. Maine, Orono.

Fish Commissioners of New Hampshire, 1869–1880. Ann. reports. John B. Clarke, Manchester, N.H.

Fletcher, W. W. 1972. Cultivating the waters. New Hampshire Board of Agriculture. John B. Clarke, Manchester, N.H.

Goldsmith, M. 1857. The increase and preservation of fish and game. Pages 1–7 *in* G. P. Marsh, Report made under authority of the legislature of Vermont, on the artificial propagation of fish. Free Press, Burlington, VT.
Green, S. 1889. Fish culture. Pages 40–43 *in* Fish Commissioners of New Hampshire. John B. Clarke, Manchester, N.H.
Ham, A. J. 1850. Petition of A. J. Ham and 44 others, inhabitants of Green Wales, and Webster, praying for an act to prevent the destruction of pickerel in Sabattis Pond. Box 250, chapter 62, Maine St. Archives, Augusta.
Holmes, E. 1872. Dr. Holmes' report on the fishes of Maine. Second annual report upon the natural history and geology of the state of Maine. Sprague, Owen and Nash, Augusta, ME.
Industrial Journal. 1884–1904. Bangor, ME.
Judd, R. W. 1988. Reshaping Maine's landscape: Rural culture, tourism, and conservation, 1890–1929. J. Forest Hist. 32 (4):180–190.
Maine Board of Agriculture. 1857–1892. Agriculture of Maine. Stevens and Sayward, Augusta.
Maine Commissioners of Inland Fisheries and Game. 1900–1904. Ann. repts. Augusta, ME.
Maine Farmer. 1864–1910. Augusta, ME.
Maine Woods. 1897–1905. Phillips, ME.
Marsh, G. P. 1857. Report made under authority of the legislature of Vermont, on the artificial propagation of fish. Free Press, Burlington, VT.
Moore, J. B. 1893. History of the town of Candia. George W. brown, Manchester, N.H.
New Hampshire Board of Agriculture. 1871–1891. New Hampshire agriculture. John B. Clarke, Manchester, N.H.
Perry, F. J. 1894. From colonization and depredation to conservation and education: Progress report of the Vermont Fish and Game Department. Unpubl. rept., Vermont St. Archives, Montpelier.
Pinchot, G. 1937. How conservation began in the United States. Ag. Hist. 11 (4):262–263.
Seely, J. W. 1845. Draining marshes and ponds. Cultivator 2 (Oct):305.
Somers, A. N. (1899). History of Lancaster, New Hampshire. Rumford Press, Concord, N.H.
Vermont Commission on Restoration of Sea-Fish to the Connecticut River and its Tributaries. 1866. Report. Freeman Steam Printing, Montpelier, VT.
Vermont Watchman and State Journal. 1877–1885. Montpelier, VT.
Weeks, J. M. 1860. History of Salisbury, Vermont, A. H. Copeland, Middlebury, VT.
Wilson, H. F. 1936. The hill country of northern New England: Its social and economic history, 1790–1830. Columbia Univ. Press, N.Y.

Wildlife and Irrigation Systems Along the Snake River, Idaho

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During the early twentieth century, people often envisioned Idaho's irrigated landscape in strikingly mechanistic terms. In their imaginations, the land resembled a factory or laboratory, a place in which farmers, with scientific precision, assembled nature's raw materials—soil, water, plants—into industrial products. In 1911, journalist W.F.G. Thacher conjured such a scene after visiting the Twin Falls South Side irrigation project. "Here," said Thacher, "agriculture is reduced to one of the exact sciences. The farmer knows the elements of his soil; he knows the amount of water he has to depend upon; he knows practically what the weather will be. He proceeds like a chemist in his laboratory."

Such words resonated among farmers, engineers, journalists and other people who believed that irrigation agriculture gave humans an unusual degree of control over the environmental conditions in which they raised their crops. In Idaho, however, the hopeful proponents of irrigation never achieved such technical mastery. Idaho irrigators did create a vastly productive agriculture, but nature never allowed them to turn their farms into laboratories.

Ultimately, natural processes as much as human design shaped the irrigated landscape of southern Idaho. More precisely, a reciprocal interaction between people and nature created it. Irrigators repeatedly attempted to establish technological control over the environment, but with each attempt, nature responded in unexpected, often uncontrollable ways. As nature changed, irrigators tried yet again to shape, control and exploit it, even taking advantage of the opportunities that its changes seemed to offer them. Gradually, this interplay created a new landscape that consisted of much more than just the sterile canals, static monocultures and degraded "ecosystems" typically associated with industrial agriculture in the American West. This was a complicated, dynamic, richly ironic landscape, one that reflected a conjuncture of human ambition and natural processes.

Wild animals constituted an important part of southern Idaho's irrigated landscape. The types and numbers of wildlife in irrigated areas resulted from a process in which irrigation agriculture first destroyed certain habitats and then created others. By building dams, canals and farms, irrigators ruined the habitat of particular fish, bird and mammal species. Much of this destruction, of course, was the logical extension of the farmers' and engineers' quest to impose their technical mastery on nature. Yet, while the irrigators were destroying—uprooting and burning sagebrush, plowing fields, digging canals and damming rivers such as the Snake—they also were unwittingly providing new kinds of habitat for other wild animals. And ironically, the wild animals that eventually flourished in these new habitats clearly showed that the scientific control of nature, finally, could only be achieved in the human imagination.

