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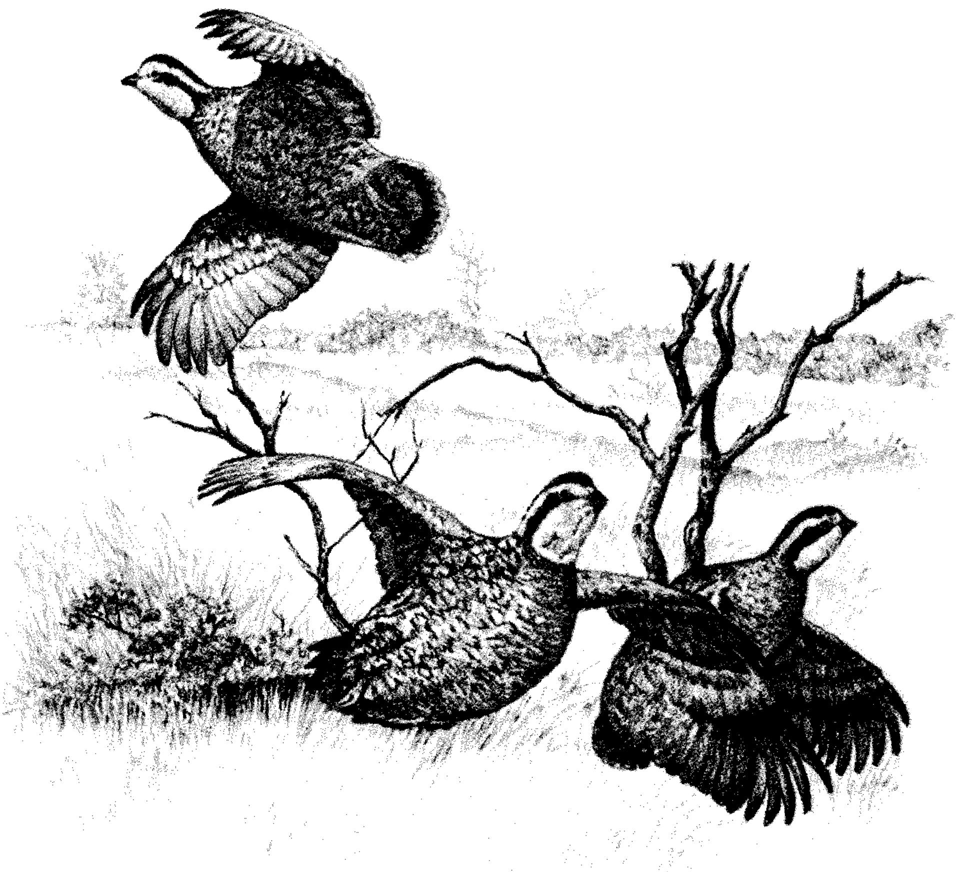

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Opening Statement

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

The 61st North American Wildlife and Natural Resources Conference begins with government and natural resource management in turmoil. In accord with the theme of this Conference, "Facing Realities In Natural Resource Management," realities are that institutions and programs are under siege.

In the United States and Canada, federal, state and provincial natural resource agencies are being profoundly affected by a broad, pervasive antigovernment sentiment. Staffing and organizational patterns that took decades to develop are being reduced and restructured. Colleagues in government in both countries report likely reaching staff levels comparable to those in 1960 before the year 2000. While greater efficiency in government is desirable and an outspoken goal of the public, it appears to be happening without a clear idea of capabilities that will remain. The rate and manner of redirection in both countries may do more damage to our ability to manage than the more visible legislative changes we tend to focus on.

Some members in the United States Congress, with a new and vocal majority, are proposing to change the notion of a public land base from a multiple-use balance between competing interests of recreation, wildlands, watershed and commodity production—to favor commercial and commodity interests. To be fair, part of this is in reaction to environmental groups who seem to have decided all public lands should be protected as parks. There are excesses on both sides, but right now, Congress is a bigger threat.

As we meet here in Tulsa, federal water rights are in jeopardy, livestock grazing is proposed to dominate uses on public lands, protection of wetlands and endangered species may be weakened, and scarce old-growth timber is being cut because Congress has set aside environmental laws. Private property rights, regulatory reform and giving away public lands are being actively debated. Reallocation of the resources and the land base is a throwback to the policies of the past century.

Perhaps no single issue is as much a threat to resource management and public use as the many proposals to privatize or otherwise divest the public s interest in a public land base. Legislative proposals, congressional hearings and assessments from think tanks suggest that federal management of the public lands is a failure and that the U.S. would be better off with local or private control of that land base. Claims of ownership at the county or state level are strident, but clearly conflict with the legal origins of the public lands. The so-called "county supremacy movement" received a setback in recent weeks when a federal court reaffirmed that the federal government is indeed the legal entity responsible for managing the public lands. Perhaps this ruling can reinsert some reason into this strained and misleading dialogue.

What would America be like without a public land base? How would it feel? What implications would that have for the millions of users who hike it, fish it, graze it, log it and all who enjoy just knowing that it is there? The very foundations of natural resource management in America are based on concepts of publicly owned wildlife and natural resources, a public land base, and public agencies (both state and federal) to manage these lands. Our system of public lands strikes a balance with the more than two-thirds of the landscape that is privately owned. America would be an intrinsically different place without its public land base. Much of the legislation and management affecting public lands came from the energy of those at this Conference. We should take from this international gathering a renewed resolve to stop some of the nonsense going on regarding grazing, timber management, public land transfers and other issues.

We have not yet struck a balance in fully keeping the public trust embodied in that land base. Conservation history tells us our public lands were established for multiple purposes—a limited amount is parks and a much larger amount is set aside for truly multiple uses. Yet, the dichotomy between multiple use on a sustainable basis and absolute protection seems sharper. Advocating no timber cutting or cattle grazing on public lands is as unrealistic as claiming that forest health needs require setting aside environmental laws and accelerating cutting of old growth. Either choice will pay negative returns in the long run.

There is an increased need for unity of purpose regarding natural resources. Concepts such as sustainability of resource uses, the wisdom of partnerships to achieve common goals, the need for balance between private property ownership and an obligation to act in the public interest, and recognition that many problems facing resource management spill over from public to private and private to public ownerships call for reestablishing that unity. Most of our problems cannot be solved by single actions but will require joint solutions. Within this mix of concepts, there are realistic examples that offer hope.

May 14th will be the 10th anniversary of signing the North American Waterfowl Management Plan between Canada and the United States. Mexico has since joined this benchmark effort, which has pioneered a unique cooperative approach to securing and managing land in North America. Through setting clear and recognizable goals for target populations of waterfowl and their habitats, a much broader program has evolved on a truly landscape scale, linking the three countries through projects which promote ecosystem approaches to management.

Progress has been achieved through the core concept of regionalized "joint ventures." From the beginning, its success has depended on cooperators coming together, embracing some mutual goals, and serving their individual needs by achieving those goals. From the start, it was apparent that no single entity would be "in charge." The joint venture approach arose from the local/regional level to facilitate collaboration by federal and state agencies, local and national conservation organizations, and private landowners. Together, they conduct joint projects that achieve mutual objectives.

How different this has been from the customary top-down government-driven approach of the past. Yet, these projects embody watershed management, changes in grazing and tillage practices, improved approaches to agricultural programs on the ground, and a variety of nonregulatory tools. Of importance is the model of loosely organized, intensely committed groups with divergent missions, but achieving some of their own goals by working in tandem with others. Joint ventures have reached outside waterfowl circles. An innovative planning effort is underway in the Lower

Mississippi Valley to overlay mutual habitat objectives for waterfowl, shorebirds and songbirds—to seek benefits in possibly pooling resources to achieve common goals.

Another example is a newly announced effort in Coordinated Resource Management in the state of Missouri. Agency and private interests earlier identified a practical ecosystem management framework for considering resources in Missouri, recognizing above all the needs of people on the land. Now, the first more intensive plan for a region of the Ozarks has been released for public comment. Involving local landowners, state and federal land management and resource agencies, and other interests, the plan essentially describes desired future conditions for such resources as forests, streams, native habitats and wildlife resources, with specific attention to the needs of the public that values those resources. While it is receiving criticism because of the paranoia about government and imagined intrusions on private property rights, it is exemplary of what is needed for unity of purpose in the future.

The Migratory Bird Treaty between Canada and the United States has been the subject of intense interest and activity in recent years. After more than twenty years of controversy, amendments to treaty language have been agreed to between the two countries to more fairly and effectively recognize the needs of native peoples and others living in the far North who have limited access to that resource because of its migratory habits. These agreements are necessary because of changes in Canadian law and long unrecognized needs of Native peoples in Alaska. These agreements will strengthen international migratory bird management for the future. As always, implementation details bear watching, but the interests of all involved can best be protected through involvement in the process. The use of cooperative management boards and true comanagement agreements which are used in Canada are increasing.

Long-standing tools, such as the flyway process for managing migratory bird harvests, have been reviewed and, through the International Association of Fish and Wildlife Agencies, changes for the future are under consideration to address a broader array of migratory bird resources. We now are moving into full implementation of the Harvest Information Program, which at last provides detailed information on harvest to provide more confidence in population management. A far-sighted development in the application of the adaptive resource management concept has been used in a preliminary fashion for managing migratory bird hunting seasons in 1995-96. As this process is refined and explained, it will offer a clear scientific means to balance the competing needs of resource conservation with public use. Finally, the Partners in Flight program, focusing on neotropical migratory birds, has come through more than five years of initial development and now involves partners from Canada to Central America in its conservation efforts.

A program designed to bring the ranching community and wildlife interests into more cooperative relationships held a symposium in February to mark its first four years of progress in "Seeking Common Ground." The symposium featured stories about successes and failures in working together to balance often competing objectives of livestock grazing and fish and wildlife conservation. Demonstration projects from Montana to Arizona are affecting resources on a landscape scale and, slowly but positively, achieving the kind of gains that seem elusive through sole reliance on regulatory processes. Partners include the Rocky Mountain Elk Foundation, National Fish and Wildlife Foundation, USDA Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service, state fish and wildlife agencies, Farm Bureau, Cattleman s Association and many others.

In one example, a Seeking Common Ground demonstration project meshed with ongoing Coordinated Resource Management processes to affect more than 300,000 acres of grazing land in Southcentral Wyoming. Improvements in both aquatic and terrestrial habitats have been achieved in just a few years without having to reduce livestock stocking rates. Through innovative movement of livestock and grazing for shorter, more intensive periods in fenced pastures, terrestrial and aquatic habitat have responded quickly. Most of all, people with differing objectives in an area of considerable interspersion of public and private land ownership have come together to improve the landscape in ways that already are benefiting fish, wildlife and ranching. Other projects are moving slowly and most are not without disagreement. Some parties come to the table only when they see no other alternative, but the important thing is that they are involved. A better future for fish and wildlife habitat and ranching will result. Similar projects have attracted attention in Canada as well.

At a time when the United States is more polarized than ever over timber management, the 7th American Forest Congress attracted almost 1,500 people in what was billed as a "citizen s congress," to consider a vision of America s forests for the future. The Congress attempted to build on the results of 51 local workshops held nationwide. Specific results are not yet available, but two encouraging trends emerged. While there were polarized views presented and attempts were made to force a focus on activist agendas, a more centrist mood prevailed. A major theme emerged to seek conflict resolution mechanisms other than through the courts, involving an array of local agencies and other interested parties in seeking consensus.

All of these examples share, in one way or another, a common concept. There is no "boss" or top-down authority, but there is a dependence on a leader or leaders who communicate and build bridges between people with differing interests. These collaborative movements are positive progress that can reduce the top-down role of government, involve affected parties, benefit resources and reduce the livelihood of attorneys. Certainly, parts of these efforts include necessary regulations, laws and agency actions needed to carry out a part of the job. But overall, new progress in dialogue, understanding and, most importantly, in the quality of resources is being achieved by "checking guns at the door" and entering into discussion while trying to agree and progress toward common goals. This is a move toward a unity of purpose. It is facing reality for natural resource management. It is sensitive to private property concerns and the needs of people.

Next year, the U.S. will celebrate the 60th anniversary of the Pittman-Robertson Federal Aid in Wildlife Restoration Act. This is the law that shifted excise taxes collected on firearms and ammunition from the general treasury to a dedicated fund for wildlife restoration back in 1937. The program returns collected funds to the states through the Fish and Wildlife Service, on a 75:25 percent matching basis. Since 1937, about $3 billion has enabled state agencies to apply scientific management programs to habitats and wildlife that form the core of wildlife management in the United States today. While funding sources have expanded in a few states, the more than $200 million in funds going to the 50 states this year, combined with hunting license revenues, remain the backbone of wildlife management funding. This classic approach essentially utilizes funds from resource users, with full cooperation from industry, to be applied through public agencies to restore and manage wildlife on both public and private lands, to continue the opportunity for the public s enjoyment of those resources.

One might think such a program would not need description at this Conference. However, recent review of public knowledge and attitudes in four Southwestern states revealed that a substantial majority (82 percent) of even the hunting public was unaware of this program and what it does and has done for wildlife. We badly need a strong outreach program to let people know how this work has been done and how it will continue. But the strength of the wildlife restoration program still lies in this partnership of the public, business, agencies and pursuit of a common mission.

Other joint efforts to positively affect wildlife and fish resources also are moving ahead in spite of the chaos in government. Teaming With Wildlife, the initiative to fund fish and wildlife diversity programs in the states through a user-pays mechanism similar to Pittman-Robertson and Dingell-Johnson/Wallop-Breaux, now boasts more than 600 supporting organizations nationwide.

In addition to this coalition building, supporters are contacting industry and the Congress to urge their support. A large array of the traditional hunting and fishing organizations have joined in during the past year, supporting the concept and extending their established leadership to continued progress on behalf of wildlife resources

The logic of building on the highly successful federal aid restoration program for wildlife and fisheries is clear. The new concept includes collection of excise taxes on certain outdoor equipment, funneling it through the existing administrative process in the Fish and Wildlife Service to the states, and the states then carrying out programs to benefit a wide array of fish and wildlife. State agencies have the legal mandate for most of the wildlife within their borders and, for them to be effective players in a growing array of concerns about declining populations and habitats, this program is logical, practical and urgent. While there still are some questions about mechanisms and funding sources, and uneven knowledge about how federal aid programs currently work, no one disagrees with the need for a broader based program to manage wildlife in America. This deserves the full understanding and support of everyone at this Conference.

Finally, I am pleased to announce a partnership on behalf of wildlife interests established between the Wildlife Management Institute and a growing number of wildlife management organizations. Called the "Wildlife Partners Network," this year-old program pursues that unity of purpose of assuring scientifically based wildlife management to allow responsible use of resources. We at the Institute provide timely information on the activities of Congress and public land-management agencies to empower each of the partners to understand fully the proposed actions, process for decisions and mechanisms by which each organization can act in its own interest on behalf of wildlife and wildlife habitat. The Wildlife Partners Network is not a coalition that attempts to act as a body, nor do the Partners attempt to represent each other. The Network is growing as a forum to bring wildlife conservation organizations together to discuss problems and analyze alternatives to improve management programs of mutual interest. It is another small step in directing our mutual energies in pursuit of common interests and unity of purpose in the realities of managing wildlife and wildlife habitats.

The Environmental Agenda

The Honorable John H. Chafee
United States Senate
Washington, D.C.

I am delighted to have this chance to visit with you this morning. You are the kind of folks I like to be with.

As perhaps you know, I am pinch hitting for Senator Bob Dole. He had a tough decision to make—whether to be with you or pay a bit more attention to California that has its presidential primary tomorrow with 163 winner-take-all delegates up for grabs. He finally chose to be in California. I am happy about that as it made it possible for me to be with you. Since Bob can't be here, I'll put in a few favorable words on his behalf occasionally in my remarks!

It is very significant, I believe, that, in his letter of invitation to Senator Dole, Lonnie Williamson said "Natural resource conservation never has been a partisan issue and is not one now." That is absolutely true.

A Democratic President, Lyndon Johnson, in the 1960s laid the foundation for the major environmental laws that came later. He signed antipollution and open space legislation into law, including the creation of Redwood National Park, the Wilderness Act, and the Land and Water Conservation Fund. Monies from that fund, for example, permitted me as Governor to purchase land for open space, wetlands and parks—that have given such pleasure to thousands of Rhode Islanders ever since. What a magnificent law that was and still is.

Building on the Johnson foundation, a Republican President, Richard Nixon, in the early 1970s urged passage and signed into law legislation to establish the Environmental Protection Agency, the President's Council on Environmental Quality, the National Environmental Policy Act, the Clean Air Act and the Endangered Species Act. The Clean Water Act also was enacted during the Nixon Administration.

The early Senate environmental leaders, who cooperated with Republican and Democratic Presidents alike, were Republican Senators Howard Baker and Bob Stafford, and Democratic Senators Jennings Randolph, Frank Church and Ed Muskie and, of course, Democratic Senator Gaylord Nelson, who conceived the idea of Earth Day.

That bipartisan tradition persists today. For example, Senator Dole has been a Senator since 1968—28 years—and Republican leader for the last 10 years under both Republican and Democratic Presidents. During his Senate career, Bob Dole has voted for every major piece of environmental legislation that has passed the Congress.

Those bipartisan efforts have brought about tremendous, tangible change. Gregg Easterbrook, author of the book *A Moment on the Earth*, in testifying before the Senate Committee on Environment and Public Works on July 13 of last year, called successful protection of the environment the greatest social achievement of the United States of the past quarter century. There is a lot in what he says. Let's consider, briefly, the successes we have had.

Since its enactment in 1973 (by a vote of 99 to 0), the Endangered Species Act has achieved remarkable results. Populations of whooping cranes, brown pelicans and peregrine falcons have come back from near extinction. The bald eagle—the majestic symbol of our great land—has been moved from the endangered to the threatened list in the lower 48 states, and the grizzly bear is not far behind. Both the California gray whale and the American alligator have recovered to the point that they have been removed from the list. Those are all visible species. Let's look at less visible plants. The MacFarlane's four o'clock, a large, showy flowering plant in Oregon and Idaho was downlisted from endangered to threatened.

These successes only tell part of the story. Of the 960 species currently listed, more than 40 percent are stable or gaining ground. For many of the other species, the rate of decline has been reduced. Given *half* a chance, nature will rebound and overcome tremendous setbacks. But we must—at the very least—give it that half a chance. No group knows that better than you do.

Let's look at further successes.

Auto miles traveled in the U.S. in 15 years (1975-1990) increased by 70 percent to 2.2 trillion vehicle miles per year. In that same period, hydrocarbon emissions were cut in half (10.3 million to 5.5 million tons).

Lead in the air has a terrible effect on the mental development of children in congested inner cities. Because we mandated the use of unleaded gasoline in the early 1980s, lead in the air has declined by 98 percent. What an achievement!

In 1970, only one-third of U.S. lakes and rivers were "fishable and swimmable"; today, two-thirds are, and the percentage continues to rise.

Most of the United States is experiencing reforestation, not deforestation.

The tonnage of waste Americans send to landfills peaked in 1988 and has been declining since, as recycling takes hold. There is a lot of good news out there in areas you and I are concerned about, and those of you present here today are responsible for much of it.

One example is the recovery of the striped bass. The striped bass is a magnificent fish, one that has been valued up and down the Atlantic coast for centuries. So it was with tremendous alarm that we learned of its precipitous decline in the late 1970s. By 1983, commercial harvests had dropped by 77 percent and sport harvests had declined more than 85 percent since 1979. An Emergency Striped Bass Study by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service showed the cause of decline to be overfishing and habitat degradation.

Less than 20 years later, through the cooperative efforts of state fish and wildlife agencies and the federal agencies, most Atlantic striped bass stocks have recovered. This dramatic turnaround is proof positive that if we act quickly to reduce the threats, we can recover imperiled species.

When it comes to wetlands conservation, perhaps no program has been as successful as the North American Waterfowl Management Plan. The Plan—signed 10 years ago by the U.S. and Canada in 1986, and joined by Mexico in 1994—provides for international cooperation through the development of conservation partnerships known as "joint ventures." Funding for these projects (under the North American Wetlands Conservation Act) leverages federal funds on a better than one for one basis with those from conservation groups, such as Ducks Unlimited and others.

To date, 384 wetland conservation projects have received funding totaling $152 million from the North American Wetlands Conservation fund, and $293 million from partners—$445 million in all. Well more than 2 million acres of wetlands have been protected, restored or enhanced in the United States and Canada. And several million acres of wetlands in Mexico are benefiting from projects under the NAWMP.

It seems to me that the way the Plan operates—involving partnerships between federal, state and private entities—represents the wave of the future for environmental protection. It is perhaps the best, most successful example we have of a cooperative ecological venture, and right here in this room are the people who have made it work.

This is not the federal government forcing regulations on unwilling landowners. Rather, the Plan is something that everyone affected has sought and become involved with. By protecting wetlands that provide habitat for ducks, we are protecting almost one-third of all endangered species that live in wetlands. By conserving valuable wetlands, we also aid in pollution abatement and reducing flood damages.

Due to a variety of conservation efforts, and some decent rainfall, not since 1955 have we witnessed such a spectacular migration of waterfowl as this past year. I am informed that it was the best since 1955—that was 40 years ago. An estimated 83 million ducks, 12 million more than last year and 24 million more than 1993, migrated south for the winter. Biologists attribute this success to habitat restoration efforts in the prairie pothole region of the Dakotas and to extensive rainfall. And, some successful federal programs—such as the Conservation Reserve Program and Swampbuster—have contributed significantly to the rebound. These programs just received additional support from the 1996 Farm Bill.

This Farm Bill, just passed out of Conference last week under the leadership of Senator Dole, is a true conservation success story—probably the most environmentally sensitive Farm Bill ever. The Conservation Title reauthorizes the Conservation Reserve Program at 36.4 million acres. It provides $35 million for farmland preservation near urban areas and gives $300 million to restore the Florida Everglades. The Farm Bill also guarantees over seven years nearly $1.4 billion to curb water pollution through the Environmental Quality Incentive Program.

The Wetlands Reserve Program has been increased from 300,000 acres to 975,000 acres—these represent restored wetlands and the funding for this program is now guaranteed and not dependent on the whims of the Appropriations Committees.

All involved with this effort, especially Senator Dole, but along with many others, have reason to be extremely proud of the wildlife conservation aspects of the new Farm Bill.

The great environmental issue of the day is not, however, the battles of the past—or even of the upcoming months. It behooves us to look ahead, to consider how we will build on the momentous success of the latter 20th century.

This will be no easy task. It will involve much more than simply standing up to those who do not hold our view of environmental stewardship. We are going to have to transform significantly our way of fostering environmental protections.

In the past, we were spurred into action out of alarm and disgust over grossly visible problems such as fish disappearing from our rivers, a river catching on fire, raw sewage floating in harbors, black smoke spewing from smokestacks, and animals and birds becoming extinct. In the 1970s and '80s, it was not difficult to determine the sources of those hazards to our health and affronts to our senses: they were largely big industry and other easily identified point sources such as cities. We went after those companies or municipalities and curbed the offending activities, and we have enjoyed the successes I have listed.

By and large, the big corporations, after spending billions of dollars and with considerable effort, are in compliance with the laws we now have. We won't make any new, substantial gains against pollution if we continue to grapple with it in the same way we always have. We have almost done as well as we can using those methods.

In contrast, today we are dealing with invisible "holes" in the ozone layer and trace amounts of toxic chemicals such as benzene measured in parts per billion or parts per trillion.

Many of those untreated threats to the environment and human health come from thousands of small, diffuse sources: the neighborhood bakery, the dry cleaner, the corner service station, wood-burning stoves and fireplaces and malfunctioning septic systems in our own homes. To achieve further reductions in water pollution, for example, we won't be able to target the pipe pouring chemicals into a river. Instead, we will have to deal with chemicals used by farmers that seep into the ground, enter the ground water and eventually end up in the lake, river or drinking water well.

In fact, one of the greatest sources of water pollution these days is just plain "runoff" from our streets. What is that exactly? Oil and grease that drips from automobiles, animal waste, lawn fertilizer and garden pesticides, garbage that is blown by the wind from trash receptacles. And who is responsible for runoff? All of us are. I was horrified to discover that, each year, do-it-yourselfers who change the oil in their own cars pour about 23 times more oil down municipal storm drains than was spilled by the Exxon Valdez. And that's each year!

Much of the water pollution is caused by pollutants in the air—such as mercury from coal burning that settles in waters such as the Great Lakes.

Let me offer five suggestions on how we might achieve future progress on environmental improvement:

1. We need to understand what are the true threats to our environment.

Let's establish our priorities in a scientific fashion. This is extremely important, as we have limited federal resources to devote to cleanup. As we ascertain what the worst threats are, we would find it prudent to use that data to guide us in allocating ever scarcer federal dollars.

Let me give you an illustration of what I mean. In Congress, there is considerable pressure to clean up toxic waste dumps known as Superfund sites. The Superfund program historically has gobbled up $1.5 billion in federal funds each year—a full quarter of the total EPA budget—and an equal amount of private money—a total of about $3 billion per year. And yet, as far as hazards to our health and the environment go, inactive and abandoned hazardous waste sites are way down on the list. The EPA's own Science Advisory Board has said so.

2. We need to educate citizens and businesses about the benefits of a clean world and their role in keeping it so.

This is not a new idea. Mrs. Lady Bird Johnson said in 1965 that "perhaps the most important [thing] will be to help educate our people that the beauty of their land depends upon their own initiative and will."

One very effective approach has been to focus on schoolchildren—the individual polluters of tomorrow—to change their behavior for life. This is a very effective tactic. The "Don't be a Litterbug!" warning of the 1960s has meant cleaner sidewalks and roadsides in 1995. In my home state of Rhode Island, one teacher has so warned her 4th grade pupils about the dangers of styrofoam (one of the culprits in ozone depletion), not only will they never use a styrofoam cup, but they have gone on a fervid anti-styrofoam campaign that has included letters to their elected officials. I can testify to that!

We must ever improve the science curriculum to increase understanding of complex, intangible environmental threats such as ozone depletion and radon—to build support for solving those problems. We cannot hope to implement solutions to our environmental problems without the involvement of an educated and scientifically literate public. Only then will the political debate and direction of environmental policy focus on real risks, and not anecdotes that make catchy copy.

The education effort should not, however, be limited solely to children. We should direct our efforts at the business community as well. We must make businesses understand that green practices are profitable.

Government has a role, I believe, in explaining the benefits of clean practices. It can show how an investment in pollution prevention technology today can avert a costly cleanup tomorrow, for example. Government action also can spur corporate innovation. Clean air regulations have resulted in the automobile industry's production of an ever cleaner car, at considerably less cost than originally estimated.

3. Let government actions involve incentives. Let's not be in solely a punishing mode.

We must work to encourage the voluntary conservation of farmland, ranches, forest land, wetlands, wildlife habitat, open spaces and other environmentally sensitive property. The Endan-

gered Species Act immediately comes to mind as a law that provides many punishments and few inducements. One way we might change it is through the "Safe Harbor" concept advocated by Interior Secretary Bruce Babbitt. The idea works like this: a landowner agrees to make habitat improvements on a portion of his or her property, to make it attractive to endangered species and to protect those endangered species residing there. In return for this commitment, the landowner, on the balance of his or her land, can build, harvest trees or otherwise make use of the land in ways that the Endangered Species Act might normally prohibit—and landowners are assured that no new restrictions will apply to his or her property in the future. It seems to me that your efforts with "Seeking Common Ground" involving ranchers and others is similar to what I've referred to.
Let us also provide incentives, through the tax code, to entice individuals to maintain ownership of unspoiled property. Estate tax breaks to folks who enter into a conservation agreement would be a good start. Regrettably, many people who inherit farms or woodlands from their parents must sell it to developers in order to pay the estate tax. Such people could use the government's help in keeping their land and keeping it free of condominiums!

Congress must acknowledge that there always is room for improvement in our environmental laws. No law is carved in stone. If we can make the laws clearer and easier to comply with and if we can invent better incentives for compliance, then we ought to. Such actions would go a long way toward reducing much of the criticism of our laws and the animosity toward their enforcers that currently exist.