Irrigation destroyed and created wildlife habitats in all parts of the environment, but streams were perhaps most affected by this transformation. Dams, reservoirs and irrigation diversions created a new aquatic environment in creeks and rivers that often was inhospitable for fish such as native trout and salmon (*Oncorhynchus* spp.) (U.S. Fish and Wildlife Service 1960, Simpson and Wallace 1982, Caldwell and Wells 1974). Dams and irrigation diversions disrupted their migration and spawning runs. Some fish, particularly trout, entered irrigation systems only to end up in fields or stranded in canals (Goulder 1877). Warm temperatures, along with nitrogen and phosphates from fertilizers and livestock excrement, promoted the growth of algae and other aquatic plants; these plants, in turn, deprived trout, salmon and other fish of oxygen. Reservoir ''drawdowns'' and irrigation diversions, particularly during periods of decreased precipitation, exacerbated the harsh conditions.

Certain fish, however, found the new aquatic environment invigorating, and these species flourished. Natives, such as Utah chub (*Gila atraria*) and suckers (*Catostoumus* spp.), thrived in the warm, deoxygenated, muddy water, as did numerous introduced species. Carp (*Cyprinus carpio*), brought to Idaho in the 1880s and 1890s (Linder 1963), probably best exemplified the ability of introduced fish to proliferate in the aquatic environment of irrigation. Carp bred rapidly in sluggish streams, in the slack of reservoirs, in the warm, turbid waters that contained plentiful aquatic vegetation. Moreover, through its feeding habits, carp edged out its competitors; it ate voraciously, and by rooting in the mud for plants, stirred up sediments that made the water intolerable for fish needing cleaner conditions. Carp was ideally suited to aquatic habitats shaped by irrigation, and Idahoans, to their dismay, eventually found that they could not destroy the fish in its new home (Linder 1963, Mauer 1978).

Proliferating beyond human control, carp demonstrated that the ecological transformation wrought by irrigation in Idaho streams did not just entail the destruction of ''native'' fish and their habitat. More than that, the transformation resulted in an entirely new aquatic environment, one that easily sustained fish such as carp. And in a sense, the original fish, species such as salmon and trout, were more ''foreign'' or ''alien'' to this new environment than the carp itself. Indeed, because salmon and trout could no longer easily survive in creeks and rivers heavily altered by irrigation, humans had to breed them in hatcheries before transferring them to streams. Carp required no such artificial nurturing; they, unlike their weaker salmonid cousins, truly ran ''wild.'' In a sense, carp became the dominant ''native'' fish of the habitat that irrigation had created. That people subsequently scorned the carp as a ''trash fish'' detracted nothing from its supreme ecological victory.

As carp and other fish took over streams altered by irrigation, residents of the Snake River Valley found new, more ''artificial'' habitats for fish such as trout. Irrigation agriculture had inadvertantly created three habitats, too. Drainage ditches, which collected seeping irrigation water, provided suitable habitat for fish. Drain water could be relatively clean and of even temperature, and often flowed the entire year. Idahoans introduced trout and other fish into irrigation system drains; during the 1920s, for instance, the Ada County Fish and Game League stocked Boise Valley drainage ditches with fish (The Idaho Farmer 1927b, *see also* Grebe 1938).

Drainage water from irrigation also provided opportunities for aquaculture. Irrigation water on the Snake River Plain infiltrated a huge underground aquifer which discharged as springs in the Snake River canyon between the Twin Falls area and Bliss. Geologists estimated that between 1902 and 1956, irrigation had increased the volume of the springs by more than 50 percent (Crandall 1953, Mundorff et al.

1961). The springs, augmented by irrigation seepage, offered fish propagators an outstanding source of clean water which remained at a relatively constant temperature (Klontz and King 1975, The Idaho Statesman 1972, Gramer and Rosenwald 1980). Jack Tingey, a Utah Fish and Game Department official, established the first successful commercial fish farm in the canyon in 1928, near Thousand Springs. By 1975, food fish companies operated at least fourteen fish farms in the area, raising mostly trout. The U.S. Fish and Wildlife Service also maintained a fish hatchery in the canyon, near Hagerman.

During the 1970s, availability of water from irrigation facilitated an expansion of aquaculture into the area around Twin Falls (Klontz and King 1975, Gramer and Rosenwald 1980). Farmers, working under contract to fish companies, constructed trout ponds on their lands. Irrigation drainage systems supplied most of the water for the ponds. Some of the drainage water, however, flowed not from artificial drains but from seemingly natural "springs," places at which seeping irrigation water emerged from the ground.

Aquaculture demonstrated the extent to which irrigation had facilitated the drastic alteration of fish habitat along the Snake River in southern Idaho. But just as irrigation affected fish, so did dams, canals and farms alter the habitat of birds.

Irrigation agriculture drove birds from the landscape, replacing large areas of wild vegetation with cultivated fields. The sage grouse (*Centrocercus urophasianus*), for instance, declined in number as settlers cleared large sagebrush tracts to make way for crops (U.S. Fish and Wildlife Service 1960).

Conversely, irrigation agriculture provided habitat for numerous bird species. Native birds, including the magpie (*Pica pica*), thrived around irrigated farms (The Idaho Farmer 1927a). Introduced species, such as the English sparrow (*Passer domesticus*), also quickly adapted to the irrigated landscape (The Idaho Farmer 1919). In a way, these birds were the avian equivalent of suckers and carp, because they flourished in a habitat shaped by human activity. And as their numbers increased, they contradicted the notion that irrigation had allowed humans to create an agriculture that they could precisely regulate. Through irrigation, Idahoans did produce high yields, but they always had to consign part of their yields to nature, to birds such as the sparrow. Idaho farmers, like other tillers of the soil, hated the sparrow, but such sentiments only indicated the success of the bird in adapting to the irrigated landscape.

Irrigation agriculture, however, also provided habitat for birds that humans found more desirable. During the late nineteenth and early twentieth centuries, people brought several species of "game birds" to Idaho, most prominently the ring-necked pheasant (*Phasianus colchicus*) (Allen 1956, Caldwell and Wells 1974, Salinger 1950). The irrigated landscape provided pheasants with an outstanding habitat (Lauckhart and McKean 1956). Although nominally wild, the pheasant lived around farms, feeding on crops and taking cover in fields and among the weeds and other wild plants growing rank along fencerows, canals and drainage ditches. At times, however, birds such as the pheasant carried on a tenuous existence in farm lands (Fish and Wildlife Service 1960, Caldwell and Wells 1974, Salinger 1950). Agricultural activities—and farm animals, such as dogs and cats—often destroyed their nests. After World War II, the expansion of sprinkler irrigation, more intensive land use and the consequent destruction of habitats, particularly fencerows, reduced their numbers.

(This did not bother some farmers, who considered the pheasant a pest like the sparrow.) To maintain pheasant populations, Idahoans bred the birds in state-run game farms; like salmon and trout, they best survived when humans artificially nurtured them.

Birds such as pheasant most often found habitat in irrigated fields, but many avian species also flocked to Idaho's irrigation reservoirs, which offered resting and feeding sites and, on occasion, places to nest. During the early twentieth century, thousands of birds congregated around these large bodies of water—American Falls, Lake Walcott, Lake Lowell and others. Taking note of the birds, government officials decided that the reservoirs would serve a secondary role as wildlife refuges. In 1909, an executive order established ''bird reservations'' (later national wildlife refuges) at two of these, Lake Walcott (Minidoka Bird Reservation) and Lake Lowell (Deer Flat Bird Reservation) (Palmer 1916, Dille 1916). At Deer Flat, wildlife managers eventually maintained grain and alfalfa fields, and even sowed the reservoir mudflats with barley and corn to provide refuge birds with feed (Dart 1950). Minidoka was more satisfactory as a bird refuge than Deer Flat; the water level of Lake Walcott fluctuated less then Lake Lowell's, encouraging the aquatic biota on which birds fed and providing a more stable habitat for nests. By the early 1940s, the U.S. Fish and Wildlife Service had enhanced the refuge by installing special cut-off dykes which prevented water from flowing out of shallow arms and inlets when the reservoir level dropped (Gabrielson 1943).

Just as reservoirs provided birds with habitat, so did irrigation agriculture inadvertently provide numerous mammalian species with places to feed and reproduce. Destruction, as always, preceded this creation of habitat. As irrigators built canals, ditches and farms, they closed parts of the landscape to many mammals, especially in low lands and riparian areas along creeks and rivers (U.S. Fish and Wildlife Service 1960). Yet, as particular mammalian habitats disappeared, certain wild mammals moved in to occupy the new habitats that irrigation agriculture created.

Aquatic environments associated with irrigation and drainage systems, for example, attracted large numbers of beaver (*Castor canadensis*) and muskrats (*Ondatra zibethicus*). Within these new and unique riparian habitats, beaver and muskrats found ample plant food and home sites (*see* Neal 1931, Peters no date). Willow trees (*Salix* spp.) and other plants provided nourishment for beaver, which burrowed into canal banks to make their dens. Beaver also used willow and other vegetation for dam building. Muskrats found a favorite food in the fleshy, starchy roots of cattails (*Typha* spp.), which grew luxuriantly in many canals and ditches. Like beaver, muskrats made their houses in the banks of these waterways.

Farm ponds, small irrigation laterals, drainage ditches and other low places where seeping irrigation water collected, offered particularly important habitat for beaver and muskrat (Neal 1923, Neal 1941, Twin Falls Canal Company [TFCC] 1953). Often untended or sporadically maintained, these places provided a more secure environment than irrigation canals. Irrigators would not tolerate beaver and muskrats in their irrigation systems, and they attempted to remove the animals, usually by trapping, if they discovered them there. In addition, irrigation companies and districts eventually adopted the practice of closing and draining canals each autumn, which made canals inhospitable for beaver and muskrats. Thus, when a canal company ''turned out'' the water each autumn, beaver and muskrats migrated from the canals to drainage ditches and other wet places within the irrigated landscape. There they reproduced and come spring repeated their attempts to establish themselves in the main canal system.

Besides beaver and muskrat, several other wild mammals flourished in conjunction with the expansion of irrigation agriculture in Idaho's Snake River Valley (*see* Aberdeen-Springfield Canal Company [ASCC] 1923, TFCC 1953, no date, Lovin 1979). Black-tailed and white-tailed jack rabbits (*Lepus townsendii, L. californicus*) periodically migrated from desert land into farm fields, where they consumed tons of hay and alfalfa. Ground squirrels (*Spermophilus townsendii*) dug burrows within fields and adjacent areas, particularly in the banks of irrigation canals and ditches. Their numbers burgeoned as they gorged on cereals and other crops. Pocket gophers (*Thomomys Townsendii, T. talpoides, T. idahoensis*), much like ground squirrels, thrived in and around fields and canals. Feeding on root crops, including potatoes, pocket gopher populations rapidly increased. Squirrels and gophers in turn attracted other mammals which favored them for food. Badgers (*Taxidea taxus*) made their way into irrigation systems, burrowing into canal banks in search of their underground prey. Irrigation also created habitat for the yellow-bellied marmot (*Marmota flaviventris*) or "rock chuck," which made its home in rock piles along canals and irrigated fields.