4. Let us always remember that everything in this world is interrelated.

In 1855, Chief Seattle (of the Suquamish people of the Pacific Northwest) wrote, "All things are connected like the blood which unites one family. Whatever befalls the earth, befalls the sons of earth. Man did not weave the web of life. He is merely a strand of it. Whatever he does to the earth, he does to himself."

And, because everything is connected, every part of the whole is intrinsically valuable. When Noah led the animals into the Ark, he included *all* species: "one pair, male and female, of all beasts, clean and unclean, of birds and of everything that crawls on the ground." God did not direct him to select only the most beautiful animals, or the edible ones, or those that might aid in finding a cure for cancer, but *all* creatures.

If these creatures are going to survive, their environment must be capable of sustaining them. And, as Professor E. O. Wilson pointed out to our Committee last year, "When a natural ecosystem, say a forest remnant or a freshwater stream, is protected to save a particular species, an umbrella is thrown over hundreds or thousands of other species...[and] the great panoply of lesser known, often unknown, and frequently invisible organisms are what sustain natural environments."

It isn't enough just to list 30 animals on the brink of extinction, we have to save everything that surrounds them. We have brought the bald eagle and the peregrine falcon back from the brink of extinction, but we can attribute that to the banning of DDT in 1972. To keep other species from dying out, we will have to adopt a much more vigorous, habitat preserving approach. This was the conclusion of a National Research Council report that was commissioned by Congress four years ago and released this past May: "Habitat protection is a prerequisite for conservation of biological diversity."

It is terribly important that we preserve diversity in nature, not just one type of tree or shrub, not just one flock of birds (and thus only one gene pool). There is danger in monoculture. William Robert Irvin, of the Center for Marine Conservation, testified before our Committee on this subject last July. He said, "Just three species—corn, wheat, and rice—provide half the world's food. This incredibly thin reed on which human survival depends is susceptible to devastating insect infestations and blights. One of the best ways to protect domesticated crops from such disasters is to crossbreed them with wild varieties," such as the endangered Texas wild-rice.

There is strength in diversity. We can preserve diversity in nature only by conserving a number of separate lands, forests and fields.

5. The United States must remember how important is the example it sets and be a leader in international environmental treaties. We have to get across to others what you know:

Namely, the importance of the worldwide influence of the United States in environmental matters. If this wealthy nation of ours clearcuts rainforest in the Tongass or drills in the Arctic National Wildlife Refuge, how can we then say to the Kenyans "don't seize the plains for cattle grazing"; or to the Brazilians, "don't use your rainforest for timber"?

We carry a double burden: care for our own land and always be conscious that we are setting an example. The rest of the world watches carefully what we do.

One of the ways we can be influential is by fostering international treaties. Plants, animals, air and water are unaware of national boundaries. This fundamental concept has been recognized ever since the Migratory Bird Treaty of 1918, the first effort to bring together countries with different interests and goals to agree on a common effort for wildlife conservation.

We have made some fine strides in international environmental cooperation over the past few years. For example, the Montreal Protocol to end global production of CFCs was signed by President Reagan in 1987 and the Earth Summit (which President Bush attended) produced an international treaty on global climate change in 1991.

The recent Panama Declaration shows how countries with diverse economic needs were able to gather together and agree to an improved conservation plan for protecting dolphins while, at the same time, permitting tuna fishing to continue in the Eastern Tropical Pacific.

The Massachusetts Audubon Society is a shining example of a private group that understands that wildlife knows no boundaries. Because of that group's expertise in land protection, it was sought out by the Audubon Society in Belize. The result was the formation of the Programme for Belize, through which the Massachusetts Society organized the purchase of 229,000 acres of rainforest and songbird habitat in Belize.

May our nation be a true leader in an international battle for a cleaner global environment, one that gives wildlife a chance.

A brief summary of my five points. Let us: use the best science we have to make wise decisions about environmental protection; educate citizens and businesses about the benefits of a world free of pollution and blight, and their individual role and responsibility in achieving such a world; change the posture of our government from an adversarial one to a cooperative one; remember that everything on earth is connected, what we do to one species affects others and we cannot be selective in our protective efforts; and accept and promote America's role as international leader and example.

Eighty-six years ago, the first of the great environmental Presidents, Teddy Roosevelt, a Republican I hasten to note, said the following, "Of all the questions which can come before this nation, short of the actual preservation of its existence in a great war, there is none which compares in importance with the central task of leaving this land even a better land for our descendants than it is for us."

These are the sentiments that each of you believe in, and that I believe in and that Bob Dole believes in.

Thank you.

Current Issues in Natural Resource Policy

Peter D. Coppelman
U.S. Department of Justice
Washington, D.C.

I am pleased to be here to address this distinguished gathering of people doing important work to protect our wildlife and natural resources. I am particularly honored to appear on the same platform as Senator Chafee, long an advocate for environmental protection. I have been asked to discuss some of the burning issues of the day in natural resource policy from the perspective of the Clinton Administration. First, I will set the scene by addressing the political context in Washington that affects all of these issues. Then, I will give the Administration's perspective on those matters where, in my present capacity, I have taken a lead role for the Justice Department in shaping the Administration's position. My responsibilities are on the natural resources, as opposed to the environmental protection side of the house. I operate where law and policy intersect, and spend about a quarter of my time at the White House.

The issues I will address are: (1) implementation of the timber provisions of the Rescissions Act, (2) the Administration's ecosystem management initiative, (3) federal response to the county supremacy movement, and (4) proposed legislation to divest the federal government of ownership and/or management of some of the federal lands. By any measure, that's a full plate.

The Broader Context

What is the political environment in Washington in which we are operating today? All environmental laws are under a triple pincer assault by extremist elements of the now Republican majority in Congress. First, they are being attacked writ large by the Contract with America's witches brew of endless cost benefit analyses and risk assessment studies, multiple judicial review of environmental regulations, and takings compensation legislation. In effect, each of these initiatives is an attempt to kill all the birds with one stone. Second, environmental laws are being attacked frontally in the reauthorization process. These laws include the Endangered Species Act, the Clean Water Act, Superfund, and others. Soon to be added to the list is the National Forest Management Act. Third, they are being undermined in the appropriations process by budget slashing and substantive riders that bar implementation of key portions of the acts.

So, you might ask, "How are we doing?" Sometimes I think the best response is to quote General Ferdinand Foch who, during the second battle of the Marne, cabled his superiors as follows: "My center is giving way, my right wing retreats—situation excellent—I am attacking!"

I take heart from the fact that we are beginning to see a turnaround. When the takings provisions of the Contract with America passed the House in March 1995, only 15 courageous Republicans voted against them but, late last year, 63 House Republicans voted correctly to strip substantive riders off the EPA appropriations bill.

Nonetheless, this highly polarized, highly partisan atmosphere directly affects all of the issues we will discuss today. There are many significant problems that have developed in the implementation of natural resource statutes, and particularly in the interaction among the various statutes affecting management of the public lands, such as the NFMA, NEPA and the Endangered Species Act. In an atmosphere of trust and good will, the Administration could sit down with the Republican leadership and try to address these problems in a rational manner.

Unfortunately, it appears to us that the Republican leadership, particularly the leadership of the natural resource committees of the House and Senate, seems more committed to extreme measures rather than targeted solutions to identifiable problems. I cite their strong support for takings compensation legislation, radical regulatory reform proposals, and the timber provisions of the Rescissions Act that simply wiped all environmental laws off the books for the benefit of the timber industry, an industry that can do, and has done, substantial environmental damage.

Timber Salvage Provisions of the Rescissions Act

Let's turn specifically to the timber salvage provisions of the 1995 Rescissions Act. As you may know, Congress, in the Rescissions Act passed last July, included two very controversial timber provisions. The first required the Administration to release hundreds of millions of board feet of old growth sales in Washington and Oregon that had been held up for five years for environmental reasons. These sales had to be issued under their original terms and conditions which were inconsistent with the standards and guidelines of the President's Forest Plan. The second provision that applies nationwide authorized the offering of salvage sales in the national forests without compliance with any environmental laws, and eliminated administrative review and greatly truncated judicial review of the sales.

Many commentators and many environmentalists have said that the President has no one to blame but himself for the environmental damage that has ensued, because he signed the Rescissions Act. Some environmental spokesmen have even gone so far as to write off the Administration on the basis of this act alone. I would like to make these points in response. First, the President did not ask for these provisions. When Congress enacted the timber salvage sections of the Rescissions Act last summer we had gone from gridlock in the Pacific Northwest to the gradual harvesting of timber in an environmentally responsible manner under the President's Forest Plan. The Administration's view of Congress' intervention was that, in acting to fix what wasn't broken, Congress may well have broken what had just been fixed. In other words, both the old growth provisions and the salvage provisions of the Rescissions Act were unneeded and unwanted.

Second, the President did not support these provisions. In fact, he opposed them vigorously and, indeed, vetoed the Rescissions Act when it first reached his desk in part because of these provisions. The problem developed during negotiations following the veto. The President had objected to about a dozen provisions of the Rescissions Act. During subsequent negotiations, all of his objections were resolved except for the timber provisions. The question became whether he would veto the entire bill solely because of these provisions.

The final bill contained much that the President wanted. It reprogrammed 16 billion dollars of federal spending in ways that he supported. The bill contained money to rebuild the bombed out federal building in Oklahoma City, and other needed disaster relief money. Ultimately, the decision was made in the White House (a decision which many opposed) that Congress had made the President an offer he couldn't refuse, so he signed the bill. At the same time, he directed the federal agencies to implement the timber provisions to the maximum extent possible consistent with all environmental laws. Unfortunately, the timber industry found a sympathetic judge who has interpreted the timber provisions to require the cutting of a great deal more old growth than the Administration thought was at issue in the negotiations.

A Lesson Learned

That being said, the Rescissions Act and subsequent developments have had the salutary effect of teaching the Administration a bitter lesson that it has tried mightily not to repeat. I submit to you that the President's actions since July of last year provide strong evidence that the lesson of the Rescissions Act debacle has been well learned. I refer to the President's strong advocacy for environmental protection in the context of the budget debate; his rejection of anti-environmental riders in appropriations bills for Interior, Agriculture, EPA and Commerce; and his firm opposition to the antienvironmental provisions of the Contract with America.

On October 28, 1995, in a speech to environmental journalists in Boston, Vice President Gore said: "Any reconciliation bill that opens ANWR to drilling, [the President] will veto, period. It doesn't matter what else is in the bill. If they satisfied us one hundred percent on every single other item in that bill, and they opened ANWR to drilling, he will veto it. It's that clear." No more offers from Congress that the President can't refuse!

Also, I think you will see a clear trend in the President's overall priorities over the past year toward placing increasing emphasis and importance on environmental issues. In last year's State of the Union address the environment barely received a mention. This year. the President devoted five minutes—an entire section—of his hour-long address to the environment and, as commentators noted, his speech was strongest on the issue of defending the environment from congressional cuts.

Indeed, I would go so far as to say that the Clinton Administration is primarily what stands between where we are today and outright destruction of the laws that protect the environment for all Americans. Without the President wielding the veto and, even more important, the threat of veto, there is a great likelihood, for example, that takings compensation legislation would already have turned the Environment Division of the Justice Department into a private property owners' bank.

Ecosystem Management

In the face of legislative gridlock, the Administration has moved forward administratively on a number of environmental fronts. Perhaps first and foremost is the Administration's ecosystem initiative. This initiative was kicked off in September 1993, when the National Performance Review, led by Vice President Gore, issued a final report entitled, "Creating a Government that Works Better and Costs Less." One of the actions recommended by the report is: "The President should create a process to establish ecosystem management policies across the government." [ibid.] From the point of view of federal government's natural resource environmental programs, ecosystem management is one of the most specific, far-reaching and profound changes being sought by the Clinton Administration's National Performance Review.

An ecosystem, simply defined, is an interconnected community of living things, including humans, and the physical environment with which they interact. Ecosystem management is based on a collaboratively developed vision of desired future ecosystem conditions that integrates ecological, economic and social factors affecting a management unit defined by ecological, not political, boundaries. The report recognizes that there are many barriers to managing at the scale of ecosystems, including interagency conflicts, incompatible data bases, a lack of research on ecosystem functioning, inconsistent planning and budget cycles, and differing agency organizational structures.

Perhaps most important, the boundaries of ecosystems do not follow arbitrary administrative boundaries that define units of the National Forest System, National Park System or other federal land systems. Often, they are defined by watersheds. Therefore, ecosystem management requires a shift from the federal government's traditional focus on individual agency jurisdiction to considering the actions of multiple agencies within larger ecological boundaries. Further, since nonfederal lands often are encompassed within ecosystem boundaries, it is important to find ways to increase voluntary cooperation with state, tribal and local governments, as well as nongovernmental organizations and the public.

Although the Administration's ecosystem management initiative is, to a large extent, still in its formative stages, what undoubtedly will be the Administration's most comprehensive ecosystem management project is already complete. I refer, of course, to the President's Forest Plan for the old growth forests of the Pacific Northwest. The President himself convened a Forest Conference in Portland, Oregon, in April 1993. He then directed his cabinet to craft a balanced, all-inclusive, long-term policy for the management of more than 24 million acres of public lands. The scope of this ecosystem management effort was unprecedented and breathtaking. The federal agencies involved—the Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Marine Fisheries Service, and Environmental Protection Agency—produced an ecological, economic and social assessment of the affected region, a draft environmental impact statement, a final environmental impact statement, and Record of Decision. In the process, they responded to more than 100,000 public comments.

As someone who was intimately involved in the development of the President's Forest Plan, I can tell you that all of us—the scientists, policy makers and lawyers—were sailing in uncharted waters. The legal challenges were particularly daunting. How could the advice of the best scientific minds outside of government and input from affected states and interest groups be obtained without violating the Federal Advisory Committee Act? How should the results of broad-based ecosystem analysis that is not required by statute be plugged into those planning processes that are mandated? What is the legal justification for applying the same standard of environmental protection across federal lands that are managed according to a variety of substantive standards? How should conflicting mandates of the various statutes implicated by ecosystem management be reconciled? We didn't know the answers, because many were questions of first impression. We could not even be certain of the answer to the bottom line question: was ecosystem management as implemented in the Forest Plan legal? Certainly, the many environmental and industry groups who attacked the plan from all sides didn't think so.

On December 21, 1994, Federal District Judge William Dwyer in Seattle, the same Judge who had time after time enjoined all old-growth timber harvesting within the range of the northern spotted owl, issued a decision rejecting all legal challenges to the plan and completely vindicating the government's ecosystem approach. Judge Dwyer found that the government had the authority to adopt an interagency plan on an ecosystem basis pursuant to a myriad of statutes which govern the federal forest lands at issue. The statutes examined by the court included the National Forest Management Act, the National Environmental Policy Act, the Oregon and California Lands Act, the Federal Land Policy and Management Act, the Multiple Use Sustained Yield Act, and the Organic Administration Act. Judge Dwyer even went so far as to observe that "given the current condition of the forests, there is no way the agencies could comply with the environmental laws *without* planning on an ecosystem basis" (Opinion at 32 [emphasis in original]). So ecosystem management has not only leaped its first hurdle, it has received a ringing endorsement from probably the most important and knowledgeable judge in the country.

Pursuant to the recommendations of the National Performance Review, the White House set up an Interagency Ecosystem Management Task Force, chaired by Katie McGinty, Director of the White House Office on Environmental Policy. The Task Force identified "Survey and Assist" case studies where mature interagency ecosystem-based activities are ongoing, but may need some assistance. These case studies were: 1) Anacostia River Watershed (Army Corps of Engineers); 2) Great Lakes (EPA) Lake Superior and Glacial Lake Chicago Crescent; 3) Coastal Louisiana Wetlands (EPA); 4) South Florida Ecosystem (Department of the Interior); 5) Southern Appalachian Highlands (Forest Service); 6) Pacific Northwest Forests (Forest Service and Interior); and 7) Prince William Sound (NOAA).

The Survey Teams went to the field to elicit lessons learned from ecosystem-based management efforts to date and to identify opportunities to assist these efforts, either through the elimination of existing impediments or the encouragement of successful approaches and techniques. Thus far, the Task Force has issued two reports generally entitled "The Ecosystem Approach: Healthy Ecosystems and Sustainable Economies." Volume I is an "Overview." Volume II covers "Implementation Issues," including budgeting, institutional approaches, public participation, science and information management issues, and an extensive discussion of legal authorities. Volume III, which discusses results of the case studies, should be available within the next several weeks.

Just recently, the Vice President announced a major acceleration in the Administration's already substantial commitment to restoration of the Everglades and Florida Bay ecosystem. I have had the privilege of serving on the Federal Interagency Task Force that is working closely with the Governor's Commission for a Sustainable South Florida to develop a comprehensive blueprint for ecosystem restoration. If anything, the scope of this undertaking exceeds that of the President's Forest Plan for the Pacific Northwest.

The Task Force will continue in existence as an ecosystem management "implementation committee" pursuant to a Memorandum of Understanding signed by officials in several federal agencies. That committee will ensure that agencies continue to find ways to promote ecosystem management.

The County Supremacy Movement

Let's turn next to some of the major challenges to federal ownership and management of the federal lands. One of these is the County Supremacy movement, an important and volatile part of the current climate that also includes the wise use, property rights and militia movements. While each of these movements is different, they all seem to emerge from the same wellspring of antigovernment fervor that is creeping into American life in all parts of the country and at all levels of wealth, and, in some pockets of the country, has become a dominant theme. In the rural West, we are seeing a resurgence of the Sagebrush Rebellion of the late 1970s. To oversimplify a bit, this is something that seems to flare up in response to Democratic administrations in Washington that seek to assert federal control over commodity development activities on the federal lands, particularly grazing. The last Sagebrush Rebellion was sparked in part by Interior Secretary Cecil Andrus' attempts to reduce overgrazing on BLM lands.

The County Supremacy Movement is the current manifestation of the Sagebrush Rebellion. Counties throughout the West have passed two types of county supremacy ordinances. First are "custom and culture" ordinances, also called "Catron County style ordinances," after the county in New Mexico that first passed one in 1991. These ordinances essentially say that the federal government cannot reduce the level of commodity outputs on the federal lands, such as grazing, timber harvesting and mining below the levels that have come to be the "custom and culture" of the county without county approval. Second are ordinances which simply declare that the United States does not own land, but that the land instead is held by the states. These are also called "Nye County style ordinances," after the Nevada county that first passed one in 1993. You might have seen the cover story on Nye County in "Time Magazine" a few weeks ago. About 35 counties have passed one version or the other of these ordinances, and they are being considered in another 35 or so counties.

In our view, legally these ordinances are completely bogus. But politically they are quite potent. In my view the evil of these ordinances is not that they are being enforced by the counties that pass them—indeed, most are not. The evil is that they encourage unlawful defiance of lawful federal land management directives by ordinary citizens of the county. In so doing, these ordinances pose one of the greatest potential threats to domestic tranquility in our nation today. Federal officials are forced to choose between confronting angry ranchers, miners or other citizens who often threaten to respond with violence, or failing to enforce laws duly enacted by Congress for the benefit of all Americans, in which case we will simply have anarchy on the federal lands.

I want to make it clear that federal law requires that opinions of local government officials be taken into account in federal land planning processes. Individuals, communities and county governments all must be part of the decision-making process. Indeed, federal land management statutes, in particular the Federal Land Policy and Management Act, the National Forest Management Act, and the National Environmental Policy Act, encourage state and local governments and other interested parties to participate in the federal land management planning process.

But nowhere do these statutes confer a veto power upon state or local authorities or anyone else. As the U.S. Supreme Court said [in *Granite Rock*] with respect to the federal land management process, the federal government must "listen to the States [or local governments], not obey them"; "it is clear that" federal authorities have "the final authority to determine the best use for federal lands."

The Federal Government's Response to the Movement

How has the federal government responded to the County Supremacy Movement? At the outset, I want to emphasize that it is the top priority of the Environment and Natural Resources Division, to the extent we can, to assure that federal land management employees can do their jobs without fear of threats and violence, and to protect and defend the right of the federal government to own and manage the federal lands for the benefit of all Americans. In coordination with other branches of the Justice Department—including the Criminal Division, U.S. Attorneys offices and the FBI—and the land management agencies—the Forest Service, Bureau of Land Management, Park Service, Fish and Wildlife Service—we have undertaken a multi-step response to the county supremacy movement that seeks to avoid violence while firmly insisting on compliance with federal law. The Justice Department has set up a nationwide e-mail network among interested persons in all affected agencies and offices, and has established a domestic terrorism task force to deal with all indigenous movements that have a potential for violence.

A major first step in our strategy is to knock the legal props out from under the ordinances. Recently, the courts delivered a one-two punch to these ordinances. The first punch: in response to a suit brought by the United States against Nye County seeking declaratory and injunctive relief that I argued, a Federal District Court issued a decision that was a sweeping and total affirmation of the right of the United States to own, retain and manage the federal lands for the benefit of all Americans. The second punch: in response to an environmentalist suit which I argued for the United States as amicus, the Idaho Supreme Court on March 18 declared unconstitutional a "custom and culture" style ordinance passed by Boundary County. If other counties act to enforce these ordinances, we are prepared to initiate additional challenges.

I also addressed a meeting of 350 county commissioners in Saint George, Utah, last spring in an effort to convince them not to pass additional ordinances. Up to that point, they had been getting an earful of legal advice from Nye County Commissioner Dick Carver and other proponents of the County Supremacy Movement.

Beyond challenges to county ordinances directly, we are dealing with illegal actions taken by individuals under the color of the ordinances based on referrals to U.S. Attorneys' offices from the land management agencies. Each referral is evaluated on its merits and a determination is made whether to pursue criminal and/or civil remedies. In general, we are disinclined to start with criminal cases, because we don't want to turn these citizens into martyrs. For example, we filed a civil trespass action against Cliff Gardner who has been grazing his cattle on public lands managed by the Forest Service without a permit. He has persistently refused to remove his cattle from the Humboldt National Forest in Nevada despite repeated requests by Forest Service land managers. Recently, a federal court ruled in our favor, specifically rejecting the county supremacy legal theories advanced by Gardner.

On other fronts, in coordination with other federal agencies, we are training on-the-ground federal employees in techniques to deal with hostile citizens, so that federal laws can be enforced in a way that avoids confrontations and violence. And we are seeking support from influential groups for the proposition that the federal government has the right to own and manage the federal lands. These groups include the National Association of Counties, the Western Sheriffs Association, the National Sheriff's Association and the Outdoor Recreation Association.

I want to say a word about recent bombings of federal facilities in the West. A year ago a BLM facility in Nevada was bombed. This spring a Forest Service office in Carson City, Nevada, was bombed on the same day that an outhouse on a Forest Service camp ground was blown up. Most recently, a bomb exploded in the car of a Forest Service employee in Nevada. Some groups have made public statements linking these incidents to the Oklahoma City bombing, to the militia movement or to the County Supremacy Movement. In my view, these statements are irresponsible. We don't know who did any of these bombings and, until we do, we have no idea what motivated the bombers.

Federal Legislation Turning Over the Federal Lands

There is a mirror image effort to the County Supremacy Movement in the Congress by Western legislators to pass laws turning over the federal lands to states or others. Perhaps the most extreme example is S. 1031 by Senator Thomas of Wyoming that would allow states to take over all BLM-managed lands within their borders, gratis. Other ideas floating around would set up a commission to consider jettisoning some national parks, forbid net growth of public lands or authorize states to manage federal lands under various circumstances. The Administration has strongly opposed such legislation. Interior Secretary Babbitt testified February 6: "This Administration is committed to fighting for America's lands, to ensure that they remain for the benefit of all, and that they do not become private playgrounds for the richest among us." This position is drawing widespread support—even among hunters and fishermen in the West who fear losing access to the public lands. In addition, some of the states that would presumably take over the federal lands are having second thoughts. Recently, the Idaho State Controller issued a report concluding that "[transfer] proposals in Congress raise more questions than they answer and have the potential to be a financial disaster for our states." It now appears that at least the most extreme versions of the proposed legislation are dead for this Congress.

I expect that Western proponents of such legislation will abandon for now their more egregious global assaults in favor of targeted rifle-shot approaches. I think I can predict with confidence, however, that they won't give up.

Conclusion

I am hopeful, but not optimistic, that the debate about the environmental issues we have discussed, as well as other issues of interest to this group, such as reauthorization of the Clean Water Act and the Endangered Species Act, can take place in a rational, civilized manner. The bigger problem is the contentious, polarized and fractious context in which the debate is occurring that I discussed at the outset of my remarks. But if more Republicans follow Senator Chafee's lead, we can return protection of the environment to the bipartisan support it always has and always should enjoy.

4-H Wildlife and Fisheries Recognition Awards, 1995

Marie Glasgow, *Mt. Sterling, Illinois*

Marie has been a volunteer 4-H leader for more than 15 years. Her interest in the out-of-doors was apparent as early as age nine, when she spent the summer collecting ants in support of a research project for Western Illinois University. As a 4-H youngster, Marie chose a conservation project that encouraged her to pursue a degree in biology. With her background in biology and an interest in forestry and natural resource conservation, members of her 4-H club became active on the forestry judging team, livestock judging team, horticulture judging team and the wildlife habitat judging team. Marie has chaired and served on numerous county and state extension committees, participated in recycling programs, served on the county school board and taught natural resource conservation at summer camps.

Joe Gray, *Jefferson, Maine*

Joe also has been a volunteer 4-H leader for more than 15 years. His lifelong interest in natural resources and professional career as a forester have provided the bases for the programs he conducts with 4-Hers. He has guided and taught other leaders as well as youth about bird house construction, plant identification and bird feeding projects. Joe developed 34 conservation-oriented slide presentations that he delivers at schools, youth groups and other organizations throughout the state; he conducts about 100 of these programs each year. As a natural history instructor, each year at Tanglewood 4-H Camp and Learning Center, Joe conducts a wide variety of educational programs ranging in subject from bats to rainforests. He is involved in many other activities; for example, the local chapter of the Audubon Society, Scoutmaster for a Boy Scout troop for 10 years and Treasurer of the Jefferson County Historical Society.

Denise Wecker-Seipke, *Clawson, Michigan*

Denise has been a volunteer 4-H leader for 16 years. She has led club projects in forestry, mammals, birds, water quality, recycling, fishing, wildflowers and soils. Between 1985 and 1992, Denise was the owner and operator of a day care program and utilized 4-H natural resources programming as a cornerstone of her after-school and summer activities. Her club members play an active role in local, county and state NREE events and have become key leaders in the state program, acting as counselors at the Great Lake 4-H camp and assisting in the development of the "Fishing in the Parks" initiative. Denise has taken a lead role in developing and presenting a weekend training program for teachers and 4-H leaders. She has worked to promote 4-H partnerships with schools, government resource agencies and nonprofit organizations. She currently is a member of the Michigan State University Natural Resources Committee Task Force.

Cecil Hockett, *Salem, Missouri*

Cecil has been a volunteer 4-H leader for 16 years, active in both county and state wildlife, fisheries and forestry educational events. He and his wife Gloria were the local chairpeople for the National 4-H Wildlife Habitat Invitational hosted by Missouri in 1992. Cecil served four years as the Missouri 4-H wildlife and fisheries coach for the team that participated in the National 4-H Wildlife Invitational. He continues to help leaders and youth in the 4-H wildlife project area and share his love of the outdoors, fishing and hunting with others. On the state level, he has served on the wildlife and forestry planning committee that is responsible for providing long-range planning for outdoor education and environmental stewardship opportunities for the young people of Missouri.

Inez Saum, *Columbus, Mississippi*

Inez has been a volunteer 4-H wildlife and fisheries leader for more than 12 years. She coached the 1993, 1994 and 1995 first-place wildlife habitat evaluation teams in Mississippi. A state-trained and certified wildlife and rifle instructor, Inez became a 4-H leader years ago by helping her own three children with their 4-H projects. Twelve years later, she still is the club advisor. Over the years, she has taught more than a hundred wildlife management workshops and established a county 4-H field and stream program. Inez had nearly 40 youth involved in wildlife, air rifle, archery and shotgun training programs. Her 4-H club has won first place in the state twice and has been selected as the outstanding club in the county for seven consecutive years.

Lynda Nelson, *Ferron, Utah*

Lynda has been a volunteer 4-H fisheries and wildlife leader for more than 18 years. She is known locally as "the 4-H Lady." Her family consists of a husband, Grant; son, Travis; six stepchildren; eight grandchildren; two sons-in-law; one daughter-in-law; and lots of animals! Over the years, Lynda's 4-H club, "The Wildlife Bunch," has learned about conservation, forestry, trapping, raising rabbits and pheasants, hunter ethics, archery, rifle, shotgun and black powder safety, wildlife identification, and taxidermy. Lynda says, "I am like a child eager to learn more and will continue to be involved in 4-H, particularly in wildlife conservation and shooting sports projects. The 4-H Wildlife Habitat Judging Contest is an excellent program that I will continue to promote in the county and state and throughout the Western United States. My goal is to be a member of the National Wildlife Habitat Judging Committee and the National Shooting Sports Committee. Also, I would like to promote these projects in the local schools."

The 1996 Guy Bradley Award

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

When we as natural resource professionals are asked to recite the ingredients of successful wildlife conservation, do we remember to include law enforcement? Law enforcement is an intergral part of the formula that includes biologists, habitat managers, and a host of other state and federal land management professions. Collectively, they form the "thin green line" dedicated to conserving this nation's fish, wildlife and plant resources for future generations. In recognition of law enforcement's role, the National Fish and Wildlife Foundation presents the Guy Bradley Award.

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 given annually to that person, or persons, whose dedication and service 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, the Department of Justice, and PacifiCorp. This year, the Foundation is pleased to recognize another dedicated individual.

David Klabak, Wisconsin Department of Natural Resources

David Klabak serves as a Conservation Warden with the Wisconsin Department of Natural Resources in Madison, Wisconsin. Dave has been with the Department for 17 years and has demonstrated an extraordinary commitment to the conservation and protection of our natural resources. He consistently maintains a comprehensive vision for conservation which includes both vigilant law enforcement and thoughtful appreciation of how that enforcement enhances the higher goal of preserving wildlife for future generations.

Dave's commitment has been especially impressive over the past five years, as he has played an instrumental role in two large-scale illegal fishing investigations in Lake Michigan. Dave was involved in virtually every aspect of the investigations, from undercover sting operations to grand jury testimony. He developed and implemented a written plan of goals and objectives for Wisconsin's involvement in the investigation, and worked unselfishly with other jurisdictions, using his leadership and experience to build a unified multi-agency investigation team. Dave's efforts in one investigation alone led to the prosecution of 12 individuals and 4 corporations for the interstate sale and transportation of illegally taken fish and wildlife under the Lacey Act. These convictions resulted in substantial jail sentences, fines and restitution totalling more than $300,000, forfeiture of two fishing vessels, suspension of fishing privileges, and the permanent loss of wholesale fish dealer licenses for several defendants.

Dave's dedication, excellence and professionalism are a tribute to his Department and to the wildlife law enforcement profession. For these qualities of character and for his numerous law enforcement achievements over the past 17 years, we are proud to honor Conservation Warden David Klabak.

The Award

In recognition of Dave's efforts on behalf of wildlife conservation, the National Fish and Wildlife Foundation is pleased to present him with a commemorative plaque, together with a check for $1,000. Dave has asked that this cash award be donated to the Natural Resource Foundation to be directed to the Wisconsin Conservation Wardens Exhibit and Museum.

The Foundation recognizes that Dave is only one of the many dedicated individuals who deserves recognition. We look forward to recognizing many others in the years to come. The Foundation would like to thank Terry Crawforth, John Doggett, Ken Goddard, Terry Grosz, Max Peterson, Rollie Sparrowe and Jim Timmerman 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. *Issues and Problems in Predation Management to Enhance Avian Recruitment*

Chair
Terry A. Messmer
Berryman Institute
Department of Fisheries and Wildlife
Utah State University
Logan, Utah

Cochair
Frank C. Rohwer
Delta Waterfowl and Wetlands Research Station
Portage, Manitoba *and*
School of Forestry, Wildlife and Fisheries
Louisiana State University Agricultural Center
Baton Rouge, Louisiana

Introductory Remarks

Terry A. Messmer

Wildlife Management Approaches

Bolen and Robinson (1995: 2) define wildlife management as "the application of ecological knowledge to populations of vertebrate animals and their plant and animal associates in a manner that strikes a balance between the needs of those populations and the needs of people." Implicit in this definition is the suggestion that humans have an obligation to manage populations so that they remain viable. Maintaining viable populations is the focus of conservation biology. Maintaining populations of desirable species to meet human food and recreational needs is the traditional focus of fisheries and wildlife management.

Unfortunately, many bird populations have declined in recent decades. These declines are reason for concern because they threaten the viability of populations or interfere with human recreational objectives. Wildlife population declines typically follow habitat loss; continued habitat loss appears inevitable until the human population and per capita consumption of natural resources are stabilized (Daily and Ehrlich 1992, Houghton 1994).

Loss of habitat brings into focus a management dilemma. When faced with reduced habitat, wildlife and conservation managers frequently set goals of increasing the productivity of desired species on remaining habitats as a way to minimize the detrimental effects on populations. However, this often is difficult in the absence of intensive management, because remaining habitat fragments may be adversely influenced by the uses of surrounding lands (Fahrig and Merriam 1994, Paton 1994, Helmers and Gratto-Trevor 1996).

In theory, the conservation biologist trying to enhance sparse populations to ensure viability would advocate management strategies similar to those used by the wildlife biologist trying to produce a harvestable surplus. Both first should attempt to identify the weak links in the population process and then design and implement appropriate management solutions (Caughley 1994). There is mounting evidence in many avian populations, including both game and non-game species, that recruitment rates have declined and are insufficient to maintain population densities at historic levels (Cowardin et al. 1985, Klett et al. 1988, Martin 1992, Beauchamp et al. 1996, Martin et al. 1996). In many cases, the primary cause of low recruitment is predation of eggs and young (Ricklefs 1969, Sargeant and Raveling 1992, Helmers and Gratto-Trevor 1996, Sullivan and Roper 1996, Witmer et al. 1996). If both conservation and wildlife biologists identify high nest predation as the problem, then the next question is "what is an appropriate solution?" The conservation and wildlife biologists may have different answers for this question because of differing population management goals.

Managers can take three approaches to address population problems: (1) passive management or preservation, (2) indirect manipulation of the populations by habitat management, and (3) direct manipulation of populations. The preservationist approach seeks to manage the ecosystem in question by minimizing human influence or intervention. This passive form of management has little appeal to wildlife managers and is increasingly questioned by conservation biologists (Soule 1991, Baskin 1994, Western 1994). There are few preserves in North America that have their pre-European settlement species compositions intact and that are large enough to contain the ecological processes (fire, migrant grazers, water cycles, etc.) that are essential to maintaining the system. Moreover, these preserves struggle to exclude external threats from animals or plants of adjacent altered habitats (Janzen 1986, Walker 1989). Active management will be needed at most bioreserves.

The indirect management approach implements habitat management techniques to increase population size by raising birth rates or survival rates. This approach is the holy grail of wildlife management. It is clear that habitat is necessary for population survival, but less clear that habitat management alone is the most cost effective and efficient way to enhance populations (Lokemoen 1984).

The direct management approach involves activities that have immediate effects on population birth or death rates. The most common direct management activity is regulation of harvest. Other direct forms of population management include stocking programs with captive-reared individuals, translocation programs and the reduction of predator populations. Many of the direct approaches are controversial among wildlife and conservation biologists, who view this management as inefficient and unsustainable. Conversely, the immediate and direct effects on populations make such approaches popular with resource users.

Biological Questions About Managing Predation

Manipulation of predator numbers to increase populations of some prey species probably is the most controversial of all approaches to population management. There are a variety of biological issues and public opinions surrounding this issue. Probably the most important questions
are those concerning biological issues. First, we need to know the impact of predators on their prey populations. Do predators maintain prey populations at levels lower than would exist without the predator as part of the community? We cannot offer generalities to this question, since each management situation must be examined separately.

A second question is whether we can manipulate predator populations or predator behavior enough to impact recruitment of the prey population. Even substantial reductions in the number of some predators may have little effect on prey abundance. Remaining individuals of the predator population can show strong density-dependent responses of increased natality and decreased natural mortality, so the population may quickly recover from predator reduction programs (Knowlton 1972). Moreover, individuals of the same predator species or other species may shift their diet and consume prey that would have been taken by the predators that were eliminated (Greenwood 1986, Sargeant et al. 1987).

A third key biological question is, "what effect will predator removal have on prey species not targeted by the management plan?" Predator reduction programs must be designed and implemented carefully to avoid increasing prey species that might negatively impact adjacent land or other components of the community being managed. The failure to anticipate or correct detrimental impacts could undermine other wildlife or conservation management programs (Conover 1994).

For many species of concern, especially non-game species, we are just beginning to assess the importance of predation to the population (Martin et al. 1996). Game species have received disproportionate research attention, especially since the question of the effects of predation on prey populations is easier to address for these species. Waterfowl hunters are concerned about fall flight estimates because these numbers affect harvest regulations and hunter opportunities. Nest predation directly influences the size of the fall flight, thus, waterfowl managers regularly endorse predator management and struggle only with selecting effective and acceptable ways to reduce nest predation. In contrast, the deliberations about predator management are more difficult if the goal of waterfowl management is to enhance breeding populations. Decreased nest predation will increase fall populations of ducks, but, if density-dependent regulation of population size occurs in winter, then the post-winter population may not be closely correlated with the previous fall's population. This means that the effectiveness of managing predation levels during the nesting season could depend on whether the management goals are for enhanced teal populations in September, quail populations in December, gobbler populations in April or long-term populations of Kirtland's warblers (*Dendroica kirtlandii*).

This session will examine the biological information regarding the effects of predation on the dynamics of bird populations. Several papers will examine the available management options and evaluate their feasibility. These topics will be addressed from a variety of standpoints, for a variety of taxonomic groups and for categories of birds that range from scarce to abundant. Although not the central focus of this session, any discussion of predator management also must address its social acceptance. Some authors will elaborate on these issues. We believe that a review of the history of predator management is important to help frame the forthcoming discussion.

Predators and Predation: A Historical Review

Early Wildlife Management Doctrine: Predator Control

Predator control was one of the earliest forms of wildlife management. Colonists, true to their European ancestry, viewed predators as competitors for the food that was essential to their survival. When wildlife consumption made the transition from subsistence to sport hunting, predators retained their status as competitors with humans. In addition to predator control, early wildlife management focused on the introduction and propagation of game birds and fish. These activities tended to reinforce the view of the manager that predator control was an essential component of management. Managers often had a direct hand in propagation, so they were understandably less tolerant of sharing the fruits of their efforts with predators. Several states implemented bounty systems to control predators. Even where bounty laws were not in force, sportsmen were urged to kill predators at every opportunity (Hornady 1913).

Social and Scientific Changes in the 1930s

The 1930s had austere beginnings: the stock market crashed, the U.S. entered the depression and the "Dust Bowl" devastated local economies and wildlife populations. Roosevelt's election signaled that the U.S. was ready for major social changes. Perhaps this climate of change predisposed scientists of the day to accept new ideas.

The field of wildlife management experienced major changes, largely due to Aldo Leopold's influence, especially through his book *Game Management* (McCabe 1987). Leopold recognized and articulated the need for sound ecological science as the basis for management decisions (Leopold 1933). During this period, the first North American Wildlife Conference was held. Cooperative Wildlife Research Units began using Leopold's principles to train future wildlife managers. Pittman-Robertson money began flowing to the states and the Migratory Bird Hunting Stamp Act accelerated the development of the refuge system. In spite of Leopold's writings and the growing emphasis on habitat management, few questioned the necessity or value of predator control programs.

Predator Control versus Habitat Management: A Postwar Paradigm Shift

With the end of World War II, veterans took advantage of educational opportunities to enter wildlife management professions, and wildlife agencies grew rapidly as demands for hunting and fishing increased. Wildlife biologists questioned the efficacy of many predator control programs. Agencies began to abandon game propagation and predator control in favor of wild stock transplants and habitat management. Bounty systems were discontinued.

Before the War, public attitudes toward predators had been shaped by books such as *Little Red Riding Hood*. After the War, movies and television transformed predators from ugly and ominous to playful, beautiful and important components of the wildlife community. This view was reinforced by the growing ecological movement.

Conflicting Goals and Management Strategies

Today, more than ever, wildlife science wrestles with the concept of what is a "natural community" and what role the wildlife manager should take in the stewardship of communities. This debate focuses on the right and capacity of humans to manipulate the "natural" environment. One side of the argument suggests that nature still can manage the land and its wildlife better than humans (Noss and Cooperrider 1994). The opposing view holds that humans have every right to manage to suit their needs. This suggests that managers must be bold enough to shape new ecosystems and should only be constrained by sound ecological principles (Johnson and Mayeux 1992).

At first glance, the latter view seems contrary to the movement to preserve biodiversity. However, many conservation biologists now view sustained use of resources as the most practical way to preempt the loss of biodiversity (Beissinger and Bucher 1992, Western 1994). Many now suggest that relying on preservationist approaches applied to the 5 percent of land encompassed in national parks will not be adequate to preserve biodiversity (Baskin 1994).

There seems little doubt that management policies must be flexible enough to incorporate a variety of approaches if biological diversity and healthy populations that both consumptive and nonconsumptive users want and enjoy are to be maintained. When defining management policies, natural resource administrators must clearly articulate their agencies' goals for managed populations and the contribution that each management approach will make in achieving the desired outcomes. We believe predator management should be considered when examining options for population management. Predator management can be very effective at enhancing populations, but such programs must be based on sound scientific evidence.

Finally, it is important to remember that society places a high value on predators. Therefore, meeting the public's dichotomous desire for a landscape with abundant predators and high densities of desirable birds will be difficult to achieve.

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Prairie Duck Populations and Predation Management

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Introduction

The purpose of our paper is to discuss strategies for managing mammalian predation on prairie-nesting ducks and issues likely to affect predation management in coming years. Predation management is a complex, often emotional subject for which there are no easy solutions or pat answers (Berryman 1972). Because knowledge of the functioning of natural systems can help direct management efforts, we first want to examine briefly some events that we think may have influenced the recent recovery of duck populations. Near the end of the last decade, breeding populations of many North American prairie-nesting ducks were greatly depressed; estimates for mallards (*Anas platyrhynchos*), blue-winged teal (*A. discors*) and northern pintails (*A. acuta*) were at or near record low levels. By 1995, however, the estimated total breeding population of ducks in North America was the highest since 1980 and 11 percent above the long-term (1955-1994) average (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1995).

A primary factor affecting populations of prairie-nesting ducks is low recruitment due to predation on nesting females (Johnson and Sargeant 1977, Sargeant et al. 1984), eggs (Cowardin et al. 1985, Klett et al. 1988, Greenwood et al. 1995) and ducklings (Talent et al. 1983, Cowardin et al. 1985, Orthmeyer and Ball 1990). Predation on breeding grounds is related to habitat conditions (Cowardin et al. 1985, Greenwood et al. 1995) and make-up of predator communities (Greenwood 1986, Johnson et al. 1989, Sovada et al. 1995). Species that nest in early spring are especially vulnerable to predation (Johnson and Sargeant 1977, Blohm et al. 1987, Greenwood et al. 1995). Risk to breeding females from predation is greatest during years of good water conditions when the nesting period is prolonged.

The Prairie Pothole Region (PPR) of the northern Great Plains is the primary breeding ground for ducks in North America (Batt et al. 1989). Most upland areas suitable for farming in the PPR have been converted to cropland (Lynch et al. 1963, Boyd 1985, Sugden and Beyersbergen 1984, Higgins 1977). In many areas, the only remaining upland habitat for nesting ducks is along roadsides, fence rows and other isolated small areas of undisturbed cover (Greenwood et al. 1995, Higgins 1977, Sugden and Beyersbergen 1984).

Recovery of Duck Populations

Four events seem to have influenced the recent recovery of duck populations.

Reduced predator control. In the mid-1970s, coyote (*Canis latrans*) populations in the PPR began to rebound following years of suppression (Johnson and Sargeant 1977). This rebound followed the 1972 ban of toxicants to control predator-caused damages on federal lands or through federally funded programs (Nixon 1972), restrictions on aerial hunting and easing of other control programs. Although coyote and red fox (*Vulpes vulpes*) always have occupied the PPR (Hall and Kelson 1959), in sympatric populations, coyotes exclude red foxes from large areas (Sargeant et al. 1987, Voigt and Earle 1983). Both species prey on nesting ducks, but because foxes are particularly severe predators of upland-nesting ducks and eggs (Sargeant et al. 1984, Johnson et al. 1989), a coyote-dominated predator community is more favorable to nesting ducks than one dominated by red foxes (Sovada et al. 1995). Although coyotes were scarce throughout much of the PPR in the late 1970s (Johnson and Sargeant 1977), they occupied much of the PPR in North and South Dakota by the early 1990s (Sovada et al. 1995). Security provided to coyotes by large expanses of land idled through the Conservation Reserve Program (CRP), enacted by the U.S. Department of Agriculture (Young and Osborn 1990), and reduced harvest resulting from low pelt prices probably enhanced recent expansion of the species' populations.

Drought of 1980s. A prolonged period of drought occurred throughout much of the PPR from the mid-1980s into the early 1990s. Drought affected the Canadian portion of the PPR first (Greenwood et al. 1995) and, later, the U.S. portion (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1995, Todhunter 1995). An obvious effect of drought was the precipitous decline in breeding ducks (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1995). Less obvious was the related decline in mink (*Mustela vison*) populations (Sargeant et al. 1993). Mink are serious predators of over-water nesting ducks and ducklings (Eberhardt 1973, Eberhardt and Sargeant 1977, Arnold and Fritzell 1987). Drought reduces reproduction of mink (Eberhardt 1974) and has catastrophic effects on mink populations (Sargeant et al. 1993). In the early 1990s, mink populations were extremely low in much of the PPR.

CRP enacted. Beginning in 1985, millions of hectares of cropland were restored to perennial grassland under CRP (Young and Osborn 1990). In North Dakota, South Dakota, Minnesota and Montana, this amounted to more than 3 million hectares (Jones and Kruse 1995), of which about 2.5 million were in the PPR (Kantrud 1993). CRP fields are attractive to ducks and can be highly productive (Kantrud 1993, Reynolds et al. 1994). However, during the mid-1980s, CRP fields' potential for increasing recruitment of ducks was greatly diminished due to drought (Kantrud 1993). CRP fields also are attractive to and provide productive nesting habitat for a variety of nongame bird species (Johnson and Schwartz 1993a, 1993b).

Drought ended. During 1993-1995, conditions for breeding ducks may have been the best ever observed in some areas of the PPR (Krapu 1994, U.S. Fish and Wildlife Service and Canadian Wildlife Service 1995). Nesting cover was abundant in the U.S. portion of the PPR due to CRP. In North Dakota, beginning in June 1993, precipitation was above long-term averages for 14 of 19 consecutive months (National Oceanic and Atmospheric Administration 1993, 1994). After years of drought, numerous ponds contained abundant detritus that provided optimum conditions for production of benthic macro-invertebrates (Neckles et al. 1990) needed by laying females and ducklings (Swanson and Duebbert 1989). Red fox numbers were low, favoring high nest success, and mink numbers were low, favoring high rates of duckling survival. These conditions lead to production of "Super-Crops" of ducks (Lynch 1984); however, such conditions seldom are synchronized for more than a few years at a time. Lynch et al. (1963) suggested that, where habitats are altered by agriculture, high duck production is likely in only 2 to 3 years out of 10.

Strategies for Managing Predation

CRP replaced cropland with grassland in much of the U.S. portion of the PPR, but when enrollment periods begin to expire in 1996, prairie landscapes again will change markedly. Change also is inevitable in predator populations. So the question arises again, "What can be done to reduce effects of predation on duck production in the PPR and how should management be applied for maximum effect?"

There are nine mammals and seven birds that commonly prey on ducks in the PPR (Sargeant et al. 1993). A variety of methods have been tried or suggested for reducing effects of some of these predators on ducks (Sargeant and Arnold 1984). Most methods protect only the nesting hen and eggs from mammalian predators; few target avian predators or enhance survival of ducklings. Most methods affect duck production on a local scale; few methods have potential to affect duck populations at the landscape scale. Methods can be grouped into those that (1) physically separate or conceal prey from predator; (2) alter predator foraging behavior or food supply; or (3) affect predator distribution or abundance, including both lethal and nonlethal methods.

Separate or conceal prey. Management of grassland habitat to provide dense nesting cover (Duebbert et al. 1981) is practiced under the assumption that heavy cover will repel predators and prevent nests from being detected. Although dense cover is attractive to ducks and several studies have reported high nest success in this habitat (Schranck 1972, Duebbert and Lokemoen 1976, Kirsch et al. 1978, Livezey 1981, Cowardin et al. 1985, Sugden and Beyersbergen 1986, 1987), a review by Clark and Nudds (1991) was inconclusive on reported benefits of dense nesting cover. Clark and Nudds (1991) suggested that concealment of nests was important to survival of duck nests in the PPR only when predation was predominantly by birds. Use of dense nesting cover is appealing for various reasons, especially economics (Lokemoen 1984), but use of this practice alone in local areas probably is of limited value in reducing predation on nesting ducks where mammals are primary predators. Planting of dense vegetation actually may be counterproductive where Franklin's ground squirrels (*Spermophilus franklinii*) occur because this predator prefers dense cover (Choromanski-Norris et al. 1989).

Physical barriers, including moats constructed across peninsulas (Lokemoen and Messmer 1994, Lokemoen and Woodward 1993) and nesting islands (Jones 1975, Giroux 1981, Higgins 1986, Lokemoen and Messmer 1993), also are used to protect nests. Fences, usually electrified, are used as barriers across peninsulas (Lokemoen and Woodward 1993), around tracts of nesting habitat in uplands (Lokemoen et al. 1982, Greenwood et al. 1990, Gatti et al. 1992) and around individual nests (Sargeant et al. 1974). Barriers can be effective in preventing destruction of nests by mid-sized and larger mammalian predators, especially when used in conjunction with trapping or a toxicant to keep predators from the protected area during the nesting season (Greenwood et al. 1990).

Barriers are not effective with all mammalian predators. Semi-aquatic species, such as mink and raccoons (*Procyon lotor*) are not deterred by water barriers, and Franklin's ground squirrels, mink and weasels (*M. erminea* and *M. frenata*) can penetrate fences easily. In addition, mortality sometimes occurs among ducklings that cannot exit through mesh fences (Sargeant et al. 1974, Pietz and Krapu 1994, Trottier et al. 1994). The electric fence is one of the most cost-effective methods of increasing nest success of ducks in local areas; creation of water barriers by excavating dikes or constructing islands is one of the most costly methods (Lokemoen 1984).

Another method of separating nests from mammalian predators is with elevated structures (Zenner et al. 1992), including nest baskets (Bishop and Barratt 1970, Doty et al. 1975) and earth-filled culverts (Higgins et al. 1986, Ball and Ball 1991). The mallard is the only duck that readily uses nest baskets (Bishop and Barratt 1970, Doty et al. 1975). Although elevated structures are relatively cost-effective (Lokemoen 1984), each nest basket generally protects only one nest. Single earth-filled culverts may simultaneously contain nests of both mallards and Canada geese (*Branta canadensis*) (Ball and Ball 1991). Raccoons sometimes climb support poles, and avian predators may destroy eggs in nest baskets unless overhead covering is provided (Doty 1979). Methods that separate or conceal prey from predators function mostly at the local scale, although individual applications can be aggregated regionally to reduce administrative costs and possibly increase effectiveness.

Alter foraging or foods. Conditioned taste aversion (CTA) employs a natural biological process to alter the foraging behavior of predators (Nicolaus et al. 1982, 1983, Nicolaus 1987, Conover

1989, 1990, Dimmick and Nicolaus 1990). To protect eggs from predation, individual predators first must develop an aversion to chemically treated eggs placed where predators will encounter and consume them. Aversion then must be generalized to untreated eggs in naturally occurring nests. The aversion must translate to visual, olfactory or other externally provided cues, because if consumption or disturbance of eggs is required to elicit the aversion, the method is of little value in protecting eggs in naturally occurring nests.

Several compounds have potential for eliciting a CTA, but some are toxic and the response to compounds differs among species (Conover 1989, 1990). Thus, it is unlikely that a single compound will be effective for any major group of egg-eating predators in the PPR. CTA may be especially difficult to establish with red foxes. Foxes seldom eat eggs immediately upon encounter, but rather cache eggs for future consumption (Kruuk 1964, Tinbergen 1965). Tests with American crows (*Corvus brachyrhynchos*) have shown encouraging results and suggest that individual crows may avoid consumption of eggs for a considerable time after being conditioned to avoid them (Dimmick and Nicolaus 1990). Search for potentially usable compounds and the high cost of evaluating each compound with individual predator species are likely to be deterrents to screening and testing of a variety of aversive agents. For compounds that may be consumed by non-target species, registration may be difficult because of food and drug regulations. Unless it is possible to develop a CTA simultaneously in several species of predators inhabiting an area, compensatory predation by animals that have no aversion to consuming eggs may reduce success of this method.

Manipulating availability of food has been suggested to reduce consumption of eggs (Crabtree and Wolfe 1988). Theory behind this approach is based mostly on findings from arctic and subarctic ecosystems, where there are fewer species of predators and prey than in the PPR. In those ecosystems, abundance of alternate food for predators has been found to be inversely related to predation rates on birds and eggs (Larson 1960, McInvaille and Keith 1974, Pehrsson 1986, Summers 1986, Beintema and Müskens 1987). Byers (1974) suggested that nest success of ducks in the PPR was higher during years when indices of small rodent numbers were highest. Crabtree and Wolfe (1988) suggested that provision of supplemental foods for striped skunks reduced predation on duck nests. However, a study similar to Crabtree and Wolfe's (1988), conducted in central North Dakota during 1993-1994, failed to confirm the benefits to nesting ducks of providing supplemental foods for striped skunks during the nesting season (D. G. Pietruszewski and R. J. Greenwood unpublished data).

Lethal methods. Lethal control of predators to increase nest success or productivity of ducks has shown variable results; efficacy depends on method used and size of area treated (Balser et al. 1968, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980, Greenwood 1986, Doty and Rondeau 1987, Sargeant et al. 1995). Removal of individual species of predators (Greenwood 1986) or several species of predators (Sargeant et al. 1995) during the duck nesting season from small (less than 500 ha) areas managed for nesting ducks may result in moderate increases in nest success; however, variability in nest success among treated areas can be high due to compensatory predation by unaffected predators. Restrictions on methods permitted for use and other factors (e.g., inflexible work schedule of field personnel) may impact success of removal efforts (Sargeant et al. 1995). Removal of several species of predators with unlimited techniques from relatively large (less than 26,000 ha) areas, either during the duck nesting season (Balser et al. 1968, Schranck 1972, Garrettson et al. 1996) or year round (Duebbert and Kantrud 1974, Duebbert and Lokemoen 1980), can result in high duck nest success and brood production. Lethal control can be quite cost effective (Lokemoen 1984), especially when toxicants that require no daily maintenance are used. Depending on methods used, lethal control can affect duck production on large areas of landscape.

Although effective, lethal control is unpopular today and often is opposed by the public, even to protect endangered species. Issues raised involve humane treatment of animals, moral issues, and antihunting and antitrapping sentiment (Kirkpatrick and Turner 1985). Other issues also affect use of lethal control. For toxicants, costs of registration are extremely high and likely will detract from development of new compounds. Furbearer managers and fur harvesters may object to reduction of valued furbearers. To be effective in managing predation on nesting birds, predators must be removed just before and during the nesting season; because pelts have little monetary value in spring, there is little incentive for fur harvesters to participate in control efforts at that time.