All of these mammals belied the notion that through irrigation, humans had "conquered" the desert and created an agriculture which they could control with scientific precision. Irrigation, it was true, had produced abundant fields; yet those abundant fields also turned out to be feeding grounds for wild mammals. And farmers did not view these creatures as pernicious pests just because of their crop consumption; by burrowing into canal banks, mammals such as beaver and pocket gopher sometimes caused the canals to break (ASCC 1924, Hodge 1978). Ironically, wild mammals threatened to destroy the very waterways that for many people symbolized man's scientific and mechanistic triumph over nature.

Through hunting, trapping and poisoning, irrigation system managers kept the canals intact, but human institutions ultimately conscribed the efforts of irrigators to exterminate burrowing mammals. Economic, legal and bureaucratic factors, as well as human values, all imposed limits on mammal control programs. Within these limits, irrigators and their allies in government destroyed mammalian "pests"; outside the limits, some wild creatures always managed to survive unmolested.

Economic factors, for example, restricted irrigators' efforts to reduce or eliminate mammal populations. Perhaps most importantly, irrigators and government officials allocated only a limited quantity of resources—time, money, equipment and personnel—for mammal extermination. They took enough action to keep their systems in operation, to keep gopher or muskrat populations from overwhelming their canals, but they would not or could not take stronger measures. They found it more economical, for example, to set traps and lay poison than to line all their canals with concrete (a precaution against breaks caused by burrowing mammals). Thus, to the extent that canals remained unlined, animals such as pocket gopher or muskrat could potentially survive in them.

Economics also limited private trapping and hunting, two activities which removed mammals from canals. Historically, irrigation companies and districts in Idaho relied on independent trappers to take fur-bearers from their canals. But fur prices always influenced the amount of trapping that went on. When fur prices fell, trapping declined, and then populations of muskrat or other mammals increased (Neal 1923, ASCC 1935). Furthermore, trappers had no incentive to take *all* the mammals along a particular section of canal. They trapped only so long as the mammal population in that area rewarded their efforts. Once they reduced the population to a certain level, trappers moved on to more densely inhabited places (TFCC 1921, ASCC 1948). The few remaining muskrats or other mammals then regenerated. Finally, broad economic trends, not just the specific economy of trapping, influenced trapping and hunting. In the Great Depression of the 1930s, people augmented their income by trapping for furs, and by trapping and hunting to collect the bounty that irrigation companies offered for ground squirrel and pocket gopher. But during the 1940s, gasoline rationing, more remunerative jobs elsewhere in the economy and the movement of young men into the military, reduced the amount of trapping in irrigation systems (ASCC 1942, 1945, TFCC 1944). As trapping waned, muskrats and other canal-dwelling mammals increased.

Besides economic conditions, legal and administrative factors limited control programs, thus allowing mammals to survive and perpetuate themselves in irrigated areas. When muskrats and other species moved between quasi-public irrigation systems and private and public lands, property boundaries prevented their human exterminators from pursuing them (ASCC 1948, 1963). And in fact, irrigators and other people did not always want to follow mammals onto someone else's land; according to legal and capitalist conventions, the owner of a piece of property, not his or her neighbors, was responsible for destroying the pests that occupied that property. Landowners, however, were not equally prompt or diligent in the struggle against mammals. Irrigation system managers, for example, frequently called on farmers to trap and poison ground squirrel and pocket gopher so that rodents living on farms would not reinfest recently cleaned canals (ASCC 1925, 1957).

Idahoans soon recognized the necessity of coordinating mammal control among property owners, and they modified their laws and policies accordingly. Beginning in 1907, the Idaho legislature enacted a series of rodent control measures which permitted county commissioners to set up special public funds to assist farmers in extermination efforts (Idaho 1907). In 1919, Idaho established an entirely new rodent control act. This law authorized county commissioners to provide for the destruction of rodents on private property when landowners themselves failed to exterminate the creatures (Idaho 1919). The law also officially united efforts on the county level with the work of public agencies, such as the Bureau of Biological Survey and the Idaho Fish and Game Department.

These measures, although facilitating mammal control in Idaho's irrigated areas, ultimately contained inherent limits. Implementation of the rodent control act required petitions from farmers, identification of areas infested with mammals, coordination between the public and government agencies, and, as always, the allocation of limited resources (*see* ASCC 1939, 1949). While bureaucracy slowly lurched forward, mammals proliferated. Similar administrative factors affected control programs overseen by the Idaho Fish and Game Department. In 1945, for example, the department divided the state into "beaver allotments" in which "caretaker" trappers removed beaver from "problem areas" such as canals (Idaho Fish and Game 1946). But some allotments—at least initially—were too large for caretakers to patrol efficiently, and beaver still managed to enter and damage irrigation systems (Goslin 1946).

In combination with these factors, human values imposed restrictions on control programs, thus allowing the survival of mammals in the irrigated landscape. Unlike irrigators, many people did not view muskrats and beaver as vermin requiring eradication. Because many people valued muskrats and beaver for their furs and even as important wildlife symbols, laws regulated the trapping of them. Farmers sought to amend wildlife statutes, and beginning in the 1920s, the Idaho legislature periodically relaxed the law in response to increases of beaver and muskrats in canals and the corresponding complaints of farmers (The Idaho Farmer 1923). But ultimately, fur trapping regulations still provided beaver and muskrats a measure of security in and around irrigation systems. Laws regulating the use of poison also influenced wildlife in irrigation systems. In the early 1970s, public opposition to poisoning compelled government restrictions on the use of Compound 1080, which made destruction of ground squirrels and pocket gophers more difficult for irrigators (Dance and Isaak 1972, Weston 1972).