Nonlethal methods. Inhibiting reproduction is an appealing nonlethal approach to population management of wild animals (Allen 1982, Kirkpatrick and Turner 1985, Warren 1995). This method was proposed as early as the 1960s for managing predation by carnivores (Balser 1964, Linhart and Enders 1964), but its use in North America today is primarily with ungulates (Garrott 1995). With carnivores, inhibition of reproduction is suggested to reduce predation by reducing food demand of females that have no young to support and by reducing recruitment, thereby decreasing population size. Perhaps the most compelling reasons for using reproductive inhibitors to control predator populations are social; the approach is humane and likely to be accepted by the public (Kirkpatrick and Turner 1985). However, Kirkpatrick and Turner (1985) questioned whether the cure is worse (i.e., unforeseen side effects) than the problem, and suggested that extensive preliminary studies are necessary, species by species, to assess treatment effects before field application is attempted. In the PPR, this could include evaluation of effects on at least eight carnivores with variable breeding times.

An important consideration in use of reproductive inhibitors is the proportion of a population that remains reproductively active after treatment (Garrott 1995). This is influenced by the proportion of animals detected, the proportion detected that is treated and the efficacy of the agent. Ideally, a population to be managed should be isolated geographically to limit immigration and emigration (Garrott 1995). There are few isolating mechanisms among predator populations in the PPR. In addition, reproductive and/or dispersal characteristics of some carnivores in the PPR (e.g., red foxes [Allen 1983], raccoons [Fritzell 1978], striped skunks [Greenwood and Sargeant 1994]) permit rapid recovery from population depletion.

Among canids, compounds tested or suggested for inhibiting reproduction range from steroids to, more recently, immunocontraceptive vaccines (Kirkpatrick and Turner 1985). Vaccines offer short-term reversible contraception suitable for rare or highly valued species, but may not be adequate where long-term population control is required or where the goal is dramatic reduction of the population (Garrott 1995). Where long-term control is desired, a technique that results in permanent sterility is more appropriate. However, widespread use of treated baits that may result in permanent sterility is unlikely to be popular with the public, especially where domestic animals may be exposed.

Another nonlethal approach to managing canid populations utilizes interspecific interactions among species. Red foxes avoid areas occupied by coyotes (Voigt and Earle 1983, Sargeant et al. 1987), and this interaction can influence productivity of nesting ducks (Johnson et al. 1989, Greenwood et al. 1995, Sovada et al. 1995). At low population levels, coyotes are thought to be less detrimental to nesting ducks than are red foxes (Sovada et al. 1995). Coyotes also may influence presence of raccoons, and badgers may influence presence of striped skunks (Johnson et al. 1989). Management of carnivore communities to favor coyotes may benefit nesting ducks over large areas of landscape, but also can create other conflicts. Coyotes prey on livestock and wild ungulates, especially young. Therefore, conflicts in objectives may ensue even within a game management agency, because management goals may differ among individuals or groups.

Future Predation Management in the Prairie Pothole Region

Wildlife professionals in rural areas continue to be faced with the challenge of reducing overabundant populations of wild animals. With increasing frequency, managers in urban and suburban settings face a similar problem (Warren 1995). Traditional methods of managing predator populations (e.g., hunting, trapping, poisoning) may not be appropriate or permitted in many areas, but few new approaches are available. Low fur prices due to instability in world markets have reduced, at least temporarily, incentives for public harvest of furbearing species. Changing human demographics have reduced numbers of fur harvesters in rural areas. Thus, managers in the PPR likely will get little help from the public in managing populations of mammalian predators, at least in the near future. This fact and fiscal austerity will require managers to focus efforts to enhance duck production where returns will be greatest.

The PPR is a dynamic area where factors that affect duck production, especially condition of wetland habitats, change continually. In this unstable environment, ducks have become opportunists in settling breeding habitat (Johnson and Grier 1988). Historically, ducks in the PPR had numerous options for breeding areas. Presently, however, in much of the PPR, options for breeding ducks are limited due to conversion of wetland and upland habitats to cropland.

Reynolds et al. (1996) discussed methods for identifying landscapes with greatest management potential for duck production, based wetland abundance. We believe identification efforts also should include abundance of grassland and the entire PPR, not just the U.S. portion. Nest success in the PPR is correlated with amount of perennial nesting cover in the landscape (Greenwood 1987). Knowledge of distribution of both wetland and grassland habitats at the landscape scale would enable managers to better target areas for treatment. This information also would provide a much needed framework for prioritizing areas for protection of threatened habitats.

We believe managers should conduct some type of periodic assessment at the landscape scale of predator populations, at least canids. Make-up of the predator community affects duck production (Johnson and Sargeant 1977, Greenwood et al. 1995, Sovada et al. 1995); knowledge about the predator community is important for management decisions to enhance duck production. Although changes in predator populations usually occur gradually (Sargeant et al. 1993), factors such as epizootics may result in rapid changes. Allen and Sargeant (1975) provided guidelines for an inexpensive and reliable method of assessing distribution and abundance of red foxes in North Dakota using rural mail-carrier surveys. Queries of farm operators and rural residents could provide additional information on canid distribution.

We believe that plans to enhance duck production, including predation management, should be based on long-term goals and be tailored to specific local and regional needs; a variety of approaches probably will be necessary. Management applied at the landscape scale to benefit duck populations, especially habitat enhancement (e.g., planting of nesting cover), is likely to be most effective when conducted in areas where nest success is highest (Greenwood et al. 1995). In areas where predation is severe and management to enhance duck production is mandated because of ownership or other reasons, more intensive management (e.g., use of barriers) of local areas may be the best choice. However, some types of intensive management (e.g., predator removal from small tracts) applied at the local scale may not be cost-effective when used where predation rates are high (Sargeant et al. 1995).

Evaluation is an important component of management. If the management goal is to enhance duck production, evaluation should focus on changes in duck recruitment. Other factors (e.g., number of predators removed, amount of nesting cover planted, number of wetlands restored) are easy and appealing to document, but may have little relation to actual number of ducks recruited (Sargeant et al. 1995).

Besides management based on long-term goals, we believe managers should be prepared to respond to events (e.g., excess precipitation, epizootics in predators) that temporarily may favor high duck production in certain areas. Such unpredictable events are characteristic of the PPR and offer unique opportunities for management, especially when they occur in the grassland portion of the PPR that is known for its high potential to produce ducks (Lynch 1984). As conditions change and become less favorable for duck production, emphasis can be redirected. In this manner, the dynamic nature of the PPR can be exploited as conditions dictate.

For example, an outbreak of sarcoptic mange (*Sarcoptes scabiei*) presently is reducing coyote and red fox populations in North Dakota and Minnesota (S. H. Allen personal communication: 1996). This epizootic has potential to affect canid populations for several years (Pence and Windberg 1994). Where areas with depleted canid populations overlap identified areas of high potential for duck production, temporary action (e.g., short-term contracts to restore wetlands, planting of nesting cover) might be used to attract breeding ducks. Simultaneous effort to reduce impacts of noncanid species in these areas might provide additional benefits to ducks.

We believe there is little rationale to expend resources for management beyond normal operations in areas where wetland conditions are poor for breeding ducks. Rather, we believe it makes more sense to consolidate resources from areas with poor wetland conditions for use in areas that have the greatest immediate potential (including favorable predator communities) for breeding ducks. Consolidating resources will require administrators to be flexible, respond quickly and focus on the entire PPR instead of local or regional aspects. The North American Waterfowl Management Plan (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986) provides a mechanism for cooperation and pooling of resources among management agencies. The challenge for future managers will be to focus efforts to enhance duck production where benefits are greatest while embracing the economic, ecological and ethical dimensions of predation management.

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Environmental Perturbations and Rates of Nest Predation in Birds

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Introduction

Nest predation commonly is the primary source of nesting mortality across a wide range of both nongame and game bird species and across virtually all habitat types and geographic locations (Martin 1991, 1992, 1993a). Perturbation of the environment through human-induced changes, such as habitat or land changes or modification of predator communities, commonly is thought to increase nest predation rates and reduce breeding productivity (e.g., Wilcove 1985, Ratti and Reese 1988, Andren 1992, Sieving 1992, Yahner and DeLong 1992). Of course, natural variation in the environment also can lead to variation in breeding productivity and very high nest predation rates in some cases (Martin 1993b). Breeding productivity exerts a major influence on subsequent population sizes and trends (Sherry and Holmes 1992, Johnson and Geupel 1996, McCleery et al. 1996, see also Martin 1991). Consequently, nest predation can become problematic when it reaches a level that creates "sink" populations (i.e., populations that cannot sustain themselves, Pulliam 1988); such populations can decline or even become extinct if not sustained by immigration (Loiselle and Hoppes 1982, Sieving 1992, Donovan et al. 1995). Indeed, long-term population declines in both nongame birds and waterfowl may be linked strongly to nest predation (Martin 1992, 1993a, Böhning-Gaese et al. 1993, Ball et al. 1994). As a result, a major issue facing wildlife managers is to understand the causal links between environmental perturbations and risk of nest predation in order to identify effective conservation strategies (Martin 1992). Here, we evaluate the common practice of using artificial nests to study patterns of nest predation, and explore the levels of nest success required for population maintenance.

Artificial Nest Studies

Rates of Nest Predation

Many studies that have examined the potential consequences of habitat and land modifications on nest predation rates have been based on experimental tests using artificial nests (e.g., see Paton 1994). This approach facilitates strong statistical design and large sample sizes with reasonably easy effort. Yet, ease should never be a substitute for accuracy and the accuracy of artificial nests in representing real patterns of nest predation is far from clear.

Studies of real populations, whether of nests or population sizes, are rarely allowed into print based on a single year of study because of the well-known annual variation in ecological phenomena. Yet, single-year studies using artificial nests commonly are accepted for publication, presumably because of clean designs and large sample sizes. Casual inspection of artificial nest studies that do provide temporal replicates shows that nest predation rates commonly increase over time. Such increases may reflect learning responses of predators (Martin 1987), suggesting some inherent biases in experiments using artificial nests (see also Willebrand and Marcström 1988, Roper 1992, Nour et al. 1993, Haskell 1995a, 1995b). Moreover, nest predation rates can vary among years with changes in predator populations, alternate prey or habitat conditions (Marcström et al. 1988, Martin 1993b), so that single-year studies may be misleading.

Of course, artificial nests may not represent real rates of predation anyway. Predation rates on artificial nests can differ strongly from rates on real nests (e.g., see Martin 1988). Determination of actual rates of predation is important to allow detection of source versus sink populations and identification of the associated environmental conditions. Identification of environmental conditions associated with source populations allows such environmental conditions to be targeted for preservation and used as a management guideline for improving habitats that are population sinks.

Patterns of Nest Predation

Identification of environmental conditions that support source versus sink populations by studying real nests provides the strongest information for habitat management. However, artificial nests still may be useful for determining the relative effects of environmental perturbations on predation risk if artificial nests can index patterns of predation among environmental conditions. Thus, an important question that needs much greater attention is whether artificial and real nests exhibit the same patterns of nest predation across variation in environmental conditions.

Certainly in some circumstances, patterns of predation rates on artificial nests mimic patterns on real nests (e.g., Martin 1996), but comparisons of patterns and rates of nest predation between real and artificial nests are few. Nonetheless, some evidence exists that artificial nests do not always mimic patterns of predation on real nests. For example, artificial nests compared with real nests yield opposite patterns of nest predation between ground and off-ground nests (Martin 1987). Indeed, a number of artificial nest studies suggest that nest predation is greater for ground nests than off-ground nests (e.g., Loiselle and Hoppes 1983, Wilcove 1985). Yet, a variety of studies on real nests suggest that predation rates are the opposite, being lower on ground than off-ground nests (Martin 1993a, 1995). Studies by Haskell (1995a, 1995b) indicate that differences in nest predation among forest fragments suggested by artificial nests may be an artifact of changing predator communities and differences among predators in their response to artificial nests and eggs used in such studies (see also Martin 1987). Such potential directional biases may strongly influence the patterns we observe and our interpretation of those patterns.

Artificial nest studies may incorporate an array of possible biases. Eggs used in artificial nest studies commonly are larger than eggs of the species being simulated, which may bias the kinds of predators that can eat them (Roper 1992, Haskell 1995a, 1995b). Lack of parents at artificial nests could influence the cues, such as scent (Sieving 1992) or parental activity at the nest (Ratti and Reese 1988), that predators use to find real nests. Finally, artificial versus real nests may differ substantially in nest appearance, placement or conspicuousness (Martin 1987). Thus, artificial nests may not describe either actual rates or patterns of nest predation, and results obtained from them should be tested against real nests or viewed with great caution. Tests of possible biases are badly needed, and single-year "quick-and-dirty" studies should be strongly discouraged.

Ultimately, artificial nests are used to try to ascertain potential effects of environmental conditions on risk of nest predation. Once environmental causes of increased nest predation risk can be identified, land-management practices potentially can be modified to mitigate problems. As a result, accurate identification of patterns of nest predation relative to environmental conditions is critical. Artificial nests may provide an accurate index in some cases, but clearly not always, whereas real nests can provide an accurate measure most often. Yet, even real nests only allow identification of environmental correlates of nest predation. Predation risk ultimately is determined by environmental influences on predator communities, predator population sizes, alternate prey and search efficiency of predators (Dunn 1977, Marcström et al. 1988, Martin 1988, 1993b, 1996, Sovada et al. 1995). As a result, one of the most important future avenues for improving understanding of environmental influences on predation risk lies in direct study of nest predators and the effects of environmental conditions on their populations and search strategies. Vegetation density, or density of the particular kinds of vegetation that are used for nest sites may influence predation risk by impeding search efficiency of predators (Bowman and Harris 1980, Martin and Roper 1988, Martin 1992). However, some predators may search for habitat patches that potentially contain prey (see Martin 1992, 1993b). Alternatively, predators may find nests incidental to their search for other prey (Vickery et al. 1992) in habitat patches that generally may be rich in prey. In the former situation, increased vegetation density of the type used for nesting may be appropriate for reducing predation risk (Martin 1992), whereas, in the latter case, increased vegetation density may only serve as a cue to attract predators. Such differences highlight the importance of understanding the factors influencing nest search and detection by predators. Theoretical modelling of possible environmental influences on search strategies could aid future tests and studies.

Predation Rates and Population Sources and Sinks

Measurement of actual rates of nest predation and nest success becomes important for identifying environmental conditions that support population sources and sinks. However, land managers also are faced with trying to interpret measured rates of nest predation to ascertain whether a habitat is suitable or needs management action to improve it. Measured rates of nest predation among songbird species and geographic locations vary from 0 to 90 percent (Martin 1993a). Does nest success of 30 percent represent a population in trouble (i.e., sink) or one that is self-sustaining (i.e., source)? Donovan et al. (1995) studied nesting success and predation of Ovenbirds (*Seiurus aurocapillus*), Red-eyed Vireos (*Vireo olivaceus*) and Wood Thrushes (*Hylocichla mustelina*) in fragmented and continuous habitats. The authors concluded that populations with nesting success below 30 to 32 percent, as commonly observed in fragments, reflected population sinks for these three bird species. These results provide a yardstick for these three species, but represent a narrow range of bird species and environmental conditions and do not account for correlated life history traits and annual variation in vital rates.

The three species studied by Donovan et al. (1995) represent a narrow range of life history tactics with average annual adult survival rates of 0.56 to 0.67, whereas songbirds as a group show variation in annual adult survival rates varying from 0.29 to 0.76 (Martin 1995). Similarly, waterfowl show variation in annual adult survival probability ranging from 0.33 to 0.88 (Johnson et al. 1992, Promislow et al. 1994). Differences in annual adult survival rates are correlated with differing fecundities (clutch sizes, numbers of successful broods and renesting effort) in nongame birds (Martin 1995). These different life history patterns mean that differing levels of nest success are required to achieve stable populations by differing species in different environmental conditions.

If we generate population growth (λ) isoclines demarcating where populations are self-sustaining for species with differing life history traits, we can examine the nesting success necessary to maintain populations (Figure 1). The results show that species that are single-brooded with a clutch size of four and juvenile survival of 0.3 require a nesting success of at least 76 percent to be self-sustaining. Such life history traits are typical of woodpeckers, and woodpeckers commonly have nesting success exceeding 76 percent (Martin and Li 1992, Martin 1995). This analysis also suggests that, in single-brooded warblers or other songbirds with a clutch size of four, 76 percent of the breeding pairs must fledge a brood for population maintenance. This level of pair success can be achieved by renesting efforts. For example, a Yellow Warbler (*Dendroica petechia*) typically has clutch sizes of four, but they commonly renest one to three times (see Martin 1995). As a result, their annual fecundity is about 10 eggs per year when including renesting efforts and this fecundity only requires a nesting success of about 45 percent per nest attempt if juvenile survival is 0.3 (Figure 1). Since most birds will renest at least once, and many species will renest several times, renesting effort will have a strong effect on the nesting success required for a population to maintain itself. Nonetheless, an average production of 10 eggs per year, probably typical for most

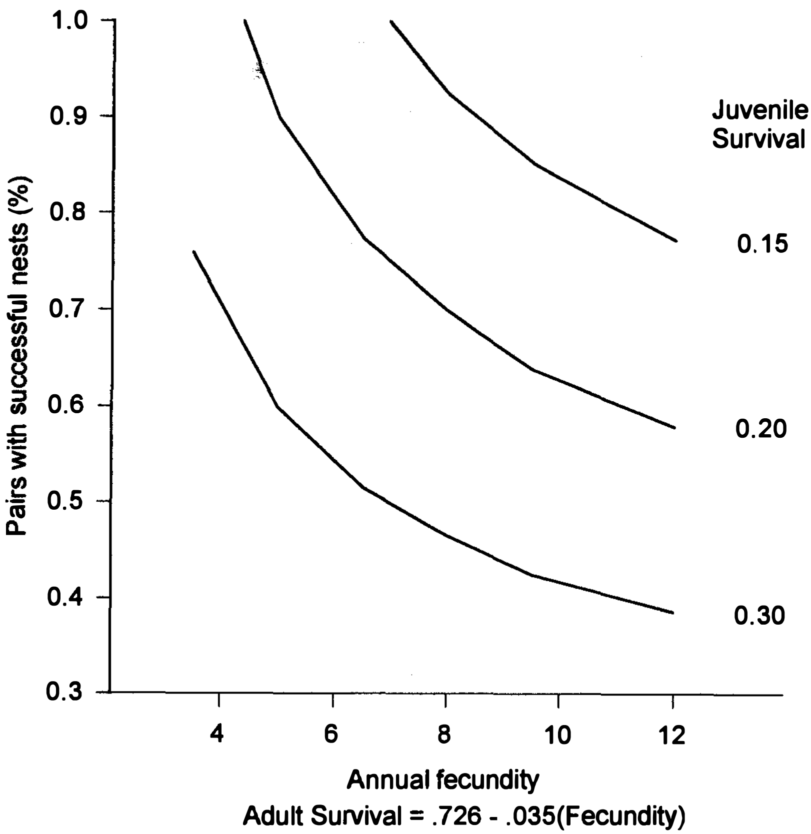

Figure 1. Deterministic population replacement isoclines as a function of the percentage of breeding pairs that must have successful nests for a given annual fecundity and annual juvenile survival rate to achieve $\lambda = 1$. Annual adult survival is estimated as: 0.726-0.035 * (annual fecundity) based on data in Martin (1995) and where annual fecundity = clutch size * number of successful broods per season. Annual fecundity is shown on the abscissa, but note that, because it is strongly correlated with annual adult survival (Martin 1995), the axis also reflects annual adult survival.

canopy-nesting neotropical migrant birds (see Martin 1995), may require a nesting success of about 45 percent (based on juvenile survival of 0.3) or above (with lower juvenile survival) to achieve population maintenance. In fact, average nesting success among a variety of canopy-nesting species has been measured as about 47 percent (see Martin 1995), suggesting that populations studied in good habitat conditions are, in fact, source populations. In contrast, nesting success in fragmented or disturbed habitats often are below this level (Donovan et al. 1995, Robinson et al. 1995).

These projections can be used as rough guidelines to nesting success required for species to achieve population maintenance, but the projections ultimately depend on accurate information on renesting effort and numbers of broods per year, as well as juvenile survival, and this information generally is lacking (Martin 1995). Moreover, our simulation is a deterministic simulation which does not account for variance in vital rates and correlation between clutch size and brood number or renesting effort. Future efforts should be directed at stochastic modelling strategies to gain further insight into relationships. Until more rigorous models are developed and more specific information on renesting effort and numbers of broods can be gathered, the most conservative estimates of the nesting success required for population maintenance should be used. Such conservative approaches then can provide a means to identify populations or habitat conditions that support source or sink populations and, thereby, allow targeting management responses. Appropriate management responses, however, also will depend on detailed knowledge of habitat requirements of species and determination of environmental influences on breeding productivity (Martin 1992, Martin and Geupel 1993). Such information is being gathered by the Breeding Biology Research and Monitoring Database (BBIRD) program, and further participation in this program is encouraged.

Acknowledgments

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Effects of Predation on Migratory Shorebird Recruitment

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Introduction

Under natural conditions, predator/prey relationships are presumed to have evolved through time to provide a balance between populations of predators and prey. This may take the form of a cyclical relationship, such as lynx (*Felis lynx*) and snowshoe hares (*Lepus americanus*), where each species appears to regulate the population growth of the other. Even when prey or predator species are migratory, presumably a balance is achieved between prey and predator populations when communities remain stable or predictable over time. However, increasing human populations and advances in technology have altered habitats through urbanization and agriculture, and species introductions have changed community structures. For example, Sergeant et al. (1993) has documented changes in the mammalian predator community in the northern Great Plains, whereby red fox (*Vulpes vulpes*) and racoon (*Procycon lotor*) are more abundant than the species were historically. These two species are major predators to dabbling ducks (*Anas* spp.) in the Prairie Pothole region, reducing nest success in some areas to less than 20 percent between 1966 and 1984 (Klett et al. 1988). The introduction to islands of predators such as the black rat (*Rattus rattus*) and Norway rat (*Rattus norvegicus*) and several species of snakes, has been shown to reduce some avian populations to near extinction (Savidge 1987).

The focus of this paper is to summarize the potential impact of predation on recruitment of shorebird communities from Arctic to subtropical breeding grounds in North America, identify potential predators, and investigate the potential additive effects of habitat degradation or loss and disturbance on shorebird recruitment. Changes in the availability of breeding habitat from urbanization or agricultural development, along with predator communities adapted to this altered landscape, may be responsible for decreased recruitment of many shorebird populations.

Although there exists a vast amount of information on the effects of predation on game species such as waterfowl and some gallinaceous birds (this session), little data has been collected for most species of shorebirds. This is partly because most shorebirds nest in Arctic and subarctic regions where research is limited and expensive. However, even information on most temperate-breeding species is lacking, due to a historical concentration on game species. We summarized the information available on nest or hatch success and percentage of egg or clutch loss from predation for three major groups of breeding shorebirds: Arctic and subarctic, interior, and coastal. These three groups roughly define three major levels of intensity of habitat degradation and disturbance, and were used to infer their potential additive effects on shorebird recruitment. The most valuable information available on determining recruitment into a population is the number of chicks per pair or breeding adult and annual survivorship, but few studies of migratory shorebirds have such data. The species with the most complete information available is the piping plover (*Charadrius melodus*), probably because it is a U.S. federally listed threatened and endangered species, so interest is high, funding is available and chicks are visible after hatch, contrary to most other species. The decline in numbers of piping plover has been ascribed to high predation rates, destruction or alteration of habitat and disturbance (Burger 1987, Prindiville Gains and Ryan 1988, Haig and Oring 1988, Flemming et al. 1988, Patterson et al. 1991).

Shorebird Breeding Ecology

Shorebirds are one of the most migratory bird groups in the world. In North America, more than 50 species of shorebirds occur during the breeding season between Arctic and subtropic regions. Many species of shorebirds migrate from breeding grounds in the Arctic to wintering areas in Central and South America. Many shorebirds return each year to historical breeding sites to nest and rear their young. Many factors, however, determine their success in maintaining populations. Clutch size consists of only four eggs for most species, and nearly all species are ground nesters, making them very susceptible to predation. In different species, one (male or female) or both parents incubate the eggs and care for the young. Species vary widely in ability and tenacity to protect eggs and young from predators. Normally, only one brood is produced by monogamous pairs, but mating systems vary widely among species and include polygyny and polyandry. Young are precocial at hatch and the attending adult(s) lead chicks from breeding areas to foraging sites within hours. Reproductive success of shorebirds is highly variable, with numerous studies suggesting that predation of nests and chicks is one of the major limiting factors in population regulation. Estimates of annual survival rates of adult shorebirds range from 59 to 94 percent, and juvenile survival from 30 to 87 percent, depending on species (Evans and Pienkowski 1984).

The information summarized below comes from many different sources; studies with different purposes and methodologies were examined. Therefore, it is difficult if not impossible to carry out statistical comparisons. Researcher influence on reproductive success is unknown in most cases, is likely to be manifested primarily in increased desertion and/or clutch predation rates, and undoubtably varies widely among studies, species and years. We only included studies with at least 10 nests for a species. Values given represent apparent nest or egg success rates. Most studies did not attempt to correct for nests depredated and never found; these are maximum estimates of success. Mayfield estimates of success (or Green's estimates of Mayfield) may not be appropriate in all studies, especially when nest failure is catastrophic (e.g., floods, severe weather, some predation events) or when most nests are found at an early stage (nest searches carried out often in an area and few nests missed; Mayfield 1975, Green 1989). Low values of reproductive success would be biased most heavily upwards (i.e., normally, more nests are missed when nest failure is common). Nevertheless, certain general conclusions can be drawn from these data.

Arctic-breeding Shorebirds

Nearly three-fourths of shorebird species nest in the Arctic or subarctic, where human disturbance is low and habitat degradation is minimal compared with interior and coastal areas. However, highly variable spring and summer climatic conditions and cyclical predator/prey relationships result in extremes in reproductive success. For example, in semipalmated sandpipers (*Calidris pusilla*) breeding in subarctic Manitoba, apparent nest success ranged from 24 to 70 percent during an eight-year study and the majority of nest loss (86 percent) was from predation (Gratto-Trevor 1992). When we compiled the available information from North American studies, we found that reproductive success of 16 species of Arctic- and subarctic-nesting shorebirds ranged from 0 to 100 percent. Similarly, the percentage of failed clutches or eggs resulting from predation ranged from 0 to 100 percent (Table 1). Both nesting success and percentage failure due to predation were high, with almost half of the studies reporting greater than 70 percent nest or hatch success (Figure 1), and more than half noting that predation caused more than 70 percent of nest failures (Figure 2). Often, the alternative cause of nest failure was desertion resulting from severe weather, partial clutch predation, predation of the adult or researcher disturbance.

Table 1. Reproductive success and predation rates of Arctic- and subarctic-breeding shorebirds.