Insights from History

Wild mammals, fish and birds demonstrated that the irrigated landscape of southern Idaho did not become the sort of place that its human founders envisioned. Humans established a measure of technical control over this environment and certainly extracted wealth from it, but their ability to dominate and control it, to reduce it to a metaphorical laboratory or factory, was limited. Nature, as wildlife showed, was not so malleable. Rather than manipulating nature at will, irrigators engaged it in a kind of back-and-forth dialogue, a dialectical process that brought into being a new landscape that was both natural and artificial.

Wild animals in the irrigated landscape were important consequences of this historic interaction between nature and humans. Animals such as carp, muskrat and magpie were, to a large degree, present in this environment because of natural factors. They lived according to their own biological imperatives, and to the extent that humans could not control them—introduced carp as much as native muskrat—they were wild. Yet such animals did not just live in nature, for they were also, in a sense, artifacts of human history and culture. They lived and sometimes thrived in habitats that humans had created—reservoirs, irrigated fields and canals. Their presence, at least in part, represented choices that humans had made. Many people today disdain the carp, but irrigators in the nineteenth century brought it to Idaho because they valued it. Irrigators viewed muskrats—" 'rats"—as a kind of vermin, but society protected them behind the law. Finally, human institutions or systems—the economics of fur trapping, for example—influenced the survival and population size of wildlife in irrigated areas.

To better understand Idaho's irrigated landscape and its wildlife, we must avoid comprehending it in the same simple terms as the irrigators of the early twentieth century. They believed that humans retained the power to manipulate the land—and its animals—to their liking. When we in the present view the irrigated landscape solely as an artificial place, or as an ecological wasteland, then we—like the early irrigators—ascribe to ourselves a degree of power over nature that we do not really have. Perhaps more importantly, when we view the irrigated landscape as purely "man-made" or simply as an ecological victim, we obscure its history and ignore all of the complicated and contingent processes that went into its creation. To better understand this landscape, we must view it as a product of history, as a consequence of a dynamic, reciprocal interaction between humans and nature that is, in fact, still at work. We must, finally, try to understand this landscape on its own terms, not according to ideal standards that we impose upon it.

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References

Aberdeen-Springfield Canal Company [ASCC]. 1923. Watermaster's annual report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1924. Manager's annual report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1925. Manager's annual report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1935 November 19. Letter to R. Mitchell et al. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1939. Annual report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1942. Annual report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1945. Annual report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1948. Manager's report to stockholders. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1949. Manager's report to stockholders. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1957. Annual report to stockholders. Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1963. Annual Report. Aberdeen-Springfield Canal Co., Aberdeen, ID.
Allen, D. 1956. Pheasants in North America. Stackpole Books, Harrisburg, PA. 490 pp.
Caldwell, H. H. and M. Wells, 1974. Economic and ecological history support study for a case study of federal expenditures on a water and related land resources project: Boise Project, Idaho and Oregon. Idaho Water Resour. Res. Inst., Moscow. 180 pp.
Crandall, L. 1953. March 31 Ground water flows of the Snake River plain. Idaho/Reclamation of Land vertical file, Idaho Room, Idaho Falls Public Library, Idaho Falls, ID.
Dance, M. and E. Isaak. 1972. March 14 Letter to Len B. Jordan. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.
Dart, S. 1950. Deer Flat National Wildlife Refuge, Nampa, Idaho, narrative report, May 1 to August 31, 1950. Deer Flat Nat. Wildl. Refuge files, Nampa, ID.
Dille, F. M. 1916. The Minidoka National Bird Reservation, Idaho. Reclamation Record 7(12):564–565.
Gabrielson, I. N. 1943. Wildlife refuges. MacMillan, NY. 257 pp.
Goslin, I. 1946. June 6 Letter to Melvin W. Smith. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.
Goulder, W. A. 1877. The valley of the Boise. The Idaho Tri-Weekly Statesman. May 29:2(cols. 1–4).
Gramer, R. and L. Rosenwald. 1980. Trout farmers routinely rely on farm ponds. March 9. The Idaho Statesman. Fish and Fishing (Trout) vertical file, Idaho Historical Soc. Archives, Boise, ID.
Grebe, G. W. 1938. What is or should be the status of wildlife as a factor in drainage and reclamation planning. Trans. N. Am. Wildl. Conf. 4:119–124.
Hodge, K. 1978. Rodents breach canal. . .[?] Twin Falls Times-News. May 12. Clippings of Conveyance of Water to the Canyon View Project file, Twin Falls Canal Co., Twin Falls, ID.
Idaho. 1907. General laws of the State of Idaho. Syms-York, Boise, ID. 618 pp.
Idaho. 1919. General laws of the State of Idaho. 653 pp.
Idaho Fish and Game Warden. 1946. Twenty-first biennial report, Fish and Game Warden of the State of Idaho. Idaho Fish and Game Dept., Boise. 65 pp.
Klontz, G. W. and J. G. King. 1975. Aquaculture in Idaho and nationwide. Idaho Dept. Water Resour., Boise.
Lauckhart, J. B. and J. W. McKean. 1956. Chinese pheasants in the northwest. Pages 43–89 *in* D. Allen, ed., Pheasants in North America. Stackpole Books, Harrisburg, PA. 490 pp.