Species	Years	Nests (n)	Percentage egg success	Percentage nest success	Percentage nest or egg loss due to predation	Location	Source
Semipalmated plover	4	15	84		0	Manitoba	Jehl 1971
	2	61	66 (65,71)	72, (83,69)		Manitoba	Armstrong and Nol 1993
Lesser golden plover	1		65		87	Manitoba	Byrkjedal 1989
Black-bellied plover	1	16	65	69	100	NWT	Hussel and Page 1976
Lesser golden plover	8	41		41 (20-80)		Alaska	Troy 1991
Semipalmated sandpiper	8	613		50 (24-70)	86	Manitoba	Gratto-Trevor 1992
	8	215		60 (13-88)		Alaska	Troy 1991
	1	14		7	100	Alaska	Erckmann 1981
	2	17		76	75	Alaska	Erckmann 1981
Western sandpiper	2	49		63	50	Alaska	Erckmann 1981
	3	215		84 (73-92)	90	Alaska	Holmes 1972
Least sandpiper	4	56	80		44	Manitoba	Jehl 1971
Dunlin	4	42		86		Alaska	Holmes 1966
	4	13	91		0	Manitoba	Jehl 1971
	8	115		49 (33-70)		Alaska	Troy 1991
	2	18		78	100	Alaska	Erckmann 1981
Stilt sandpiper	4	43	83		67	Manitoba	Jehl 1971
	8	12		58		Alaska	Troy 1991
Pectoral sandpiper	8	150		58 (44-83)		Alaska	Troy 1991
Buff-breasted sandpiper	2	45	46 (42-43)	44 (44, 44)	50, 65	Alaska	Lanctot and Laredo 1994
Long-billed dowitcher	2	17		76	50	Alaska	Erckmann 1981
Whimbrel	2	65		77	71	Manitoba	Skeel 1983
	4	25	49		67	Manitoba	Jehl 1971
Hudsonian godwit	1	10	83			Manitoba	Hagar 1966
	4	12	85		57	Manitoba	Jehl 1971
Ruddy turnstone	1	14	67	71	75	NWT	Nettleship 1973
Red-necked phalarope	8	13		61 (46-71)		Alaska	Troy 1991
	2	15		87	100	Alaska	Erckmann 1981
	5	245		56 (38-76)	84	Manitoba	Reynolds 1984
Red phalarope	1	16		19	100	Alaska	Erckmann 1981
	2	33		67	36	Alaska	Erckmann 1981
	3	36	34	33		NWT	Mayfield 1978
	8	71		77		Alaska	Troy 1991

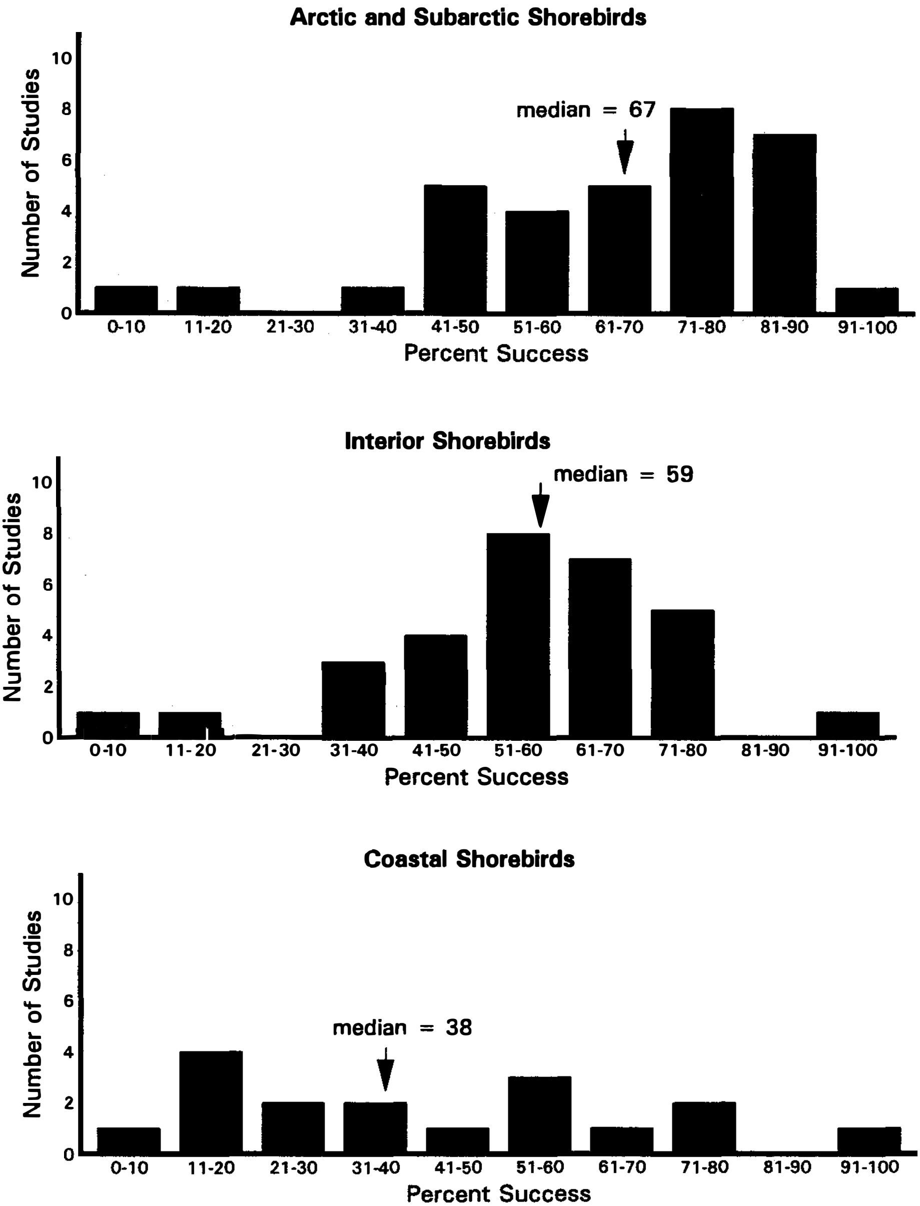

Figure 1. Reproductive success of breeding shorebirds.

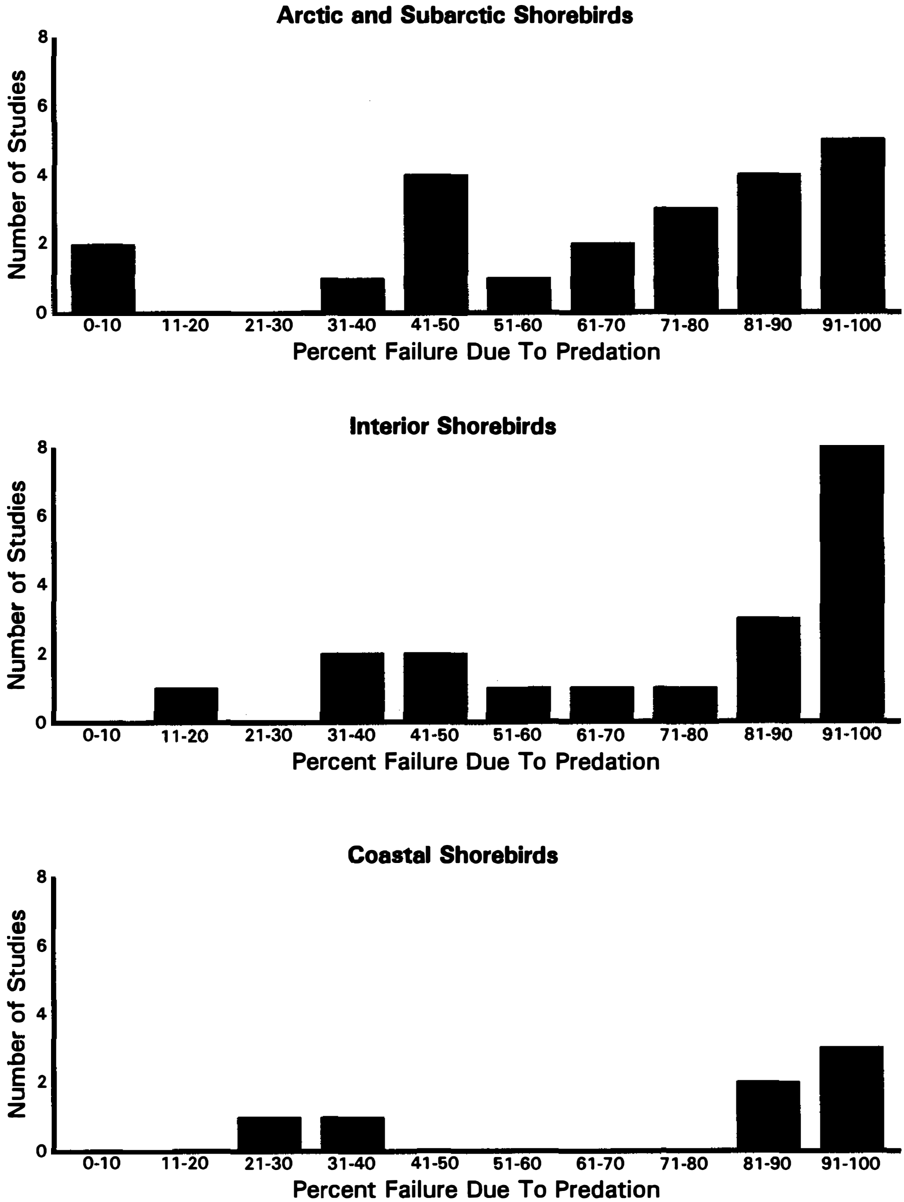

Figure 2. Reproductive failures of breeding shorebirds due to predation.

Predators of Arctic- and subarctic-nesting shorebirds include both mammalian and avian species, and the importance of either often varies temporally as well as geographically. Potential predators of eggs and chicks include Arctic (*Vulpes lagopus*) and red fox, weasels (*Mustela* spp.), jaegers (*Stercorarius* spp.), gulls (*Larus* spp.), northern harriers (*Circus cyaneus*), short-eared owls (*Asio flammeus*), snowy owls (*Nyctea scandiaca*), sandhill cranes (*Grus canadensis*) and turnstones (*Arenaria* spp.) (Holmes 1966, Baker and Baker 1973, Gratto-Trevor 1992).

Much of this variability in predation of nests may be indirectly due to microtine cycles. Many predators normally feeding on lemming and other small mammals apparently shift to shorebird eggs and young when populations of microtines crash (Larson 1960, Baker and Baker 1973, Norton 1973, Gratto-Trevor 1992).

Interior-nesting Shorebirds

Thirteen species of shorebirds breed in the interior temperate region, mainly in the prairies or the intermountain West where habitat alteration is moderate to high, but chronic disturbance is low. Interior-nesting shorebirds are all ground nesters, and nesting habitats range from unvegetated sand or gravel beaches to grasslands. Loss of wetland habitat and conversion of grasslands to agriculture are the two main factors responsible for reducing the habitat base for nesting shorebirds. The historic mosaic of grasslands interspersed with wetlands of various sizes and permanence of water have been replaced by agriculture in many areas, resulting in islands of isolated wetlands with narrow buffer zones of grasslands. Reduced search areas and increased access to predators via roadways may result in increased predation on ground-nesting birds in these areas. Additionally, some predator populations seemed to have benefited from this agricultural mosaic, such as red fox, striped skunk (*Mephitis mephitis*), raccoon, coyote (*Canis latrans*), gulls and American crows (*Corvis barchyrhynchos*) (Sergeant et al. 1993).

We found that reproductive success of 11 species of interior-nesting shorebirds ranged from 4 to 97 percent (Table 2). Nest failure due to predation ranged from 15 to 100 percent (Table 2). Again, the ranges of nesting success and predation rates are wide, but only 20 percent of the studies averaged nest success rates greater than 70 percent and half were under 59 percent (Figure 1). However, average percentages of nest failure due to predation were high, with half greater than 70 percent (Figure 2). Alternative cause of nest failure often was flooding of nests near wetlands due to heavy rainfall or storms (Grover and Knoff 1982, Haig and Oring 1988).

Potential predators of eggs and chicks include mink (*Mustela vision*), red fox, raccoon, opossum (*Didelphis marsupialis*), ground squirrels (*Spermophilus* spp.), coyote, gulls, American crow, common raven (*C. corax*) and magpies (*Pica* spp.) (Colwell and Oring 1988, Mayer and Ryan 1991, Haig 1992). The few studies documenting the type of predator preying on nests have concluded that the majority were mammalian (Mayer and Ryan 1991, Kantrud and Higgins 1992), although this may vary according to year or location. The possibility of a relationship between fluctuations in small mammal populations and predation of eggs and chicks of ground-nesting prairie birds does not seem to have been examined. If coyotes switch to nests of ground-nesting birds in years of low microtine availability, it may help explain why coyotes were found to be heavy nest predators in some studies and not in others, even though they are present in both locations.

Coastal-nesting Shorebirds

Seven species of shorebirds nest on coastal habitats in the temperate region, mainly on coastal beaches, barrier islands or uplands associated with salt marshes. Most coastal habitats for nesting shorebirds have been lost or severely degraded. More than 50 percent of coastal wetland habitats in the United States have been lost since the early 1900s, with some of the heaviest losses along the Atlantic Coast (Tiner 1984, Dahl 1990). Increased urban and industrial development and recreational use have seriously affected the remaining habitats through degradation and human disturbance. The National Oceanic and Atmospheric Administration (1980) predicted that 80 percent of the U.S. population would live within 50 miles (80 km) of the coast by 1995, and this prediction may be fairly close. Predation, as well as human-related disturbance, has been shown to result in decreased reproductive success in coastal-breeding shorebirds (Page and Stenzel 1981, Cairns and McLaren 1980, Burger 1990) and decreased annual survivorship of migrant shorebirds (Pfister et al. 1992).

Table 2. Reproductive success and predation rates of interior-breeding shorebirds.

Species	Years	Nests (n)	Percentage egg success	Percentage nest success	Percentage nest or egg loss due to predation	Location	Source
Snowy plover	2	47		55-59		KS	Boyd 1972
	2	89		58 (38-73)	58-42	OK	Grover and Knoff 1982
	4	210		60	40	CA	Page et al. 1983
	1	72		97		OR, NV	Herman 1988
Piping plover	2	150	33-34	41-42	93	ND	Prindiville Gains and Ryan 1988
	4	72		36	40	MAN	Haig and Oring 1988
		20				SASK	White 1985
		9		67	100	PPR	Kantrud and Higgins 1992
Mountain plover	1	14		50		CO	Miller and Knoff 1993
	2	101		62	15	CO	Graul 1975
Killdeer		135		64	64	PPR	Kantrud and Higgins 1992
Wilson's phalarope	6	386		35 (17-56)	41	SASK	Colwell and Oring 1988
	1	23		4	96	ND	Kagarise 1979
		136		59	85	PPR	Kantrud and Higgins 1992
Upland sandpiper	6	209		67 (14-67)	98	ND	Bowen and Kruse 1993
		27		41		KS	Bowen 1976
	9	178		48		ND	Kirsh and Higgins 1976
		30		66		SD	Kaiser 1979
		617		67	87	PPR	Kantrud and Higgins 1992
	3	29		18		MN	Lindmeier 1960
Long-billed curlew	3	119		58	84	ID	Redmond and Jenni 1986
Willet		34		52	79	PPR	Kantrud and Higgins 1992
	2	75		75 (97, 53)	100	ALTA	Gratto-Trevor and Guyn unpublished
	12	35		54		ND	Higgins et al. 1979
Marbled godwit		43		60	93	PPR	Kantrud and Higgins 1992
	2	44		70 (100, 50)	92	ALTA	Gratto-Trevor and Guyn unpublished
	12	18		39		ND	Higgins et al. 1979
American avocet	2	23		83	58	OK	Grover and Knoff 1982
	2	78	79			OR	Gibson 1971
	1	237	77	74		ND	Sidle and Arnold 1982
Common snipe		24		71	100	PPR	Kantrud and Higgins 1992

We found that reproductive success of seven species of coastal-nesting shorebirds ranged from 0 to 91 percent (Table 3). Nest or egg loss resulting from predation ranged from 25 to 94 percent (Table 3). Again, the ranges of nesting success and predation rates are wide, although reproductive success often was low, with more than half of the studies reporting averages of less than 40 percent nest or hatch success (Figure 1). Once again, the percentage of clutch loss due to predation usually was very high, with five of seven studies reporting losses greater than 80 percent (Figure 2).

Table 3. Reproductive success and predation rates of coastal-breeding shorebirds.

Species	Years	Nests (n)	Percentage egg success	Percentage nest success	Percentage nest or egg loss due to predation	Location	Source
Snowy plover	6	189	40-74	58 (38-85)	25	CA	Warriner et al. 1986
	2	72		13		OR	Wilson 1980
	1	13		0		OR	Wickham unpublished 1981
	1	10		60-80		WA	Widrig 1980
	1	14		79		WA	Saul 1982
Piping plover	2	125		46	91	VA	Patterson et al. 1991
	3	24		25	94	MA	Rimmer and Deblinger 1990
	2	24	19	17		MA	Melvin et al. 1992
	3	108		15		MA	Strauss 1990
	2	51	76 (79, 72)	35		NS	Cairns 1982
	20	174	91			NY	Wilcox 1959
Wilson's plover	2	58	39 (35-45)	35 (25-54)	83	TX	Bergstom 1988
Least sandpiper	2	49		59		NS	Miller 1983
Willet	1	16	20		84	GA, SC	Tomkins 1965
	3	226		21 (2-36)	91	VA	Howe 1982
Black oystercatcher		81	38			BC	Vermer et al. 1992
		28	56			BC	Drent et al. 1964

Potential predators of eggs and chicks include red fox, raccoon, opossum, coyote, gulls, crows (*Corvis* spp.), domestic dogs (*Canis familiaris*) and domestic cats (*Felis domesticus*) (Haig 1992). High predation rates in coastal habitats have been attributed to higher than normal predator populations due to the presence of alternate food sources near high human populations (i.e., landfills) (Howe 1982, Haig 1992). The decline in nesting success of piping plovers from the 1960s to the present probably is indicative of the general decline in nesting success at coastal sites near populated areas (Table 3).

Predation and Nest Success Summary

Nesting success was highly variable among studies, locations, years and species. However, there was a definite trend toward lower average nesting success from Arctic to interior to coastal breeders. The percentage of failed nests resulting from predation also was highly variable in all regions. No differences among Arctic, interior and coastal breeders were evident, but, in all areas, most nest failure was attributed to predation. Predation obviously is a highly significant factor affecting nesting success of shorebirds; possibly more so in southern areas due to the lower average nest success rates there, probably resulting at least in part from human disturbance to the environment.

Data are presented as success of individual nests, not pairs. Therefore, in terms of success of individual birds, the greater nesting success of Arctic breeders may be offset in part by a lower potential for renesting there (due to the shorter "window" of suitable weather conditions available). Obviously, nesting success also does not take into account nonbreeders resulting from extreme weather conditions.

As noted earlier, this analysis is based on studies in various locations, using different methods. If we excluded studies with any form of predator control (including nest enclosures, predator trapping, etc., this is not always noted, obvious or consistent in an area; for example, trapping of furbearing mammals around northern settlements has been common historically) and were more able to compare success rates directly in highly disturbed versus "natural" environments (some coastal areas are isolated and relatively undisturbed, e.g., Sable Island, Nova Scotia), we suspect that the trends we noted would be even more evident between disturbed and natural communities.

Optimally, nesting success should be reported per pair rather than per clutch, and effort should be made to obtain fledging success estimates for more species of shorebirds in relation to nesting success. Future studies on effects of predation on shorebird recruitment should focus on landscape effects of habitat loss (particularly in interior regions), potential additive effects of disturbance on reproductive success (particularly in coastal areas) and the inter-relationships among members of the biotic community (e.g., explore such possibilities as shorebirds and other ground-nesting birds serving as alternate prey in years of low microtine abundance in more southern areas or species actively defending their nests or broods from predators acting as "umbrellas" of protection for nondefending species nesting nearby).

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Predation and Galliforme Recruitment: An Old Issue Revisited

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Many galliformes, such as the eastern wild turkey (*Meleagris gallopavo silvestris*) and northern bobwhite (*Colinus virginianus*), are ecologically and economically important gamebirds. Population dynamics of the two species differ, but the wild turkey and bobwhite both exhibit high reproductive potential, and autumn population size is largely a function of reproductive effort and success. Managers and hunters desire high recruitment rates, and predation often has been cited as a major limiting factor for gamebirds (Reynolds et al. 1988). In the last three decades, wild turkey and bobwhite have exhibited contrasting population trends. Changes in land-use patterns at the landscape level have simultaneously contributed to increasing turkey and declining bobwhite populations. Although these two species are quite different ecologically, predation processes can substantially affect realized reproductive success of both species, and changes in predator populations and efficiency have had common effects on both species. These two species serve as excellent models of recruitment to examine limiting factors and develop future management strategies. In this manuscript, we attempt to interpret relationships between predation and recruitment in the context of modern landscapes. This paper reviews extant information and proposes hypotheses where definitive information is lacking. Each species will be addressed separately.

Eastern Wild Turkey

The wild turkey was abundant in the eastern U.S., but nearly was extirpated by subsistence and market hunting, and widespread land clearing and forest cutting. Populations have been restored; for example, there were only 3,500 turkeys in Mississippi in the 1940s and more than 350,000 by 1986 (Kennamer et al. 1992). Number of gobblers harvested in a spring, gobblers-only season increased from about 5,000 in 1972 to nearly 60,000 in 1987 (Hurst 1995). Hens are integral to recruitment while, after mating, gobblers are inconsequential. Predation on gobblers is negligible (Speake 1980, Ielmini et al. 1992). Over a five-year period in Mississippi, 93 percent ($\underline{n}$ = 140 gobblers) of radio-marked gobbler mortalities were from harvest; predation was insignificant (Godwin et al. 1992).

During the restoration era, with exponentially expanding turkey populations, predation was negligible (Markley 1967), but later became a limiting factor (Miller and Leopold 1992). However, few long-term (at least 10 years) studies of turkey population dynamics have been conducted on established, stable (equilibrium) turkey populations (Leopold et al. 1996). Newton (1993: 144) stated, "In any population, predation can be considered limiting if it prevents or slows a rise in numbers." Predation might hold some bird populations below the level that resources would permit (Martin 1992). Because neither mortality nor recruitment depend solely on predation, it cannot account completely for a given population density (Newton 1993). Reynolds et al. (1988: 72) concluded, "Predation is just one of an array of interelated factors which can influence the dynamics of a gamebird population...." Reviews of predation theory and related factors affecting predation can be found in Sih et al. (1985), Hudson and Rands (1988) and, for the wild turkey, in Porter et al. (1990a), Miller and Leopold (1992) and Vangilder (1992).

Predation on Eggs, Poults and Hens

Wheeler (1948: 36) stated, "There is a wide discrepancy between the breeding potential of the wild turkey and the actual annual addition to the population." Artificial egg studies determined that most (85 percent in Alabama, 80 percent in Kentucky) nests were depredated, primarily by raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*) and Virginia opossums (*Didelphis marsupialis*) (Davis 1959, Pharris and Goetz 1980). Speake (1980) reported that nest ($\underline{n}$ = 119) predation on four areas in Alabama averaged 44.5 percent. The raccoon was the principal predator. In Massachusetts, predation on eggs or females accounted for most (93 percent) nest losses on a population perhaps at carrying capacity (Vander Haegen et al. 1988). In north Missouri, predation was the major cause of hen and nest losses (Vangilder et al. 1987, Vangilder and Kurzejeski 1995). Predation of eggs or hens accounted for 93 percent of known nest failures in central Mississippi (Palmer et al. 1993b). On two other study areas in Mississippi, predation of eggs and hens was the primary cause of low recruitment (Chamberlain et al. in press). Nest predation was high (83 percent) for two areas in the Arkansas Ozarks, 1992 through 1994 (Badyaev 1995).

Poult mortality from hatch to four weeks post-hatch is high: 77 percent in Massachusetts (Vander Haegen et al. 1988), 80 percent in New York (Glidden and Austin 1975), 87.3 percent, 74.5 percent and 69.8 percent in Alabama (Exum et al. 1987, Everett et al. 1980, Speake 1980), 61.9 percent in Missouri (Vangilder et al. 1987) or with additional data, 55 percent (Vangilder and Kurzejeski 1995) and 77.3 percent in Mississippi (Palmer et al. 1993b). Poult mortality by four weeks of age varied from 41.9 to 70.5 in northern Missouri (Vangilder and Kurzejeski 1995). Often, causes of poult mortality have not been identified, but Speake (1980) reported for known deaths (49 percent, 136 poults): mammal (42 percent), bird (16 percent) and reptile (7 percent). Another 17 percent of mortalities were caused by unknown predators. Of the mammalian predation, free-ranging dogs (*Canis familiaris*) that killed brood hens (usually all poults then die) accounted for 57 percent and raccoons for 24 percent. Peoples et al. (in press) conducted a five-year study of radio-marked poults in northern Florida and southern Georgia, and determined only 34 of 344 poults that hatched from 39 clutches survived beyond 28 days. Predation accounted for 88 percent of 106 identified deaths, and the raccoon was the leading cause of mortality. A major knowledge gap regarding recruitment exists because little is known about juvenile (more than 4 weeks old) turkey behavior (dispersal) or survival.

Average annual hen survival in northern Missouri was 0.435 and predation accounted for 54.9 percent of the total losses. Seasonal losses were highest during spring (Kurzejeski et al. 1987). With additional data, annual survival averaged 0.558 in northern Missouri. However, the authors stated "we did not observe substantial hen mortality directly related to nesting" (Vangilder and Kurzejeski 1995: 31). In the Missouri Ozarks, hen survival rates averaged 0.514 and 0.560 on two areas, and on average, predation accounted for 60 and 76 percent of the total mortality. In central Mississippi, annual hen survival rate over a 10-year period averaged 0.66 (range: 0.45-0.81) using telemetry data and 0.68 (range: 0.31-1.00) using mark-recapture data, and the lowest survival was during the breeding period (Hurst 1995). Another study in Mississippi found annual hen ($\underline{n}$ = 111) survival rate over a five-year period averaged 0.68 (range: 0.499-0.81), and most (95 percent) mortality was from predation and occurred during the breeding period (Palmer et al. 1993a), which agrees with Speake (1980), Everett et al. (1980) and Vander Hagen et al. (1988). Little et al. (1990) reported spring hunting and predation during nesting and brood rearing were major mortality factors in Iowa. Bill Palmer (personal communication: 1996) noted successively lower survival rates for each stage of reproduction (i.e., egg laying, incubating and brood rearing).

Predators of hens include feral dog, gray fox (*Urocyon cinereoargeteus*), red fox (*Vulpes vulpes*), bobcat (*Felis rufus*), raccoon and great-horned owl (*Bubo virginianus*) (Miller and Leopold 1992). The coyote (*Canis latrans*) became abundant in the Southeast, including Mississippi, during the 1980s and predation on nesting and incubating hens now is a factor (Hurst 1995, Chamberlain et al. in press).

Recruitment Rates

Few recruitment rates have been published and, in most cases, density of turkeys and predators are unknown. In southern New York, Glidden and Austin (1975) stated that a 20-percent annual recruitment rate (females) was adequate to sustain the turkey population. Recruitment of females into the autumn population in a three-year study in Massachusetts was 0.59 (Vander Haegen et al. 1988), and natality and recruitment were similar to New York, with both populations likely at carrying capacity. Using field-collected data on reproductive parameters in Missouri and modeling, recruitment averaged 1.61 to 1.63 (Vangilder 1992). He assumed for his model that recruitment (summer gain) was not related to population size (i.e., recruitment was independent of density). In New York, Porter et al. (1990b) suggested that density-dependent recruitment of young is maximal at low levels of abundance. In central Mississippi, a low-density (0.50 hens per square kilometer) turkey population experienced a significant ($\underline{P}$ = 0.049) decline over a five-year period (1988 to 1992): poults per hen averaged 1.3 from summer capture data, nesting and nest success rates were low, hen survival was lowest during the breeding period, poult survival rate was low, and renesting and juvenile hens contributed little to reproduction. Over the 10-year period, recruitment (juvenile-to-adult hen) averaged 0.292. Predation on breeding hens, eggs and poults was the major limiting factor (Palmer et al. 1993b).

Northern Bobwhite

Throughout much of the range, historically high bobwhite populations were a by-product of land-use practices. Primitive agricultural practices and patchwork forest operations created a perfect mosaic of early and mid-successional plant communities to which bobwhite are adapted. In recent decades, bobwhite populations have declined precipitously. Since 1966, U.S. Fish and Wildlife Service breeding bird surveys reflect a 2.4-percent per year decline in indices of bobwhite abundance and the rate is increasing. Population trends from 1966 to 1979 exhibited a 1-percent per year decline, whereas trends from 1980 to 1994 declined 2.8 percent per year. Declines in bobwhite populations have been documented better since 1966; however, apparent declines were noted as early as the late 1920s. In fact, Herbert Stoddard's seminal work in 1931 was instigated by perceived declines throughout the Southeast. Stoddard (1931: 415) noted that "Not many years ago the level of bobwhite abundance was higher than at present over their range as a whole....Agricultural conditions have gradually changed and become less favorable for the birds, however, while shooting has increased." Recent declines have been attributed to many factors, but the most likely are large-scale deterioration of quail habitat quality associated with advanced natural succession, intensive monoculture farming and intensive forest management (Brennan 1991). Trends in silvicultural and agricultural practices that maximize fiber and commodity production have reduced landscape heterogeneity and habitat suitability for bobwhite throughout its range.