Linder, A. D. 1963. Idaho's alien fishes. TEBIWA: The Journal of the Idaho State Museum 6(2):12–15.
Lovin, H. T. 1979. Sage, jacks, and Snake plain pioneers. Idaho Yesterdays 22(4):13–24.
Mauer, R. 1978. Plan abandoned to kill Lake Lowell carp. The Idaho Statesman. October 14:1b(cols. 2–6).
Mundorff, M. J., E. G. Crosthwaite, and C. Kilburn. 1961. Ground water for irrigation in the Snake River basin of Idaho. *In* U.S. Department of the Interior, Bureau of Reclamation, and Corps of Engineers, Upper Snake River basin, Wyoming-Idaho-Utah-Nevada-Oregon, III:2, Coordination and reports of cooperating agencies, U.S. Geological Survey—Ground Water Branch.
Neal, E. H. 1923 January 13. Letter to Chase Clark. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1931 November 12. Letter to State Game Warden. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.
———. 1941 December 2. Letter to Owen W. Morris. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.
Palmer, T. S. 1916. The Deer Flat National Bird Reservation, Idaho. Reclamation Record 7(5):221–223.
Peters, A. No date. Early history of the Twin Falls Canal Company and my adult life with the company. File 1511.01, Twin Falls Canal Co. Twin Falls, ID.
Salinger, H. E. 1950. Factors affecting pheasant production on the irrigated lands in southern Idaho. M.S. thesis, Dept. Forestry, Univ. Idaho. 103 pp.
Simpson, J. and R. Wallace. 1982. Fishes of Idaho. Univ. Idaho Press, Moscow. 238 pp.
Thacher, W. F. G. 1911. Buhl, Idaho—the land that beckons. Pacific Monthly 24(12):717–718.
The Idaho Farmer. 1919. Untitled news brief. The Idaho Farmer 24(28):5.
———. 1923. Farmers win new game law. The Idaho Farmer 31(19):8.
———. 1927a. Untitled news brief. The Idaho Farmer 39(15):4.
———. 1927b. Untitled news brief. The Idaho Farmer 39(20):4.
The Idaho Statesman. 1972. An honest-to-goodness true fish story. April 30. The Idaho Statesman. Fish and Fishing (Trout) Vertical File, Idaho Historical Soc. Archives, Boise, ID.
Twin Falls Canal Company [TFCC]. No date. Operation of the Twin Falls Canal Company. General Information on the Canal System file, Twin Falls Canal Co., Twin Falls, ID.
———. 1922. Annual report of canal operations for season of 1921. Twin Falls Canal Co., Twin Falls, ID.
———. 1938. Annual report for 1938. Twin Falls Canal Co., Twin Falls, ID.
———. 1944. Annual report of the general manager for 1944. Twin Falls Canal Co., Twin Falls, ID.
———. 1953. Twin Falls Canal Company annual report. Twin Falls Canal Co., Twin Falls, ID.
U.S. Fish and Wildlife Service. 1960. A preliminary survey of fish and wildlife resources, upper Snake River basin. *In* U.S. Department of the Interior, Bureau of Reclamation, and Corps of Engineers, Upper Snake River basin, Wyoming-Idaho-Utah-Nevada-Oregon, III:1, Coordination and reports of cooperating agencies.
Weston, B. W. 1972. March 10 Letter to Frank Church. File 4.07, Aberdeen-Springfield Canal Co., Aberdeen, ID.

The Evolution of American Wildlife Policy

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Since the early nineteenth century, American wildlife regulation has followed a course common to the Anglo culture of English-speaking countries: an increasing public interest in a wider range of wildlife, greater human pressure on wildlife and its habitat, and increasingly complicated programs of preservation, usually justified by science. At the beginning of this period, people were concerned only with species they could use or which harmed them, and no one thought of preservation. The rise of sport hunting in the middle of the century required the preservation of some large mammals and some birds. Government took an active (if negative) role, restricting access to game, then building law enforcement agencies, more recently establishing positive programs of research and restoration. Early in the twentieth century, public demand for nature preservation led to legal protection for most mammals and birds. In the last 30 years, a second wave of interest, grounded in a popular version of ecology, has produced programs that, in theory, include almost all species. A comparison of the United States, Canada, Australia and New Zealand (and other countries settled from and influenced by Great Britain) shows the common culture as well as the specific conditions that have shaped the American system.

Enlarging Wildlife Concerns

Into the nineteenth century, people's interest in wildlife was utilitarian. The law, reflecting that, put bounties on pests and provided for local cooperative action to exterminate them (Palmer 1897, 1912, Tober 1981, Bean 1983). All four countries used these devices taken from English law. They differed primarily in their targets: in North America, mainly wolves, bears and prairie dogs; in Australia, dingoes, kangaroos and European rabbits; and in New Zealand, rabbits. Species useful for food or fur were the subject of regulation, but these were little more than the declaration of very long seasons. There was no special enforcement. Game was regarded as a non-renewable resource that would vanish as the country was settled. Species that offered no profit and caused no loss the law ignored.

Technology and social snobbery made sport hunting popular in Great Britain in the early nineteenth century. Better firearms allowed wingshooting, and Prince Albert's example encouraged others to devote more time and money on their estates to "shooting." The enthusiastic acceptance of this recreation in the colonies (including the cultural colony of the United States) changed the nature and purpose of wildlife law. It produced, in the Australian colonies and New Zealand, the first wildlife laws, in North America, ones that emphasized taking game in sustainable numbers by sportsmanlike methods. The major management tool was a limit on the human kill of game species, set by "common sense." Legislatures gradually supplemented this with a system of wardens, the extent of upper class, later popular, interest in hunting and pressure, or perceived pressure, on game populations determining the vigor of enforcement. Legally, wildlife was treated as the property of the sovereign, a doctrine derived from British law (Bean 1983), but the Australian colonies and New Zealand experimented with private ownership of game. The fate of these trials suggests why the system evolved as it did. Because neither country had species that were socially suitable for hunting (except waterfowl and some upland birds), legislatures allowed ownership of game as an incentive to import and nurture familiar and useful species. Some Australian legislatures, besides giving the landowner property rights, split the fine for violations with him. In New Zealand, the Protection of Animals Act, 1873, provided for the registration of acclimatization societies in defined districts and declared that "the property in all animals and birds in the possession or under the control of any registered acclimatisation society shall be deemed to be absolutely vested in such society."

Sport hunting never caught on in Australia. Settlers' dreams of becoming English squires died with the droughts, the failure of desirable species to take hold and the disastrous success of the European rabbit—introduced,ironically, for sport (Rolls 1979). With much land, few hunters and little pressure on the available native game (mainly waterfowl), law and enforcement remained rudimentary. Early in the twentieth century, the states dismantled the system of private ownership, but even after World War II, some areas had no licenses and very little regulation (Norman and Young 1980). Hunting did become a popular sport in New Zealand, spreading from a small elite in the nineteenth century, to a significant part of the population by the early twentieth (Holden 1987). The acclimatization societies were entrenched by this time, and the government, rather than displacing them, gave them legal powers. The country is now divided into twenty-seven districts, two run by the government, each of the others by the local acclimatization society, which sells a hunting license, hires wardens and enforces regulations. Property has been effectively abolished by allowing anyone to join the society simply by buying a license. The system continues because the government, though allowing private control, has stepped in where private efforts were not sufficient. When rabbits, in the late nineteenth, and deer, in the early twentieth century, became nuisances, they were declared pests and the government paid for control (or had the landowner pay). As scientific studies became necessary, the government undertook them. The system is becoming functionally similar to that in other countries, though legally quite different.

The protection of non-game species added a second new element to wildlife policy. It began in the late nineteenth century, driven by a rising public interest in nature appreciation common to all four countries. The United States was most active, but all the others established some sanctuaries and legal protection for characteristic or unique species. There was, though, little more than formal protection, even for favored species. Australians did not, for example, curb the trade in koala fur until the late 1920s, and bald eagle protection in the United States dates from 1940. Protection, even in national parks, was limited to the species that the tourists wanted to see. Others were ignored, unless they preyed on the "nice" ones, in which case they were shot, poisoned or trapped (Dunlap 1991, Newland 1961, Galbreath 1989).

Older programs continued, and economics and ecological disasters caused governments to take a more active role in pest control. In Australia, in the 1880s, "the rabbit menace" caused the colonies (after 1901 states) to invest heavily in fences and poisons (Rolls 1979, Stead 1928). In the United States, Western stockmen lobbied for, and got in 1915, a federal predator and rodent control program. New Zealand copied Australian techniques to cope with rabbits and, in the early twentieth century, undertook deer control measures to preserve soil and forests (Wodzicki 1950, Caughley 1983). Only Canada undertook no new, large initiatives, and even there the provinces did increase predator control efforts in the early twentieth century.

Protecting Ecosystems

The development of animal ecology and game management in the interwar period, and their application after the war, fundamentally changed wildlife policy. Management's goal had been maximum production of a few favored species. It shifted toward the preservation of all and their habitats. Science (in theory, at least) replaced emotion or common sense as a guide to policy, trained professionals took over from amateurs and complex administrative programs displaced legislative enactments (this last is quite certain). Ecology was an international development and a part of biology. Game management, in contrast, was an American idea, based in applied science. Policy debate began in the United States in the late 1930s, policy changed after World War II. Canada, Australia and New Zealand followed. The first generation of post-war students were an important influence. They returned from work at Oxford spreading the work of animal ecology, from the United States bringing ecology and game management (Crowcroft 1991). They were aided by the formation, in 1949, of national biological research offices in Canada, New Zealand, and Australia. These served as centers for education and administrative homes for programs, and, in all three countries, conscious attempts to build these agencies by hiring the best people they could find led to an influx of new people with new ideas.

The first product of field ecological studies was controversy, for the work often did not confirm or flatly refuted the received wisdom. This was particularly true for pest control. In North America, hunters, stockmen and government officials objected to the conclusions from early ecological studies of coyotes and wolves (Dunlap 1988, Meine 1990). New Zealanders objected when the American biologist Thane Riney, hired in the early 1950s, challenged the conventional links among deer, forests and erosion. (He was even less well liked for showing that there was little overlap between districts where the government concentrated its shooters and those in which erosion was most severe) (Caughley 1983). This was not simply anti-Americanism. When the Ecology Division of New Zealand's Department of Scientific and Industrial Research showed that control measures had little or no impact on rabbit populations, the local board on whose land the project had been done was ''extremely reluctant to accept the implications of this trial'' (Gibb 1983).

Ecology's greatest impact was on public perceptions of wildlife and what it needed to survive. There was, in the post-war years, considerable interest in rare and endangered species. The whooping crane in North America drew an increasing audience through the 1950s. Australians became more interested in protecting the koala, platypus and other distinctive animals. When the takahe, a bird thought to be extinct, was discovered in a remote New Zealand valley in 1948, there was a blizzard of publicity, at least by New Zealand standards. Ecology, a popular and simplified version of which began reaching the public in the 1950s, provided a focus, a way of understanding problems and a guide to their solution. It took, however, a generation for public attitudes to change and pressure to build. North American programs continued to focus on game, those in New Zealand and Australia on economic pests. As late as 1968, a New Zealand commission reviewing wildlife research found that most papers on native birds had been done by officers who had collected data while working on other projects and written up the results in their spare time (New Zealand Commission 1968). In Australia, the success of myxomatosis in reducing the rabbit population allowed federal wildlife officers to do more basic biological work on native species, but progress was slow. The United States began establishing programs of environmental protection in the early 1970s. The other countries had adopted elements of it, either complete or modified for local conditions (*see* Fox 1972, Warren 1987).