Attitudes regarding effects of predation on bobwhite populations have varied. This may be a result of latitudinal variation in relative importance of predation and regional perspectives of authors of seminal monographs on bobwhite depredation. The work of a few authors has substantially influenced the scientific community's view of the relative importance of predation (Stoddard 1931, Leopold 1933, Errington 1934, Errington 1967). Based on extensive observations of nest and adult predation, Stoddard (1931) stated that specific bobwhite predators must be controlled under certain circumstances if a harvestable surplus is to be sustained. He further asserted that relative importance of predation as a limiting factor varys with range-wide habitat quality and quantity, bobwhite harvest rate, and harvest rate of furbearing predators. Stoddard explicitly restricted his endorsement of predator control measures to nest predators (raccoon, opossum, feral cat, cotton rat [*Sigmodon sp.*] and specific snakes) and avian adult predators (coopers hawk [*Accipiter cooperii*], sharp-shinned hawk [*A. striatus*] and great-horned owl). Stoddard recognized the interspecific interactions among predators, small mammals and bobwhite, and acknowledged that reductions in one potential predator (great-horned owls or snakes) might result in increasing populations of other predators (cotton rats). In contrast, Errington (1934: 126) stated that "kinds and numbers of wild predators, migrant or resident, had no measurable impact on carrying capacity." Errington (1934) argued that vulnerability to predators was largely a function of security of winter covey ranges and that the most effective predator control was better quality food and cover. Leopold (1933: 251-252) recognized the density-dependent nature of predation, discussed positive and negative consequences of buffer prey species, described potential indirect effects of predation (energetic consequences of harassment) and noted the habitat quality/vulnerability interaction. Leopold (1933) further acknowledged that prior studies of predation had focused on consumption rate of adult prey items by individual predators or predator species. He recognized the need to quantify cause-specific mortality rates of the prey species at all life stages (egg, chick and adult).

More recent reviews of predation have addressed effects of predators on prey communities, abundance, and population growth and regulation in the context of modern landscapes (Reynolds et al. 1985, Sih 1985, Newton 1993). Recent studies have quantified seasonal and annual patterns in cause-specific mortality and identified rates and primary agents of nest failure throughout the bobwhite's range. These studies suggest that predation has substantial effects on bobwhite populations and relative importance of specific predators varies with sex, life stage, biological processes (mate acquisition, nesting, brood rearing) and local predator community structure. Several authors have suggested that some bobwhite populations may not be self-sustaining under existing habitat conditions, depredation regimes and harvest levels. We concur with Robel (1993), Roseberry (1993) and Church et al. (1993) that former paradigms regarding mechanisms of bobwhite population regulation need to be re-examined in the context of current landscape patterns. We also support Leopold and Hurst's (1994) contention that effects of predation will not be adequately understood if studied only from the standpoint of mortality on the prey species.

Predation on Eggs, Chicks and Reproductively Active Adults

Bobwhite have tremendous physiological and behavioral capacity for production. They are prolific layers and exhibit a dynamic suite of reproductive strategies that can result in high reproductive output. The high reproductive potential enables bobwhite to occupy and fill newly available habitats rapidly, annually replace populations in spite of high mortality, and quickly recover from catastrophic weather events. However, bobwhite have a reproductive potential that far exceeds realized reproductive success. This is largely from intensive predation on breeding adults, eggs and young broods (Burger et al. 1996, 1995a, 1995b).

Bobwhite exhibit a highly flexible mating system in which both males and females contribute substantial parental investment to incubation and brood rearing. The mating system combines elements of monogamy, rapid multiclutching and ambisexual mating systems (Curtis et al. 1993, Burger et al. 1995b). First nests, renests, second clutches and male-incubated nests provide a suite of reproductive strategies that bobwhite can employ conditionally, based on the fate of the first nest (Burger et al. 1995b). The contribution to production from various reproductive strategies may vary annually with length of nesting season, density, physiological condition, weather and success of initial nesting attempt. Burger et al. (1995b) reported that, during a three-year study in northern Missouri, 51.5 percent of production was attributable to female-incubated first nests, 14.7 percent to female-incubated renests, 4.4 percent to double clutches and 29.4 percent to male-incubated nests.

Although bobwhite are quite prolific, individual nests have relatively low probability of hatching. In a study of 602 nests in northern Florida from 1924 to 1927, Stoddard (1931) reported 36-percent nest success. Primary cause of nest failure was depredation (37 percent). Stoddard estimated that 11 percent of nests were destroyed by skunks, 4 percent by ants and 1 to 3 percent by each of numerous other predators. Stoddard (1931) reported that, over a four-year period, moderate trapping and night hunting of skunks "materially and progressively" reduced skunk and total nest depredation. In southwestern Georgia, from 1967 to 1971, Simpson (1976) reported that, on one study area, 17 percent of nests ($\underline{n}$ = 1,412), and, on a second area, 21 percent ($\underline{n}$ = 313) of nests, were successful. Predation was the primary cause of nest failure. Simpson (1976) reported that skunks (19.9 percent of all nests), rodents (11.5 percent), opossums (4.7 percent), snakes (2.1 percent), foxes (1.6 percent) and raccoons (1.3 percent) were the primary nest predators. More recently, in southern Georgia/northern Florida, DeVos and Mueller (1993) reported that 45 percent ($\underline{n}$ = 51) of nests were successful and predation on nests or females accounted for 89 percent of nest failures. They attributed 52 percent of depredations to mammalian predators, 28 percent to reptiles, 10 percent to unknown predators and 10 percent to mortality of the attending adult. In Tennessee, Dimmick (1974) reported that 23 percent of all nests showing evidence of use by quail ($\underline{n}$ = 766) were successful and 38.8 percent of nests that were active when located ($\underline{n}$ = 232) were successful. In southern Illinois, from 1952 to 1966, Klimstra and Roseberry (1975) reported that 33.7 percent of 863 nests were successful and 36.7 percent depredated (55.4 percent of nest failures). The attending adult was killed at 4 percent of nests (11 percent of depredated nests). They attributed 70.7 percent of nest predation to mammals, 11.7 percent to snakes, 1 percent to birds and 16.7 percent to unknown animals. Known predators in rank order of importance were house cats, striped skunks, snakes, fox, feral dogs, birds, weasel and opossum. In an agricultural landscape in northern Missouri, Burger et al. (1995b) reported 43.7 percent success for 157 nests. Thirty-eight percent of nests were depredated and an additional 13.4 percent were lost from mortality of the attending adult. Nest predation was distributed among mammals (31.7 percent of depredated nests), snakes (43.3 percent), birds (11.7 percent) and unknown predators (13.3 percent). Sixty-eight percent of nest failures in which the adult was killed were attributed to mammals, 32 percent to raptors. In an intensive agricultural landscape in North Carolina, Puckett et al. (in press) observed 33.9 percent nest success. Predation accounted for 83 percent of nest failures. Mammalian predators caused 29 percent of nest losses, snakes 43 percent and unknown predators 11 percent.

Seasonal patterns of predation apparently may vary latitudinally. In studies conducted in Iowa (Suchy and Munkel 1993), Missouri (Burger et al. 1995b) and Illinois (Klimstra and Roseberry 1975), nest success seemingly declined as the nesting season progressed. In North Carolina (Puckett et al. in press), Tennessee (Dimmick 1974), Florida (Stoddard 1931, DeVos and Mueller 1993) and Georgia (Simpson 1976), patterns suggested increasing success as the season progresses. In the northern portion of the range, early season nesting attempts may be more successful, whereas, in the southern portion of the range, late-season nests seem more successful. In North Carolina, Puckett et al. (in press) attributed increasing late-season nesting success to increasing availability of nesting habitat. Similar patterns of increasing nesting habitat might be expected in managed southeastern pine forest habitats where a significant proportion of the landscape is prescribed burned each year in winter. If nest predation acts in a density-dependent fashion, then increasing availability of nesting habitat and more uniform distribution of nests following green-up might result in a density dependent (nests per unit area of available nesting habitat) reduction in predation rates. Roseberry and Klimstra (1984) presented evidence that predation rates may be related positively to nest density. In the Midwest, most nesting activity is associated with idle fields, set-aside lands, roadsides, fence rows, pastures and hayfields (Klimstra and Roseberry 1975, Burger et al. 1994b). Seasonal availability of these habitats typically does not increase as the nesting season progresses. Conversely, mowing, haying and grazing activities may reduce availability of these nesting habitats throughout the nesting season producing increasing nesting density per unit of available habitat. In Illinois, Roseberry and Klimstra (1984) documented increasing nest predation as the season progressed and suggested that number and hunting activity of mammalian predators might increase during the nesting season due to reproduction and maturation of their young (Klimstra and Roseberry 1975).

Ecology and survival of bobwhite chicks from hatch to recruitment into the autumn population is least understood (Roseberry and Klimstra 1984, DeVos and Mueller 1993). This is, in part, from difficulties in capturing, marking and observing very young chicks whose cryptic coloration, behavior and habitat preferences make observation difficult. Brood abandonment, adoption and brood pooling further compound difficulties in accurately estimating brood survival (DeVos et al. 1993). Until suitable chick marking techniques are developed, flush counts of broods associated with radio-tagged adults best estimate chick survival. Roseberry and Klimstra (1984) reported chick survival rates of 25 to 47 percent in southern Illinois. DeVos and Mueller (1993) noted that radio-tagged broods ($\underline{n}$ = 22) produced much lower survival estimates: 38 percent to two weeks and 29 percent to four weeks. Cantu and Everett (1982) reported 13-percent survival to two weeks of age in Texas. In Alabama, Speake and Sermons (1987) reported 36-percent survival to two weeks and 25 percent to four weeks. Causes of chick mortality have not been identified; however, Burger et at. (1995a) reported intensive predation on brood-rearing adults, suggesting that predation is a primary factor contributing to high chick mortality. Clearly, estimates of brood survival and identification of factors contributing to chick mortality require additional research.

Survival of bobwhite varies seasonally and regionally, but typically is low throughout the range. In northern Missouri, Burger et al. (1995a) reported annual survival of 5.3 percent. On an annual basis, 64 percent of the October 1 population was killed by predators. They observed high avian predation during autumn-spring and increasing predation by mammals during spring-autumn. These observations are consistent with those of Curtis et al. (1988) in North Carolina, who reported 6.1-percent survival for radio-marked bobwhite in North Carolina and 25.7 percent for a radio-marked sample in Florida. Pollock et al. (1989) estimated that annual survival of bobwhite in Florida averaged 16.7 percent. Estimates inferred from studies using age-ratio and count data typically are higher (0.18, Marsden and Baskett 1958; 0.154, Kabat and Thompson 1963; 0.188 based on age ratios, 0.182 based on product of autumn-spring and spring-autumn survival rates, Roseberry and Klimstra 1984). In Missouri, fall-spring survival (0.159) was approximately half that of spring-autumn survival (0.332) (Burger et al. 1995a). Curtis et al. (1988) similarly reported that survival of bobwhite in North Carolina during winter (0.185) was lower than summer (0.328). In Florida, DeVos and Mueller (1993) observed 66.4 to 72.9 percent breeding season survival with 59 percent of mortalities to avian predators and 41 percent to mammals.

Cause-specific mortality varies seasonally and between sexes (Burger et al. 1994a, 1995a). During the reproductive period, male bobwhite are more vulnerable to avian predation than females because of the male's conspicuous mode of display. Females are more affected by mammalian-induced mortality associated with incubation and brood rearing. The combined predation risks of displaying and incubation incurred by males approximates the reproduction-related costs incurred by females (Burger 1995a). Additionally, Burger et al. (1995a) demonstrated that predation associated with incubation and brood rearing reduced survival of reproductively active birds by 16 percent. They estimated that 66 percent of the reduction in survival during reproduction was associated with brood rearing. Kabat and Thompson (1963) suggested that the physiological stress of reproduction was the primary factor affecting late summer mortality, however, Burger et al. (1995a) hypothesized that increased predation while accompanying flightless chicks caused reduced survival during brood rearing.

Recruitment Rates

Few comprehensive studies of bobwhite recruitment have been attempted. Consequently, estimates of annual recruitment rates and associated measures of variability are scarce. In southern Illinois, from 1954 to 1979, Roseberry and Klimstra (1984) estimated that March to November increase (percentage summer gain) ranged from 17 to 383 percent, and averaged 205 percent. In Tennessee, from 1966 to 1974, Dimmick (1974) observed -2.5 to 59.7 percent summer gain based on March and December censuses. Roseberry and Klimstra (1984) summarized estimates of percentage summer gain from 102 annual data sets on nine study areas and reported a mean percentage summer gain of 203. For two northern Missouri populations, percentage summer gain estimates from a population model averaged 237 (Burger unpublished data). In Illinois, the reproductive index most closely associated with annual recruitment rates was ratio of chicks hatched to females in the March population (Roseberry and Klimstra 1984). Clearly, this index is a composite of nesting rate, renesting rate, double clutching rate, male incubation rate, nest success, clutch size and egg fertility. Roseberry and Klimstra (1984) estimated that productivity of 5.2 young per hen alive at the start of the breeding season would produce percentage summer gains consistent with their estimates from 25 years of census data. The Missouri population model (Burger unpublished data) based on radio telemetry estimates of all relevant population parameters, suggested recruitment of 5.4 young per female alive at the start of the breeding season. In Illinois, variables quantifying breeding density relative to carrying capacity, winter food resources, winter snow conditions and spring precipitation apparently exerted a collective and individual effect on recruitment rates (Roseberry and Klimstra (1984). Predation may interact with the first three of these components through density-dependent nest success, security of winter covey ranges, and physiological condition of birds and subsequent vulnerability to predation.

Discussion

Predation on breeding hens, eggs and young may significantly affect turkey (Miller and Leopold 1992) and bobwhite recruitment (Burger et al. 1994a, 1995a, 1995b), but more rigorous, quantitative and holistic research must be conducted before impacts of predation are well-documented (Leopold and Hurst 1993, Weinstein et al. in press). We do know that mortality and reproductive rates of turkey are variable and are related to stochastic environmental, density-independent events (Porter et al. 1990a, Vangilder 1992). Likewise, mortality and reproductive rates of bobwhite are highly variable and are related to stochastic environmental, density-independent events, as well as density-dependent factors (Roseberry and Klimstra 1984). We will use the history of turkey populations in Mississippi and results of long-term (1983 to 1996) research on three study areas, to relate predation and other factors to recruitment. Information from studies conducted on bobwhite throughout the region will be used to draw parallels and contrasts. If predation is a major limiting factor, how did the turkey population in Mississippi increase to such a high level (more than 350,000) in the mid-1980s and why did bobwhite populations exhibit continuous declines during this same period? One possibility is that an intensive, statewide "predator control" program, called commercial and sport trapping/hunting, was operating. Many furbearers, particularly valuable raccoons, were being harvested for fur and meat. Turkey population restoration efforts coincided with high furbearer prices and harvests (Lovell et al. in press). Then, trapping and hunting effort and harvest significantly diminished because of low fur prices, due perhaps to antitrapping, anti-fur and animal rights activities (Lovell et al. in press, Hamilton and Vangilder 1992). For example, raccoon harvest by trapping in Mississippi averaged 61,390 (1976 to 1980), 39,392 (1981 to 1987), 17,901 (1988) and 5,642 (1989 to 1994). Harvest of raccoons by hunting declined by 100,000 from 1980-88 to 1990-95. Harvest of other furbearers followed the same trend. Sales (effort) of trapper licenses and trapper harvest greatly diminished (Lipe et al. 1990, Lovell et al. in press). Missouri obtains two indices of raccoon relative abundance and they have increased greatly following the plummet in fur prices (Hamilton and Vangilder 1992). Density of raccoons in Mississippi is unknown, but in 1987, two trappers caught nearly 125 raccoons in seven nights, with 45 to 50 traps per night in one small river bottom area. Predator densities (carnivores, omnivores, raptors) may be as high, or higher, today as in historic times (Miller and Leopold 1992, Vangilder 1992). Bobwhite were exhibiting region-wide population declines prior to increases in mammalian predator abundance following declines in the fur market. However, the rate of population decline has accelerated in the past 15 years. This might be a function of increasing predator populations preying on declining prey populations in a landscape that increasingly favors the predator.

Population regulation of both turkeys and bobwhite involves a complex of interacting factors, some density dependent (i.e., nest predation, diseases, intrinsic) and some density independent (i.e., weather) (Reynolds et al. 1988). In addition to predation, diseases in the turkey population may be operative. Through a statewide collection system in Mississippi, 52 sick or dead turkeys were examined at the College of Veterinary Medicine since 1989. Important diseases were avian pox, histomoniasis, listeriosis and lymphoproliferative disease. The last disease had not been found previously in wild turkeys and first was detected in Mississippi in 1992 (S. Jack personal communication: 1996), as well as Alabama. Diseases were implicated in 1990 as a major factor because in some areas with large turkey populations, landowners observed a fast (i.e., one year) and substantial reduction in turkey numbers. A rapid decline cannot be from a single "poor" hatch. In other areas, the population gradually declined over a five-year period because of four successive (1988 to 1991) low hatches and low recruitment from predation (Palmer et al. 1993b). In Missouri, "Totals [brood numbers] were below average for an eighth year in a row" (Anonymous 1996: 26).

In contrast, diseases have not been implicated in contributing to bobwhite population declines. Bobwhite are susceptible to both avian pox and histomoniosis. Avian pox infections have occured at low prevelance in wild bobwhite populations since the early part of this century (Davidson et al. 1982). Stoddard (1931) reported occurance of less than 2 percent in wild populations in northern Florida and southern Georgia. Davidson et al. (1982) reported an outbreak (12-fold increase in occurance) in this region during the period 1977 to 1979 that may have increased mortality by 1 to 25 percent. Mueller et al. (1993) reported that bobwhite exhibiting the "wet" form of pox infection weighed less and had lower survival than uninfected birds or those with dry pox lesions. In a study of 6,500 bobwhite collected in Mississippi from 1989 to 1992, incidence of pox scars (3.1 percent) or scabs (2.7 percent) did not differ substantially from historic levels reported by Stoddard (1931). It seems likely that, with exception of periodic epizootic outbreaks as discribed by Davidson et al. (1982), avian pox has not significantly contributed to bobwhite population declines. Bobwhite are known to carry and succumb to histomoniasis, however, they are less susceptible to the disease than turkeys (Kellog and Malcolm 1970) and it has not been demonstrated as an important population factor.

Diseases also could have limited some predator populations. A canine distemper epizootic (epidemic) began in southern Mississippi in 1990, spread to most parts of the state, and resulted in reduction of raccoon, striped skunk and gray fox populations. Following the epizootic, a high hatch and recruitment rate (e.g., 58 percent of hens raised juveniles on one study area) occurred statewide in spring 1992; perhaps from a temporary lapse in predation and favorable weather conditions. In Alabama, which also has a large, established turkey population, hatch and turkey harvest trends followed those in Mississippi. Four successive low hatches resulted in a reduced turkey population, but following statewide epidemics of canine distemper and rabies, high hatch and poult recruitment rates were observed in 1992 (M. Widder personal communication: 1996). The problem with disease(s) acting as a regulatory factor is that populations must attain a very high density, and have impacted the prey (wild turkey or bobwhite) for several years, before their populations decline.

Several environmental factors, including habitat modifications, have affected turkeys, bobwhite, prey and predators. Large-scale, widespread harvest of high-quality turkey habitats (i.e., mature pine, pine-hardwood, hardwood forests), and their conversion to short-rotation, even-aged pine (*Pinus* spp.) plantations or cut-overs (cut but not regenerated), have negatively impacted turkeys, positively affected turkey predators and had mixed consequences for bobwhite. Young (one- to six-year-old) plantations are early successional plant communities or old field habitats that produce diverse and abundant predator foods (e.g., small mammals, rabbits, soft mast) (Atkeson and Johnson 1979, Perkins et al. 1988). In addition to a large, diverse prey base, plantations or cut-overs have much edge and a dense road system (corridors): optimal hunting conditions for predators. Increasing timber harvest has had mixed effects on bobwhite populations. Clearcuting creates short-term habitat for bobwhite as mature forests are converted to early successional habitats. Soil disturbance associated with mechanical and prescribed fire site prep stimulates germination of important early successional food plants. However, habitat gains are short lived as stands develop into dense brush or pine plantations within four to six years after harvest. Conversion of mature longleaf pine forests to dense loblolly or slash pine plantations likely has negative effects on bobwhite populations as bobwhite are adapted to the pyric longleaf community.

Wildlife managers asked forest managers to reduce size of clearcuts (i.e., plantations), make them irregularly shaped, have a three- to seven-year interval between adjacent cuts and distribute them over the landscape (fragmentation); they obliged, and, in addition, they also greatly increased timber harvest. All of these actions serve to promote predation by creating "optimal" predator habitat. Of the 18 million acres (7.29 million ha) of commercial forest land in Mississippi, nearly 2.9 million acres (1.22 million ha) have been planted to pine, and, of these, 2.2 million (0.89 million ha) are in seedling to sapling stages. By 1990, 25.9 million acres (10.5 million ha) of plantations existed in the Southeast, and are predicted to increase to 44 million acres (18 million ha) by 2030 (Allen et al. 1995). Additionally, there are many small (e.g., 9 to 44 acre [4-18 ha]) patches of nonstocked forest land due to recent harvest (not planted) and timber salvage operations from southern pine beetle infestation (Hartsell and London 1995).

These forest management practices are ideal for increasing predator populations but have negatively impacted turkey reproduction. Nest success rate of turkeys on plantations, cut-overs and adjacent, surrounding forests could be lowered because of habitat pattern and edge (Yahner and Scott 1987). Rate of predator/turkey encounters, because of predator trips to and from plantations, could increase with patchy habitat pattern (Reynolds et al. 1988). Nest success rate was 20 percent for hens that nested in plantations and 65 percent for hens that nested in mature pine forests in central Mississippi (Seiss et al. 1990). Robinson et al. (1995) demonstrated that landscape composition, in combination with specific patch size, affects success of passerine nests. The effect of landscape pattern on predation processes are poorly understood for turkey and bobwhite.

Predator densities, through numerical responses (Reynolds et al. 1988, Newton 1993), probably were increased by conversion of other high-quality turkey and bobwhite habitats (e.g., hayfields, pastures, soybean fields) to dense old fields and pine plantations (more than 900,000 acres [364,000 ha] in Mississippi) by the Dairy Buy-out and Conservation Reserve Programs. Stoddard (1931) suggested that accumulation of dense litter associated with old field succession increases small mammal populations and, subsequently, predator densities. Finally, quality of many turkey habitats (e.g., pine forests) is diminishing because use of controlled or prescribed burning is declining rapidly. On one of our study areas, the burning rotation now is six and a half years; a three-year burning rotation is recommended for turkey habitat management (Hurst 1995) and a two-year rotation is more desirable for bobwhite.

Weather also affects turkey recruitment. Vangilder et al. (1987) and Vangilder (1992) thought that spring weather (temperature) in Missouri influenced nesting success, perhaps by impacting plant phenology. Generally, "poor" turkey hatches have been associated with wet springs. Palmer et al. (1993b) reported that predation on incubating hens/eggs was related to the last rainfall event. Average time between date of last rainfall and a predation event was one and a half days, which was less ($\underline{P}$ = 0.07) than mean time span between rainfalls between the first and last nest failure (Palmer 1993b). In Missouri, Vangilder and Kurzejeski (1995) reported that increasing poult mortality was associated with number of days in June that rainfall exceeded 10 inches (25.4 mm). Rainfall may increase predator efficiency by increasing scent at or around the nest or brood, or by improving scenting conditions for predators—our wet hen theory (Palmer et al. 1993b).

Flooding of up to 3 million acres (1.22 million ha) in the Mississippi Delta region also greatly affects recruitment, but is less of a factor outside the Delta. The most severe drought (summer 1986 to spring 1987) ever recorded in the Southeast resulted in low nest success and very low recruitment in Mississippi and most of the Southeast. It resulted in no green forage (vitamins, proteins) and, coupled with a total acorn (*Quercus* spp.) failure, caused hens to be in poor condition (low weight) in the breeding period (Palmer et al. 1993b). A tornado deforested 1,000 acres (405 ha) of mature pine forests on one of our study areas; it became an old field habitat. In February 1994, an ice storm destroyed or damaged 3.7 million acres (1.5 million ha) of forest in a 26-county area in northern Mississippi (B. Lambert personal communication); creating more old field habitats. These environmental stresses negatively affect turkeys and increase prey abundance for predators (Sih et al. 1985). Weather also might operate through vectors (e.g., midges, black flies) of turkey diseases or parasites in poults (Stacey et al. 1990).

Weather is a primary determinant of bobwhite recruitment throughout the species' range. Based on 25 years of age ratio and weather data from Missouri, Stanford (1972) suggested that drought and high temperature inhibit bobwhite reproduction. Hot, droughty conditions might increase nest abandonment, reduce hatchibility of eggs, reduce food supplies for chicks and cause premature termination of nesting season (Stoddard 1931, Roseberry and Klimstra 1984). In northern portions of the range, the extent and duration of snow cover, particularly late-winter snow, reduces breeding populations and reproductive effort (Stanford 1972, Dimmick 1984, Roseberry and Klmistra 1984). The specific effects of severe winter weather may vary in relation to habitat quality and density.

Carnivores and omnivores, specialists and generalists, prey on turkeys and bobwhite and their eggs, but none "live off" turkeys and bobwhite. Some predators could exhibit a functional response, switching to more plentiful or vulnerable prey (Reynolds et al. 1988). The main predator of turkey eggs and poults and, to a lesser extent, breeding hens, the raccoon, can form a search image, and, thus, might seek turkey nests and eggs or broods (Johnson 1970). Priest et al. (1995) reported that raccoons enlarged their home ranges and increased use of turkey-nesting habitats (e.g., pine forests) in the spring. On this same area, most hens that hatched their clutches quickly moved their broods to mature bottomland hardwood forests for brood rearing. This habitat type has the highest raccoon densities and poult survival rate was low (Priest et al. 1995).

While the turkey has been restored, large carnivores (cougar [*Felis concolor*] and red wolf [*Canis rufus*]) that preyed on mid-sized mammals remain absent. It is interesting that reintroduced red wolves are preying on raccoons in eastern North Carolina (Mike Phillips personal communication). Addition of the coyote to all ecosystems complicates turkey recruitment and population dynamics.

Summary

Predation of eggs, young and breeding hens may regulate turkey and bobwhite populations. Predation has acted in concert with other factors to stabilize (equilibrium) turkey populations and reduce bobwhite populations in Mississippi. Porter et al. (1990a) stated that a myriad of interacting influences acted on turkey populations, and that the weak link was either adult survival or reproduction. For predation to be limiting, Reynolds et al. (1988) and Newton (1993) listed several conditions: density-dependent predation, generalist predators able to switch rapidly among prey species, a rich supply of alternative prey, patchy habitats, habitat diversity, variation in vulnerability of prey (hens, eggs, poults, juveniles) and predator skills. Deleterious impacts of predation are more likely to occur as habitat quantity and quality decreases (Robel 1993). Man's land-use practices have enhanced predator habitat conditions, and man no longer preys on furbearers. Porter et al. (1990b) suggested that turkey abundances were affected by a suite of density-independent elements that defined average population size. They further thought that periodic high abundances resulted from a coincidence of favorable weather, habitat and other environmental conditions that allowed explosive population growth. We would add, a reduction in predation rate on breeding hens, eggs and poults is neccessary for increased recruitment of turkey and quail. Caughley (1977) thought the manager must identify the weakest link in the life history; we believe it is the breeding period, low recruitment. Vangilder and Kurzejeski (1995) reported that a decrease in poult mortality of 10 percent and 20 percent resulted in significant increases in simulated population sizes for Missouri. Also, Bill Palmer (personal communication: 1996) used long-term data sets from central Mississippi and determined through modeling that a small (10 percent) increase in mean nest success and poult survival rate resulted in a 75-percent increase in spring gobbler harvests. Which factor (e.g., predation, weather, forest management) can wildlife managers control? Only through long-term studies of manipulation of predator populations (Potts 1986) can we make stronger inferences regarding predator management and galliform recruitment (Leopold and Hurst 1993, Weinstein et al. in press).

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Impacts of Predation on Passerine Post-fledging Success

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Introduction

Predation on nests is recognized as an important cause of reproductive failure in passerines and other birds (Skutch 1949, 1966, 1985, Nice 1957, Ricklefs 1969, Martin 1988, 1995). The role of predation on post-fledging survival is unknown, however, as studies of reproductive success generally monitor nests only until the young birds fledge. After fledging, these birds "disappear" from most demographic studies, with first-year survival estimates based on return rates and immigration rates. We know, from these data, that first-year mortality rates are high. However, these estimates conflate dispersal and mortality (Garnett 1981, Petrinovich and Patterson 1982, Drent 1984, van Balen et al. 1987, Bryant 1989, Hötker 1989, McCleery and Perrins 1989, Payne 1989, Sternberg 1989). Therefore, few data exist on the timing and causes of mortality following fledging. Although fledging can be viewed as an escape from high levels of nest predation, fledglings still may be vulnerable to many predators. We examine here the potential role of predation on post-fledging survival in passerine birds.

Young birds continue to develop and grow over the post-fledging period. Immediately after fledging, young birds have poor flight and predator evasion skills. This is particularly true in ground-nesting species. As the fledglings develop proficiency at flying, predation risk should decline. Predation risk then may increase again when parents terminate care and the juveniles disperse from their natal territories. Few studies include the post-fledging period or examine the relationship between development and mortality rates. In addition, little consistency exists among studies in how the post-fledging period is partitioned and how mortality rates are calculated. Therefore, in this review, we present data on post-fledging mortality data: 1) during the period from fledging to independence; 2) from independence to recruitment; and 3) from fledging to recruitment into the breeding population. We then present two case studies (one temperate and one tropical species) in which more detailed data on the timing and causes of post-fledging mortality are available.

Post-fledging Survival until Independence

Reported mortality rates of birds in the interval from fledging to independence vary widely, both within and among studies (Nolan 1978, Drent 1984, Nilsson and Smith 1985, Wolf et al. 1988, Rowley and Russell 1989, Husby and Slagsvold 1992, Yosef 1993, Table 1). We are unable to report daily mortality rates because the reported interval to independence varied within species. Therefore, we present both the mortality rate and the range in the interval to independence reported in these studies (Table 1). The highest mortality rates occurred in dark-eyed juncos (*Junco hyemalis*, ~70 percent), with predation implicated as the main cause of mortality (Wolf et al. 1988). The potential importance of predation is illustrated in a study of sparrowhawk (*Accipiter nisus*) predation on banded tits. Sparrowhawks preyed on 18 to 34 percent of the young tits (*Parus* spp.) under study, mostly during the first five days post-fledging (Perrins and Geer 1980, Newton 1993). Similarly, predation by owls (*Athene noctua*) was responsible for the deaths of 40 percent of fledged northern shrikes (*Lanius excubitur*) (Yosef 1993). In contrast, starvation was a contributing factor in the deaths of 26 to 34 percent of black-billed magpies (*Pica pica*) during their first 17 to 20 days after leaving the nest (Husby and Slagsvold 1992). Unlike the previous examples, prairie warblers (*Dendroica discolor*) experienced low mortality rates, with only 18 percent of young birds dying of unknown causes during the post-fledging interval (Nolan 1978).

Table 1. Survival from fledging to independence for several species of passerine birds and observed or potential causes of mortality.

Species	Post-fledging interval (days)	Percentage mortality	Cause of mortality	Source
Dark-eyed junco	~14	68-69	Predation?	Wolf et al. 1988
Great and blue tit	10-20	18-34	Sparrowhawk	Perrins and Geer 1980, Newton 1993
Great tit	14-20	18-33	?	Drent 1984
Marsh tit		1.2-3.6 (1983)		Nilsson and Smith 1985
	11-15	13-24 (1984)	?	
Northern shrike	5-15?	40	Owl	Yosef 1993
Black-billed magpie	17-22	26-34	Starvation?	Husby and Slagsvold 1992
Prairie warbler	32	18	?	Nolan 1978
Florida scrub jay[a]	60	40	Predation?	Woolfenden and Fitzpatrick 1984, 1989

[a]Species with helpers at nest.

Survival from Independence to Recruitment

First-year survival estimates must consider both dispersal and mortality. In most studies, first-year survival estimates are based on return rates of marked fledglings, or on immigration rates and the assumption of a stable population size (e.g., Nolan 1978). Thus, it frequently is difficult to separate the role of dispersal from mortality in determining the differential survival of first-year and adult birds. Even in species that do not disperse, juvenile mortality still is higher than adult mortality (Table 2). Black-billed magpies experience high mortality during their first year. Birkhead and Goodburn (1989) found that 87 percent of 720 magpies banded at nests failed to return to breed on the study area. They state, but do not quantify, that most mortality occurred during the first 90 days after fledging, after which mortality rates were nearly constant (60 percent for females and 75 percent for males per year, Birkhead and Goodburn 1989). Among white-crowned sparrows (*Zonotrichia luecophrys*), 12 percent of male and 9.5 percent of female independent juveniles returned, while only 6.8 percent of nestlings returned to the study area to breed (Morton et al. 1991). The probability of return was strongly related to how much time the birds spent on the breeding ground prior to migration. More than 28 percent of the birds that spent more than 30 days on the breeding ground the preceding autumn returned the following spring (Morton et al. 1991, Morton 1992).

Survival from Fledging to Recruitment

Indigo buntings (*Passerina cyanea*) experienced the lowest first-year return rates reported, with a range of 2 to 10 percent at two different study areas (Payne 1989). In contrast, adult bunting annual survival was 57 percent for males and 33 to 49 percent for females (Payne 1989). First-year survival in pied flycatchers (*Ficedula hypoleuca*) ranged from 8.8 to 14 percent (Sternberg 1989, Lundberg and Alatalo 1992). This contrasts with approximately 54 percent annual survival of adults (Lundberg and Alatalo 1992). Darwin's ground finches had variable first-year survival between 43 and 51 percent in *Geospiza scandens* and 63 percent in *G. fortis*, while adult survival ranged from 70 to 79 percent in both species (Grant and Grant 1992). Again, the causes of mortality are poorly known, but starvation was reported as an important cause of mortality for finches on the Galápagos Islands (Grant and Grant 1989).

The various tit species all experience low first-year survival (Table 2). Large clutch size appears to balance high juvenile and adult mortality. For example, only 6.4 percent of fledgling great tits (*Parus major*) survived to breed (van Balen et al. 1987). In another study, first-year survival in great tits varied from 3 to 21 percent, while annual adult mortality ranged from 29 to 73 percent (McCleery and Perrins 1989). Blue tit (*Parus caeruleus*) first-year survival is very similar, ranging from 16 to 21 percent, while adult survival is relatively low (27-51 percent, Dhondt 1989). In all of the tits, including the North American black-capped chickadee (*Parus atricapillus*), juveniles disperse two to three weeks after fledging from their natal territory (Greenwood et al. 1979, Drent 1984, Nilsson and Smith 1985, McCleery and Perrins 1988, 1989, van Noordwijk and van Balen 1988, Dhondt 1989). Long-distance dispersal and low probability of resighting adds uncertainty to their overwinter survival estimates.

Table 2. Juvenile first-year survival and adult survival for several species of passerine birds.

Species	First-year survival	Percentage adult survival	Source
Dark-eyed junco	10	?	Wolf et al. 1988
Blue tit	16-21	27-51	Dhondt 1989
Great tit	3-21	29-73	McCleery and Perrins 1988, 1989
	8	44-50	Van Noordwijk and van Balen 1988
Blue tit	26	48	Saether 1989[a]
Great tit	39	52	Saether 1989[a]
European robin	28	38	Saether 1989[a]
Turdus spp.	31-47	41-70	Saether 1989[a]
Black-billed magpie	35	47	Saether 1989[a]
European starling	35	47	Saether 1989[a]
Black billed magpie	13.3	60-75	Birkhead and Goodburn 1989
Prairie Warbler	39[b]	65	Nolan 1978
Pied flycatcher	9-14	46	Lundberg and Alatalo 1992
White-crowned sparrow	7-29	?	Morton 1992
Indigo bunting	2-10	57	Payne 1989
Darwin's ground finch	43-63	70-79	Grant and Grant 1992
Splendid fairy wren[c]	35	72-76	Rowley and Russell 1990
Florida scrub jay[c]	58	79	Woolfenden and Fitzpatrick 1984, 1990
Galápagos mockingbird[c]	35	41-93	Curry and Grant 1989, 1990
Pinyon jay[c]	41-62	74	Marzluff and Balda 1990

[a]Saether (1989) cited authors for these data in appendix.

[b]Estimated.

[c]Species with helpers at nests.

Cooperative Breeders

Cooperative breeders generally have greater post-fledging survival rates, yet the mechanism of this increased survival is not clear. First-year survival in the splendid fairy-wren (*Malurus splendens*) is 33.5 percent (from fledging) or 51.2 percent (from independence), while annual adult survival is 65 percent and 72 percent (females and males, respectively, Rowley and Russell 1989, 1990). In Florida scrub jays (*Aphelocoma coerulescens*), first-year survival is 34 percent from fledging, with 40 percent mortality of fledglings before independence. Once independent, mortality in the first year is variable and high (56-79 percent), compared with the 21 percent mortality of breeders. Again, the causes of death are mostly unknown, although predation is implicated (Woolfenden and Fitzpatrick 1984, 1990, Fitzpatrick and Woolfenden 1989). First-year survival in Galápagos mockingbirds (*Nesomimus* spp.) is 35 percent, while average annual adult survival is 60 percent (Curry and Grant 1989, 1990, Curry and Grant 1989, 1990). Pinyon jays (*Gymnorhinus cyanocephalus*) have similar mortality patterns: 59 percent of juveniles, 38 percent of yearlings and 26 percent of adults die each year (Marzluff and Balda 1990).

Predators

Independent evidence for the contribution of predation to high mortality rates during the first year is demonstrated by studies of raptor diets (Table 3). Birds comprise a large fraction of the diets of several species of raptors, including owls (Fritzell and Thorne 1984, Galeotti and Canova 1994, Joy et al. 1994, Mañosa 1994, Andersen 1995, Rosenfield et al. 1995). In studies where the proportion of young birds in the diet was known, young birds comprised the majority of birds in the diet (Table 3).

Table 3. Evidence that predation on young birds is an important source of first-year mortality.

Predator	Season	Percentage birds in diet	Percentage young birds	Source
Sharp-shinned hawk	Breeding	91	39 (10-~58)	Joy et al. 1994
Peregrine falcon	Breeding	100	57-100	Rosenfield et al. 1995
Northern goshawk	Annual	82.3 (passerines and picidae = 38.2 percent)	~28-65	Mañosa 1994
Barn owl	Winter	in 98 percent of pellets (96.7 percent of food ingested)	?	Fritzell and Thorne 1984
Little owl	Breeding	?	73[a]	Yosef 1993
Long-eared owl	Winter	3.1-54.5	?	Galeotti and Canova 1994

[a]Predation took this portion of fledgling northern shrikes under study.

Case Studies

Yellow-eyed Juncos

Sullivan monitored post-fledging survival of a yellow-eyed junco population (*Junco phaeonotus*) in the Chiricahua Mountains of southeastern Arizona (see Balda 1967 for description of study site; Sullivan 1989 and Weathers and Sullivan 1989 for methods and natural history). Yellow-eyed juncos are small (0.68 ounces [19 g]), monogamous passerines that maintain all-purpose territories, provide bi-parental care of young, nest on the ground and migrate altitudinally. In the Chiricahua Mountains, juncos produce up to three successful broods of one to five young per breeding season. Yellow-eyed juncos fledge 10 to 12 days after hatching before they are capable of long-distance flight. Young juncos usually spend their first five days post-fledging perched in vegetation, being fed by their parents (pre-flight period). Once young birds develop proficiency at flying, they forage with their parents until they are evicted from the natal territory three to four weeks post-fledging (flying period). At this time, young juncos join local flocks of independent juveniles and remain in these flocks until autumn migration to lower elevation wintering sites.

Natal territories were searched for color-banded, dependent fledglings every few days until young birds appeared in local juvenile flocks or disappeared from the territory. Dependent fledglings that disappeared within 21 days of fledging or 21 to 28 days post-fledging while their siblings remained on the natal territory were assumed to have died. Independent juveniles that disappeared from the study area could have died or dispersed to other areas. To assess relative rates of mortality versus dispersal, 263 independent juveniles were color banded at the main study area and seven other areas of preferred juvenile habitats (within 1.8 miles [3 km]) from 1984 to 1986. Juveniles remained at their banding location until August (Sullivan 1989). Thus, we believe individually marked juncos can be found reliably from fledging until at least two weeks after dispersing from natal territory. Birds that disappear during this period are assumed to have died.

Post-fledging survivorship was monitored during the 1984 to 1986 and 1988 to 1990 breeding seasons. In addition, the study area and surrounding breeding habitat were searched for returning juncos each spring from 1985 to 1991. Adult juncos exhibit breeding site philopatry. The median distance between the last-known nest of one season and first-known nest of the next season is only 250 feet (77 m). First-year birds also are philopatric. The median distance from natal nests to the first-known nesting attempt is only 0.32 miles (512 m) for males and 0.21 miles (342 m) for females. We, therefore, believe that most of the birds that disappeared during the winter died.

Breeding season conditions varied greatly over the course of this study, and this variation provides insight into the causes of mortality among young juncos. The 1984 to 1986 breeding seasons were characterized by high juvenile survival and increasing population density at the main study site, Rustler Park. In 1987, a series of severe storms in late spring and a late melting snowpack appear to have contributed to the low overwinter survival in both adults and first-year birds. Breeding seasons from 1988 to 1990 were characterized by drought, declining insect prey abundance and low juvenile survivorship. During the drought, the number of breeding pairs at Rustler Park declined from a high of 49 pairs in 1986 to only 17 pairs in 1990.

Young juncos experience two episodes of high mortality after fledging (Table 4). The first occurs during the five days following fledging when the fledglings' flight skills still are developing. Several factors suggest that predation, rather than starvation, is the main cause of mortality

Table 4. Mortality during the sequence of the post-fledging period, by year, and returns in the subsequent year, for the yellow-eyed junco from 1984 to 1986 and 1988 to 1990.

		Percentage juvenile mortality[a, b, c, d]						
	Number	Percentage dependent fledglings			Percentage independent fledglings	Percentage annual survival[e, f, g]		
Year	fledged	Pre-flight[a]	Flying[b]	Total[c]	Two-week[d]	Returns[e]	Two-week[f]	Adult return[g]
1984	86	40	14	48	38	20	61	63
1985	54	26	18	39	48	17	53	65
1986	131	29	14	39	38	11	28	32
1988	82	32	16	43	71	9	54	57
1989	75	30	17	41	64	3	13	34
1990	18	33	0	33	92	6	100[h]	37[i]
Total	446	31.4	14.7	41.5	51.3	11.2	39.4	44.6

[a]Interval between fledging and when recently fledged birds are capable of sustained flight.
[b]Interval after which juveniles acquire sustained flight and before they are expelled from their natal territory.
[c]Total mortality during the dependence period.
[d]Two-week interval immediately following expulsion fron natal territory.
[e]Portion of all fledged birds that returned to the study site the following spring.
[f]Portion of birds that survived the two-week period in "d" and returned to the study site the following spring.
[g]Portion of adult birds that returned to the study site the following spring.
[h]Based on the resighting of one surviving juvenile.
[i]Based on a one-week field season in 1991.

during the pre-flight period: 1) once the young birds develop proficiency at flying, mortality rates predictor of survival during the pre-flight or flying periods for fledglings (Sullivan 1989). The dramatically decline; 2) mortality rates during the pre-flight and flying periods are remarkably constant across years (Pre-flight 2 =3.93, df=5, P=0.56, Flying 2 =2.72, df=5, P=0.74), although breeding conditions varied markedly; and 3) body mass at fledging was not a significant second episode of high mortality occurs during the first few weeks of independence (Table 4). Evidence that starvation, as well as predation, contributes to high mortality at this time is as follows: 1) juvenile mortality rates increased (2=25.3, df=5, P<0.001) and prey abundance decreased (unpublished data) during the drought years from 1988 to 1990 (Table 4); and 2) recently independent juncos are inefficient foragersand, thus, lose mass, and the amount of mass lost is a significant predictor of survival (Sullivan 1989, Weathers and Sullivan 1991).

Return rates of adult and experienced juveniles are similar for birds banded in 1984 through 1988. Only in the drought year of 1989 did juveniles that survived the two-week post-fledging interval have lower survival than adults (Table 4). These juveniles still are less experienced at foraging than adults (Weathers and Sullivan 1991) and may be more vulnerable to both starvation and predation under poor environmental conditions. In yellow-eyed juncos, the differential mortality between first-year birds and adults usually occurs on the breeding ground when food is relatively abundant. Both, predation and inefficient foraging in independent juveniles contribute to the high mortality rates experienced by first-year birds.

Western Slaty Antshrike

Tropical birds often are subject to high nest predation rates (up to 8.5 percent per day, Ricklefs 1969, Skutch 1985, Roper 1992, Roper 1996), yet, survival rates after the nesting period are largely unknown. While studying the breeding cycle of an understory neotropical passerine, the western slaty antshrike (*Thamnophilus atrinucha*), color-banded fledglings were observed until they dispersed from their natal territories. Slaty antshrikes are common, small (0.86 ounces [24 g]) birds that nest in small shrubs 3 to 9 feet (1-3 m) above the forest floor. Nestlings were color-banded at 17 nests in 1993. At three of these nests, the banded young were never seen after banding, so the nest probably failed before fledging. All of the young from the remaining 14 nests survived until independence. At this site, the post-fledging to independence period varied from 48 to 190 days. Juvenile antshrikes were assumed to have dispersed from their natal territories as they had acquired adult plumage by their last sighting, and they were no longer fed by parents. Additionally, both siblings dispersed on the same day. Predation on young birds should have resulted in the occasional loss of only one sibling.

In contrast to the yellow-eyed juncos, slaty antshrikes do not suffer from predation or starvation after fledging, at least in the year under study. After dispersal, few birds were seen again, so first-year survival cannot be estimated. Nevertheless, the high post-fledging survival documented in this study contrasts strongly with the low survival of temperate birds. In the slaty antshrike, high nest predation rates may be balanced by high post-fledging survival.

Conclusions

Although data on the post-fledging period are limited, several insights are provided from the available studies. This review illustrates the paucity of information regarding the timing and causes of mortality during the post-fledging period and throughout the first year in passerine birds. First-year survival of birds is significantly lower than that of adult birds (Table 2). On average, adults have 26.7-percent (standard deviation = 12.8, n = 18 species from Table 2) greater annual survival than first-year birds. Also, studies that partition first-year mortality indicate that mortality rates are highest soon after the young fledge and again after they become independent (Lack 1946, Perrins and Geer 1980, Sullivan 1989, Marzluff and Balda 1990, Morton et al. 1991, Newton 1993, Yosef 1993). Mortality soon after fledging probably is due to predation on easily captured, young birds. Both predation and starvation may be important in the mortality of recently independent juveniles, as shown in the yellow-eyed junco.

Relatively large birds probably suffer less predation than do small birds, both within and among taxa (Sæther 1989). Raptor diets (Table 3) also included more small birds than large ones. Small birds and recently fledged birds appear to be susceptible to predation by a larger variety of avian predators than larger or more experienced birds.

In many passerines, the young of one year are the breeders of the following year. Our lack of knowledge of population dynamics during this crucial first year presents problems in devising appropriate management strategies for songbird populations. Additional studies are needed to address how mortality during the post-fledging period and the first year influences population dynamics.

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Using Landscape Information Approaches to Increase Duck Recruitment in the Prairie Pothole Region

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Concern about decreasing numbers of some duck populations in North America was primary to the development of the North American Waterfowl Management Plan (NAWMP). Under the NAWMP, several geographical subunits, called joint venture areas, have been established to step-down the overall goals and objectives for the purpose of management action. The Prairie Pothole Joint Venture (PPJV) is a high-priority joint venture of the NAWMP. During 1991 through 1994, a planning process was conducted in the PPJV area of North Dakota, South Dakota, and northeastern Montana to develop management scenarios for meeting duck population objectives. Because predation of nests had been identified as a primary factor limiting the growth of duck populations in much of the PPJV area (Klett et al. 1988), much of the process focused on management treatments designed to reduce or limit predation on nests. Treatments included non-lethal methods, such as protection and establishment of perennial grass cover or creating nesting areas protected from predators (e.g., small islands, predator exclosures), and lethal methods, such as predator removal (Anonymous 1995). To ensure maximum benefits from each treatment, guidelines were developed for their application. A guideline common to all treatments was that each be applied to landscape units where they potentially would benefit high numbers of nesting hens. Although wetland distribution is the primary determinant of breeding duck abundance, the PPJV area is large (approximately 100,000 square miles: 260,000 km2), and wetland density, class and size vary tremendously over this area. Therefore, identifying areas where the highest duck densities occur is not a trivial task. We present a procedure to apply models developed from digital wetland data, data on duck pair/wetland relationships, and breeding duck home range characteristics to prioritize areas for nesting duck management. Using Geographic Information System (GIS) techniques, the process was applied to a two-county area in North Dakota and a map displaying the area as four priority levels based on breeding duck density was created. We demonstrate the utility of the map by selecting example areas and prescribing specific treatments based on other landscape characteristics.

Study Area and Methods

Wetland Data

Digital data for wetlands classified as part of the National Wetland Inventory (NWI) (Cowardin et al. 1979) were obtained from the U.S. Fish and Wildlife Service, NWI Office, Saint Petersburg, Florida, for Stutsman and Wells counties in North Dakota. Duck pair data, used for constructing our pair/wetland regression models, were derived from surveys where duck pairs were counted on a sample of wetland basins of various classes with class equal to the deepest water

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regime of all wetland polygons in the basin, as described by Cowardin et al. (1995). Therefore, prior to applying the model to the wetlands in our study area, we converted NWI digital wetland data into a basin class coverage using the same classification scheme from which our model data were derived. The classes were temporary, seasonal, semi-permanent, lake and riverine. Basically, this process resulted in a classification similar to that described by Stewart and Kantrud (1971) with an additional class—riverine.

Duck Pair Estimates

Basin wetlands. Breeding duck pairs associated with each wetland basin in our study area were estimated using regression models for five upland-nesting duck species: blue-winged teal (*Anas discors*), gadwall (*A. strepera*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*) and northern shoveler (*A. clypeata*). Baseline regression equations were constructed from survey data collected at the Arrowwood Wetland Management District, North Dakota, during 1982 through 1984 (Cowardin et al. 1995), and included our two-county study area. The form of the equations was:

Pairs = A w + B $\sqrt{w}$ *For semi-permanent basins.*

Pairs = B $\sqrt{w}$ *For temporary, seasonal and lake basins.*

Where: A and B are regression coefficients (Table 1).
w is the area (acres) of each wetland basin.

Table 1. Baseline regression coefficients and ratios used for estimating breeding duch pair use of wetland basins and riverine wetlands in Stustsman and Wells counties, North Dakota.

Species	Wetland basin class	Regression coefficients A	B	Ratio of pairs per acre
Blue-winged teal	Temporary		0.19839	
	Seasonal		0.47456	
	Semi-permanent	0.02539	0.43261	
	Lake		0.40138	
	Riverine			0.14351
Gadwall	Temporary		0.09920	
	Seasonal		0.18353	
	Semi-permanent	0.02231	0.17280	
	Lake		0.48119	
	Riverine			0.03456
Mallard	Temporary		0.18035	
	Seasonal		0.19954	
	Semi-permanent	0.02405	0.12304	
	Lake		0.18309	
	Riverine			0.12323
Northern pintail	Temporary		0.14879	
	Seasonal		0.11835	
	Semi-permanent	0.00244	0.09415	
	Lake		0.15727	
	Riverine			0.02780
Northern shoveler	Temporary		0.05861	
	Seasonal		0.12007	
	Semi-permanent	0.00287	0.12051	
	Lake		0.27698	
	Riverine			0.00601

These equations were adjusted to account for variation among areas and years. This adjustment (γ) was derived from waterfowl surveys in which 2,200 to 2,800 sample wetland basins were visited each year in May, 1987 to 1993. During these surveys, the area covered by water in each basin was estimated, and the number of duck pairs and indicated pairs was determined using techniques described by Hammond (1969) and Dzubin (1969). For a more thorough discussion of the field procedure and sample basin selection see Cowardin et al. (1995). γ is calculated as the ratio of pairs counted during field surveys to pairs predicted from the base regression (Cowardin et al. 1995). The adjustment (γ) was calculated for each of 14 geographical districts (Wetland Management Districts) in the PPJV area by averaging values from data collected in each district during the period 1987 through 1993. Due to a phase-in period of the survey and persistent drought in some areas, data were not consistently available for all years in all districts. We assumed that data available for each district reflected long-term average values for that district. γ was found to vary with geographical location (universal transverse mercator [UTM] coordinates), as measured from the geographical center of each district, for gadwall ($\underline{F}_{2,11}$ = 19.06, $\underline{P}$ = 0.001), mallard ($\underline{F}_{1,12}$ = 18.27, $\underline{P}$ = 0.001) and northern pintail ($\underline{F}_{1,12}$ = 18.22, $\underline{P}$ = 0.001). The γ values used in our pair models for these species were modeled using the UTM coordinates for the center of each wetland basin in our study area. For blue-winged teal and northern shoveler, γ did not vary with location and was calculated as the average of the 14 district values. Because of temporal and seasonal variation in precipitation and evapotranspiration rates, some wetland basins do not pond water during May in all years. This is particularly true for shallow basins that have a water regime other than "lake" in our basin class scheme. Therefore, to prevent overestimating duck pair numbers for these shallow basins, we adjusted the pair estimates based on the proportion of basins for each type that would be expected to pond water in an average year, as described by Cowardin et al. (1988).

Riverine wetlands. Duck pair data for the riverine wetland class were derived from surveys conducted in the PPJV area of North Dakota during May, 1983 to 1986. Survey procedures followed those described by Hammond (1969). Pair counts were conducted on 338 stream sample miles (544 km) (excluding Missouri River) during the period 1983 through 1986 and results were translated into pairs per acre of riverine wetland class using NWI digital wetland data. The model for riverine wetlands took the form:

$$\text{Pairs} = P_i \times R$$

Where: P_i = pairs of species i observed per acre of riverine wetland (Table 1).
R is the area (acres) of each riverine wetland.

Procedure

All data processing, analyses and cartographic output were completed using Arc/Info GIS software (Environmental Systems Research Institute, Redlands, California) on UNIX workstations.

The first step in the process involved using the previously discussed models for the five species to calculate a breeding duck pair value for each wetland basin in the digital database for our study area. This step estimated the average number of duck pairs that would be expected to settle in each wetland basin in May. Because these species nest primarily in uplands in our study area (Klett et al. 1988), we needed to determine the number of hens available to different landscape units based on the number that settled in the surrounding wetlands. This required knowledge of the distance hens would potentially travel from their primary core wetland (Poston 1974) to nesting cover. The distances used in our models and the source of information are presented in Table 2.

Next, we divided the study area into arbitrarily sized units 1,320 by 1,320 feet (402 x 402 m). For each unit, we summed the number of duck pairs that was estimated to occupy the wetlands within a specific distance (buffer) from the center of each unit. The buffer distance for each species equaled the travel distance presented in Table 2. Pair values for wetlands that were only partially within the buffer area were prorated based on the proportion of the wetland inside the buffer.

Table 2. Estimated distance female ducks will travel from core wetland territory to nesting sites.

Species	Travel distance in miles (km)	Source
Blue-winged teal	1.00 (1.61)	Dzubin (1955)
Gadwall	1.00 (1.61)	Gates (1962)
Mallard	2.25 (3.62)	Dwyer et al. (1979), Lokemoen et al. (1984), Cowardin et al. (1985)
Northern pintail	2.50 (4.03)	Derrickson (1975)
Northern shoveler	0.75 (1.21)	Poston (1974)

The process provided an estimate of duck pairs per square mile (pairs/km^2 x 2.59) within the buffer area of each unit in the study area. These values were translated into management priority levels and were displayed as a map for our study area. Finally, we obtained a Public Land Survey System digital file for our study area from the U.S. Geological Survey and overlaid the township and section (not displayed in Figure 1) boundaries to facilitate locating the position of units within the study area.