Environmental programs have been added to an already complex system. A confusion of agencies seems to be a universal phenomenon. Consider New Zealand, with only 3 million people and no states. In the late 1950s, even before evironmentalism complicated matters, it was geographically divided into twenty-seven districts, twenty-five run by acclimatization societies, and administratively split along other lines. The Wildlife Branch of the Department of Internal Affairs dealt with native fauna and noxious birds, and advised the Minister on game policy; its research section worked on the biology and management of game birds and waterfowl. The Fisheries Branch of the Marine Department did research on freshwater fish, while the acclimatization societies oversaw regulation. The Ecology Division of the Department of Scientific and Industrial Research was responsible for ecological studies, including those on rabbits. Rabbit control was the duty of the Rabbit Destruction Council, which oversaw the work done by the local rabbit control boards. Deer control was the job of the Noxious Animals Division of the Forest Service (which had taken over this job from Internal Affairs in 1956) (Westerskov 1957). These arrangements are not due to an antipodean fondness for confusion. Between 1963 and 1977, there were ten Parliamentary inquiries into the organization and administration of wildlife laws. All recommended simplification (National Research Advisory Council 1977). That goal has not been achieved. A complicated administration is a reflection of a complicated political reality. Biologically, wildlife is a single subject, but agencies and programs are oriented to human interests, often economic. The single wildlife agency that could serve farmers, stockmen, hunters, nature lovers, bird-watchers and a general public exists only in the mind of a political scientist.

Insights from History

The United States differs from other Anglo countries in the importance people attach to wildlife and their devotion to science as a guide. Both are reflections of American culture. American national identity is wrapped up in the conquest of the wilderness, which was also seen as a source of virtue and national strength. Wildlife regulation has often been based on appeals to this ideology. Sport hunters made the pioneer legacy a major par of their mystique, and nature advocates have often stressed the spiritual refreshment that comes from contact with the natural world. Faith in science and technology has underwritten research and a system to support it—the land-grant colleges, and their associated research and extension divisions. In all modern countries, wildlife management is, in large part, the management of people. In this country, it is, preeminently, the use of modern means to manage their dreams of primitive America.

Note on sources. This paper is based on archival research in the four countries mentioned. Space precludes citation of files and statutes; specific inquiries may be addressed to the author. The author gratefully acknowledges the support of the National Science Foundation (Award Number 8921746).

References

Bean, M. 1983, The evolution of national wildlife law. Praeger, NY. 449 pp.

Caughley, G. 1983. The deer wars. Heinemann, Auckland. 187 pp.

Crowcroft, Peter. 1991. Elton's ecologists. Univ. Chicago Press. IL. 177 pp.

Dunlap, T. R. 1991. Ecology, nature, and Canadian national park policy. Pages 139–147 *in* To see ourselves/to save ourselves. Assoc. Canadian Studies, Montreal.

———. 1988. Saving America's wildlife. Princeton Univ. Press, Princeton. 222 pp.

Fox, E. M. C. 1972. Wildlife conservation, Report from the House of Representatives Select Committee. Govt. Pub. Serv., Canberra. 93 pp.

Galbreath, Ross. 1989. Colonisation, science and conservation. Ph.D. thesis, Dept. Hist., Univ. Waikato. 547 pp.

Gibb, John A. 1983. A Brief review of rabbit research in ecology divisions since the 1950s. Unpubl. paper. Ecology Div., New Zealand Dept. Scientific and Industrial Research, March 1983. Library, Ecology Div., DSIR, Lower Hutt, New Zealand.

Holden, Philip. 1987. The deerstalkers. Hodder and Stoughton. Auckland. 333 pp.

Meine, C. 1988. Aldo Leopold: His life and work. Univ. Wisconsin Press. Madison. 638 pp.

National Research Advisory Council. 1977. Report of the wildlife research working party. Typescript, Turnbull Library, Wellington, New Zealand.

New Zealand Commission of Inquiry on Wildlife Management and Research in New Zealand. 1968. Organization of wildlife management and research in New Zealand. Government Printer, Wellington.

Newland, B. C. 1961. From Game laws to fauna protection acts in South Australia: The evolution of an attitude. The S. Australian Ornithol. 23 (March 1961), 52–63.

Norman, F. I. and C. A. D. Young. 1980. Short-sighted and doubly short-sighted are they. J. Australian Studies, 7: 2–24.

Palmer, T. S. 1896. Extermination of noxious animals by bounties. Pages 55–68 *in* United States Dept. of Agric., Yearbook of the United States Department of Agriculture, U.S. Govt. Print. Off., Washington D.C.

———. 1912. Chronology and index of the more important events in American game protection, 1776–1911. Bull. 41, Bur. Biological Survey, U.S. Dept. Agric., U.S. Govt. Print. Off., Washington, D.C. 62 pp.

Rolls, E. 1979. They all ran wild. Angus and Robertson, Sydney, Australia.

Stead, D. 1928. The rabbit menace in New South Wales. Government Printer. Sydney, Australia.

Tober, J. 1981. Who owns the wildlife?: The political economy of conservation in nineteenth-Century America. Greenwood Press, Westport, CT.

Warren, A. F. J. 1987. Management of endangered species: Policy influences and development in New Zealand. M.S. thesis, Center for Res. Manage., Univ. Canterbury and Lincoln Coll., New Zealand. 85 pp.

Westerskov, K. 1957. Training for the wild-life profession. New Zealand Science Review, 15 (Sept-Oct 1957): 67–75.

Wodzicki, K. A. 1950. Introduced Mammals of New Zealand, Bull. 98. Department of Scientific and Industrial Research. Auckland. Government Printer.

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