Results

Figure 1 shows the results of our model procedure for Stutsman and Wells counties, North Dakota. Each shade on the map represents a range of breeding duck pair density values scaled as a percentile of the land area. We reiterate that the value assigned to each unit does not represent the duck pairs modeled for the wetland basins in that unit, but rather the modeled pairs for the wetlands in that unit and those within a specific buffer distance of that unit. Additionally, because buffer zones of one unit overlap those of other nearby units, each unit cannot be considered independent of neighboring units.

Management Application

The primary purpose of the duck pair density map is to allow managers to identify "high-priority" sites where the most potential benefits can be achieved from treatments designed to reduce predation on nesting hens and their nests. The type of treatment applied to a site requires additional information that must be obtained from other sources. A summary of treatments, and their application guidelines, identified as useful in the PPJV area are outlined in the U.S. Prairie Pothole Joint Venture Implementation Plan Update (Anonymous 1995). Two examples of using the pair density map for management decisions are given below.

Example 1. On the map in Figure 1, area "A" in Stutsman County, North Dakota is characterized by a large group of high-priority units, mostly near the center of the circle. A visit to the area showed that the land cover in this area is dominated by native grassland used for cattle production. Because grassland provides high nest security compared with cropland (Klett et al. 1988), treatments designed to prevent the conversion of this land to cropland are appropriate. One such treatment is a grassland easement under a program currently administered by the U.S. Fish and Wildlife Service (FWS). Under the terms of the easement agreement, the landowner receives a one-time payment that is determined as a percentage of the land value. In exchange, the landowner agrees to an easement encumbrance on the land with the principal condition that the land must remain as grassland for the duration of the contract period (in many cases, perpetuity). Another treatment, currently being supported by the FWS and Ducks Unlimited, Inc. in the PPJV, is a program to assist landowners in establishing rotational grazing systems on grassland that previously was grazed continuously during the growing season. Rotational grazing systems are intended to improve the structure of the grass cover, thus providing increased forage for cattle and nesting cover for ducks. Additionally, by increasing the profitability of cattle production, grazing systems may help prevent conversion of grassland to alternative uses such as grain production.

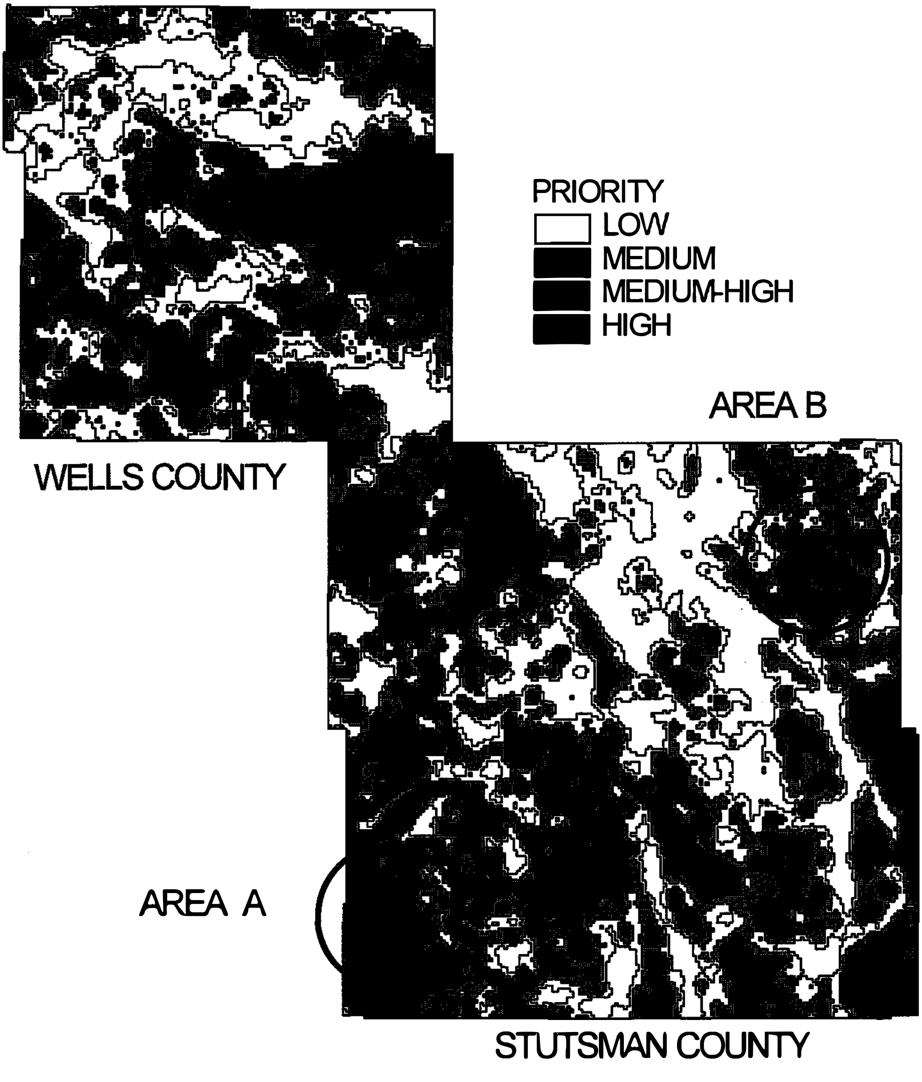

Figure 1. Map of Wells and Stutsman counties in North Dakota that shows areas of different management priority based on breeding duck density for upland nesting ducks. Example areas "A" and "B" are circled.

Example 2. Land use in area "B" (Figure 1), Stutsman County, North Dakota, is characterized by cropland used intensively for small grain production. Cropland is the least productive of all the major cover types for ducks nesting in the area (Cowardin et al. 1985, Klett et al. 1988). Since 1985, numerous cropped fields in this area have been converted to undisturbed perennial cover through the U.S. Department of Agriculture's Conservation Reserve Program (CRP). Some of these CRP fields occur in the high-priority units shown in area "B." Recent studies have demonstrated that CRP cover is attractive to nesting ducks and provides relative security from nest predators (Kantrud 1993, Reynolds et al. 1994). CRP fields that occur on high-priority units could receive priority consideration for extending existing CRP contracts and accepting additional conservation bids under future farm programs. Other programs, such as predator exclosures or predator removal, also would be appropriate in landscapes such as area "B," especially if grass cover is limited.

Discussion

Low duck recruitment in the prairie pothole region of the United States and Canada is the result of excessive predation associated with extensive landscape changes due to agriculture and other development. Improving this landscape to benefit duck production is a large, complex and costly task. Managers charged with this task in the prairie pothole region are faced with the difficult problem of applying a variety of management strategies to an almost unlimited number of situations affected by political, social, economic, geographic and ecological constraints. Not all the landscape can be treated. Most often, opportunity (a favorable juncture of circumstances) dictates the type and location of treatment application. Such an approach can lead to less than maximum benefits from the treatment. Many of the strategies needed to improve duck production in developed agricultural areas are intensive in nature. That is, they require considerable amounts of money and manpower to develop and maintain (e.g., predator barriers). Therefore, to maximize cost effectiveness, appropriate management practices should be targeted to areas where they can benefit the most breeding ducks.

We offer a tool that waterfowl managers can use to ensure that habitat treatments are applied to the most appropriate part of the landscape. We link breeding duck populations to the landscape by applying duck pair/wetland relationships and breeding duck home range characteristics to digital wetland data using GIS technology. By identifying areas of different breeding duck densities, managers can apply treatments to areas where they will potentially benefit the largest numbers of breeding ducks. For example, guidelines for electric fence exclosures (designed to reduce predation on nests and nesting hens) call for placing this treatment in areas with relatively high breeding duck densities and low amounts of competing nesting cover outside of the fence. Such guidelines are intended to increase the probability that the relatively expensive tract of fenced cover is used by high numbers of nesting hens. Our maps allow managers to find areas of relatively high duck densities easily and then, through field visits or other habitat information, select specific sites with little competing nesting cover. Our maps also provide a very useful mechanism for targeting both wetland and grassland protection (but not restoration) efforts to provide the greatest benefits to breeding ducks. Maps currently are available for all of the prairie pothole region of South Dakota and North Dakota. Within six months, we intend to complete the mapping for North and South Dakota. When digital wetland data become available from NWI for eastern Montana, we will apply the process there as well.

The described process only considers ducks in the Prairie Pothole Joint Venture area. We believe landscape changes affecting breeding ducks in this area also affect many other grassland- and wetland-dependent species. With adequate data, similar processes could be used to target management for other species. GIS modeling of densities of other species would help managers to pool resources from multiple sources to maximize benefits to a variety of species throughout the PPR. We invite other agencies and organizations to use our maps to help target their programs. In the future, we plan to develop a digital coverage of upland habitats in the prairie pothole region. Such an upland habitat layer, when combined with the pair density map presented here, would provide an even more valuable tool for prioritizing landscapes for protection and enhancement.

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Effects of Mammalian Predator Removal on Waterfowl and Non-game Birds in North Dakota

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Waterfowl managers have long been concerned about low nest success on the North American prairies. A review of duck nesting success shows that, despite great variation between studies, there is a dramatic pattern of decline in nest success in the past 50 years (Beauchamp et al. 1996). The linear regression of success versus year shows that hatching rates dropped from 33 percent in 1935 to only 10-percent nest success in 1992 (Beauchamp et al. 1996). Low nest success, which reflects high nest predation, is viewed as the most significant limitation on waterfowl productivity in the prairies (Cowardin et al 1985, Greenwood et al. 1987, Johnson et al. 1992). Most of the management effort under the North American Waterfowl Management Plan (NAWMP) in the prairie region of the United States and Canada is an attempt to elevate nest success for upland-nesting ducks.

Low duck nest success can be attributed to human alterations of nesting habitat and the predator community. Intensive agriculture has eliminated the vast majority of grassland habitat that was historically used as nesting cover. Remaining cover is highly fragmented and often occurs as a fringe of vegetation around wetlands. Reduced cover probably makes nests much more susceptible to detection by predators traveling through narrow strips of vegetation (Cowardin et al. 1985, Greenwood et al. 1987, Klett et al. 1988). Compounding habitat degradation is a major shift in numbers and types of nest predators on the prairies. Extirpation of wolves (*Canis lupus*) and reduction of coyotes (*Canis latrans*) has allowed medium-sized predators, such as red fox (*Vulpes vulpes*), skunk (*Mephitis mephitis*) and raccoon (*Procyon lotor*), to flourish (Cowardin et al. 1983, Sargeant et al. 1993). Raccoons are a recent arrival to much of the prairies, though they now are abundant and the dominant nest predator for many prairie ducks (Stoudt 1982). Abundance of medium-sized mammals and scarcity of nesting cover has been a very detrimental combination for breeding ducks.

Most attempts to increase duck nesting success have focused on ways to make nests less accessible to predators. Dense nesting cover has been the dominant management on United States Waterfowl Production Areas (WPA) and on NAWMP areas in Canada, yet this strategy typically has improved nest success by only a few percentage points, with highly variable results (Clark and Nudds 1991, D. Duncan personal communication: 1996). Improved nest success associated with the Conservation Reserve Program (CRP) suggests that landscape-level additions of nesting cover improve recruitment, but habitat improvement on this scale is not economically feasible for wildlife groups (Kantrud 1993, R. Reynolds personal communication: 1996). Intensive management efforts to make nests inaccessible, such as construction of islands and predator barrier fences, can increase nest success, but costs are high (Lokemoen 1984, Greenwood et al. 1990, Lokemoen and Woodward 1993).

An alternative to reducing nest availability is to alter predator behavior or predator numbers. Taste aversion programs attempt to train predators to avoid nests, but effects, if any, are local and require maintenance with treated eggs (Conover 1989). Supplemental feeding might satiate predators so they prey on fewer duck nests, but this technique may not be successful, is only practical on a local scale and actually may increase predator abundance (Crabtree and Wolfe 1988). Most efforts to alter predator populations have used lethal control, but there is growing interest in using sterilization to limit population growth. Sterilization is not yet effective for use on wild populations.

Predator population reduction using lethal methods has been the subject of much prior research, but most studies examining effects of predator removal on duck nest success have lacked control sites, had few or no replicates, or used poison as a removal technique (Kalmbach 1938, Balser et al. 1968, Lynch 1972, Deubbert and Kantrud 1974, Deubbert and Lokemoen 1980, Doty and Rondeau 1988). Poison is neither legal nor acceptable to managers or the public. A replicated study evaluating effects of predator removal without poisons found only small increases in nest success (Sargeant et al. 1995). In that study, there were restrictions on the types of traps used and on trapper work schedules, and removal occurred on small (142 ha average) study sites.

Our primary objective was to assess the effect of removing mammalian predators, without using fences or poisons, over relatively large (16 square miles: 4,150 ha) replicated study sites. We indexed predator activity and estimated nest success of upland- and overwater-nesting ducks, American coots (*Fulica americana*), yellow-headed blackbirds (*Xanthocephalus xanthocephalus*) and grassland songbirds (i.e., *Spizella pallida, Passerculus sandwichensis, Ammodramus leconteii*). We also measured duckling survival rates.

Study Area

We worked in the drift prairie region of eastern North Dakota. The area was slightly rolling and had abundant potholes, with small grain agriculture in the uplands. Each study site was a square block chosen because it had a high pond density and 10 to 30 percent of the upland was in grassland cover (CRP, Water Bank Program or WPA). Study sites were randomly assigned to either experimental (trapped) or control (untrapped) treatments. In 1994, we did a pilot study on effects of dabbling duck nest success with one experimental and one control area. In 1995, we applied the same treatments to these sites, and added three experimental and three control sites.

Methods

Predators were removed by four professional trappers, one at each site, using leghold traps, snares, connibears in box sets and, occasionally, shooting. Removal began in late March and ended in late July. We quantified predator activity on each site by counting predator tracks on 32 randomly selected quarter sections (160 acres: 65 ha) (Sovada et al. 1995). On each quarter section, we chose the best 10-acre (4 ha) plot that contained mud or soft soil, where we surveyed for fox, raccoon, skunk, badger, coyote and mink tracks for a maximum of 15 minutes. We compared the proportions of plots containing tracks of each predator type using analysis of variance on logit-transformed data.

We located dabbling duck (mainly *Anas discors, Anas strepera, Anas platyrhynchos, Anas clypeata*) nests by dragging a chain over upland cover (Klett et al. 1986). We searched emergent vegetation on foot to locate diving duck (*Aythya americana, Aythya valisineria, Oxyura jamaicensis*), blackbird and coot nests. Nests of grassland songbirds were located by dragging a 90-foot (30 m) rope over cover or by flushing birds incidentally. To supplement information from songbird nests, we used artificial nests (Martin 1987). Small woven baskets were placed in three different transects for 12 days at a time at each site. One trial was run in early June and another in early July. Each artificial nest contained one Japanese quail (*Coturnix japonica*) egg and one artificial egg made of plasticine clay (Nour et al. 1993). Tooth marks in clay eggs were keys to the identity of nest predators. We calculated Mayfield nest success based on nest checks every 10 to 14 days for ducks and coots, 6 days for blackbirds and 4 days for songbirds (Mayfield 1961, Johnson 1979). Apparent nest success was calculated for artificial nests. We used analysis of variance (ANOVA) to test for differences in nest success on experimental and control sites.

We conducted duck pair counts in early May, then again in late May/early June by checking every wetland on 16 randomly selected quarter sections on each study site (Stewart and Kantrud 1972). Broods were counted in mid-July, and again in early August. Brood survival of northern shovelers was estimated by marking late-incubation stage hens with anchor-and-suture backpack radio transmitters (Pietz et al. 1995), and relocating hens and broods at least once a week.

Results

Fox, raccoon and skunk were the most commonly taken predators (Table 1). Fox, raccoons and skunks comprised 30, 43 and 27 percent, respectively, of commonly taken predators removed over both years. Few badger, mink or coyotes were taken in either year. The majority of foxes (70 percent) were taken with snares, whereas most raccoons (76 percent) and skunks (71 percent) were trapped with connibears in box sets. In 1994, more plots on the control site contained fox, raccoon and skunk tracks, but differences were significant only for fox (G = 10.0, P = 0.005). In 1995, a significantly greater proportion of plots on control sites contained tracks of foxes and skunks than did experimental plots. The difference was not significant for raccoons (Table 1). Badger, coyote and mink tracks were rarely observed on experimental or control sites.

Table 1. Results of study of predator removal effects on avian production in northcentral North Dakota, 1995. Nest success and track counts are given as percentages, with sample sizes in parentheses.

	Experimental sites					Control sites					
	I	II	III	IV	Total	I	II	III	IV	Total	P =
Dabbling duck nest success	66	53	52	41	53 (587)	36	23	19	18	24 (442)	0.002
Diving duck nest success	47	57	50	65	57 (88)	41	27	18	44	29 (80)	0.031
Coot nest success	86	91	83	83	86 (122)	47	59	73	83	67 (111)	0.043
Blackbird nest success	72	87	58	87	73 (73)	80	80	68	75	75 (78)	0.649
Blackbird fledging success	84	100	86	71	87 (62)	85	95	78	70	82 (69)	0.591
Grassland songbird nest success					44 (14)					37 (21)	0.480
Artificial nest success	66	72	88	65	71 (568)	74	74	53	64	63 (568)	0.30
Trial 1	84	90	89	79	85 (294)	84	84	68	74	77 (294)	
Trial 2	48	54	86	51	61 (274)	64	63	38	54	54 (274)	
Numbers of predators removed	361	310	280	212	1,163						
Track counts[a]											
Fox	34	22	19	48	38 (126)	79	57	72	63	60 (113)	0.005
Raccoon	66	59	26	6	40 (126)	29	65	78	67	60 (113)	0.269
Skunk	9	3	6	3	7 (126)	18	22	22	10	17 (113)	0.008

[a]Percentage plots with tracks

In 1994, upland-nesting duck nest success was 52 percent (n = 220) on the experimental site and 6 percent (n = 105) on the control site. In 1995, nest success of upland- and overwater-nesting ducks was consistently and significantly higher on experimental sites than on control sites (Table 1). In 1994, approximately twice as many breeding dabbling duck pairs were sighted on the experimental (n = 260) site as on the control (n = 145); however, dabbling duck broods counted on the experimental (n = 68) and control site (n = 4) differed by an order of magnitude. In 1995, counts of diver and dabbler pairs were approximately equal on experimental and control sites, but almost three times as many broods were observed on experimental sites as on control sites (Figure 1).

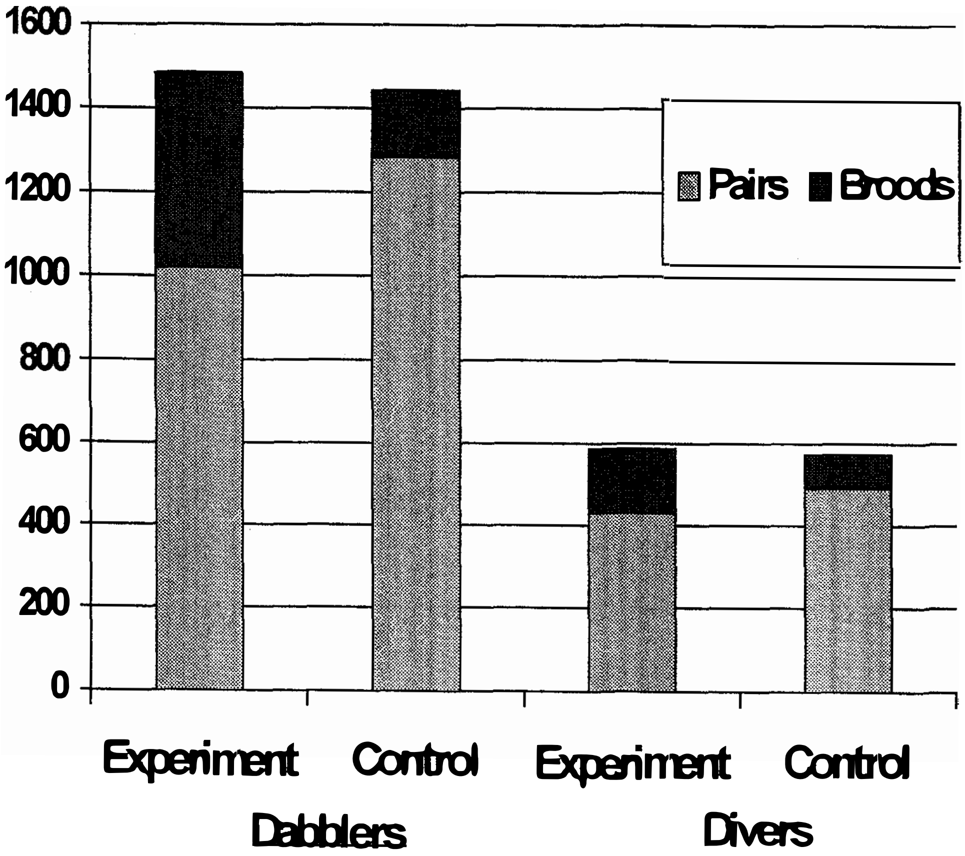

Figure 1. Counts of duck breeding pairs and broods in northcentral North Dakota, 1995.

Radio telemetry revealed small differences in brood survival on experimental and control sites (79 versus 65 percent, respectively), but brood size declined less over a 30-day period on experimental sites. We combined these two measures for an estimate of duckling survival and found that duckling survival to 30 days was 55 percent (n = 14) on experimental sites and 33 percent (n = 17) on control sites.

Coot nest success was significantly higher on experimental sites than on control sites (Table 1). Blackbird nest and fledging success did not differ significantly on experimental and control sites (Table 1). Success of natural and artificial songbird nests did not differ significantly on experimental and control sites (Table 1).

Discussion

Our preliminary results provide the first evidence from a replicated scientific study that predator population reduction by trapping alone, without the use of toxicants, can greatly improve nest success in upland- and overwater-nesting ducks. Duck nest success on treatment sites was approximately twice as high as on control sites. Intensive monitoring of shoveler broods and counts of other broods suggest that duckling survival may be elevated with predator reduction. The high brood counts of ducks on the experimental areas suggest that the high nest success resulted in dramatic improvements in duck recruitment, even if brood survival remained unchanged. Predator reduction appears to affect other bird species we studied to a lesser degree, if at all. Coot nest success was significantly higher on experimental areas than on control areas, but it was quite high even in the absence of trapping, which is typical of coots (Alisauskas and Arnold 1994).

The historic reduction in large canids appears to be at least partially responsible for shifts in the predator community toward the abundance of medium-sized predators, such as fox, skunk and raccoon, which cause low duck nest success on the prairies (Johnson et al. 1989, Sargeant et al. 1984). Trapping medium-sized predators could release small predators from a major cause of mortality, thus potentially increasing their abundance and leading to problems of increased songbird nest predation. We have no direct data on abundance of small mammals, but our preliminary data on natural and artificial nests for small birds do not support this hypothesis. Blackbird fledging success was similar with and without trapping, and blackbird nest success actually was slightly higher on control sites. Artificial and natural songbird nests did not show great differences in success in response to reduction of the medium-sized predators. Sample sizes for natural songbird nests were small, which makes interpretation of only one year of data especially risky.

Our study provides a contrast to a prior study that used trapping alone to reduce populations of the same set of medium-sized mammals that we targeted. Our study differed in two ways. First, we trapped relatively large blocks of cover (16 square miles: 4,150 ha), whereas the other trapping-only study examined relatively small blocks (142 ha average) (Sargeant et al. 1995). A second difference was that our trappers had no restrictions on daily work time and could use snares as a trapping option. In the former study, the trappers were limited by federal work restrictions and could not use snares on most of the replicates. We cannot separate the importance of these effects. We believe, however, that use of snares greatly increases the effectiveness of spring trapping, especially for fox. Snares accounted for most of the total take of foxes, which are key upland nest predators (Sargeant et al. 1984, Johnson et al. 1989).

It is unclear whether our results can be extrapolated to predator removal on unimproved habitat or smaller trapping sites. Intensive trapping did not remove all predators. On our experimental areas, we saw considerable evidence of predator activity through track counts, and more than 30 percent of duck nests were consumed by predators. Would untrapped predators be able to search intensively farmed habitat with such efficiency that nest success would not show substantial improvement? Alternatively, might predator removal increase nest success in intensively farmed habitat by an even greater margin than on CRP, which has elevated success compared with intensively farmed areas?

If predator removal is to be considered as a management option, then a logical progression of information is needed before management recommendations can be made. The first question concerns the efficacy of any population reduction technique. This is the realm of our study.

Our preliminary data suggest that predator reduction by trapping can lead to significant improvements in duck nest success. The next logical question is whether predator population reduction, which is annual and intensive management, can compete with other management in terms of cost effectiveness.

A detailed analysis of the costs of predator management is beyond this paper, but we can make some observations concerning waterfowl production. This research was partly inspired by the apparent inability of most other waterfowl management to effect more than modest improvements in nest success. To analyze cost effectiveness of predator reduction, we would calculate the number of ducks produced in excess of those normally produced in the absence of treatment (in our case, average production on CRP), then divide by trapping costs. Even this simplistic analysis is hampered because we do not know if predator reduction results in greater duck breeding populations in following years, nor do we know if predator reduction over several years increases duck nest success by a greater margin. Nevertheless, results of our preliminary analyses mirror work by Lokemoen (1984) suggesting that predator removal is one of the most cost-effective forms of waterfowl management. We plan a detailed analysis of cost effectiveness.

Assuming that our preliminary data concerning waterfowl nest success are reliable, then they may force waterfowl managers and policy makers to reevaluate their management goals and strategies. Most current waterfowl management is targeted toward creating habitat, particularly upland habitat. While this is a worthwhile goal, it may not be the most effective way to increase the autumn flight. In the United States, the Department of Agriculture has created much more upland nesting cover with the Conservation Reserve Program than wildlife agencies have been able to create in 60 years. If enhancing duck recruitment is our goal, we may be served better by using waterfowl management dollars to manage CRP grasslands in areas of high wetland abundance so that we maximize waterfowl recruitment. It may be time to consider partnerships where we acknowledge that only markets and government policy can effectively alter habitat on a landscape scale. Wildlife agencies might more effectively use their management dollars to improve productivity of the wildlife habitat that currently exists, or is created by government incentive programs and policy mandates.

A common argument against predator management is that it must be applied annually. Cost analyses can compare the investment of dollars into a long-term habitat program versus an annual effort, but there remains a strong bias toward long-term management. This bias may result from failure to recognize that even habitat programs require costly annual upkeep. Upland cover is expensive to plant and requires maintenance such as cutting, burning and reseeding that takes time, money and personnel. A benefit of predator management is that it can be targeted on an annual basis to areas where it can do the most good. Predator removal efforts can be directed to different areas in different years, as dictated by dramatically variable water conditions on the prairies. Areas with intact wetland basins that attract high breeding pair densities, yet consistently low nesting success, might be good choices for predator management. Upland habitat management provides little benefit to ducks in dry years, when intensive management is needed the most.

The third and perhaps most difficult issue concerning predator management is whether such controversial management is acceptable to the public. Potential for landowner cooperation and public acceptance must be evaluated before initiation of any large-scale predator management program that involves lethal removal. We have not attempted such research, but we can make some observations. The vast majority of our research took place on privately owned farmland. Our study has met with good landowner cooperation, despite the fairly jaundiced view of landowners in this region of North Dakota toward "the wildlife." That negative attitude largely reflects farmers' view of waterfowl and wetland habitat programs, namely wetland protection through perpetual easement purchases. We cannot make any statements about whether landowners would accept an operational predator removal program, since we made it clear to all landowners that this was a scientific study of short duration. Landowners in more urban areas probably would view predator removal with more skepticism than in this rural area of North Dakota (Kellert 1985). We certainly believe that public attitudes toward predator removal should be examined carefully if it is to be attempted on a larger scale.

Intensive habitat improvements alone have had little impact on duck nesting success. Extensive, landscape-scale habitat changes, such as CRP, appear to improve duck nest success, but our results suggest that predator removal can produce further improvements. We suggest that mammalian predator removal may complement intensive or extensive management and increase its effectiveness.

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Predator Management to Protect Endangered Avian Species

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There are about 275 species of birds on the U.S. Fish and Wildlife Service's (USFWS) list of threatened and endangered species (USFWS 1995). The International Union for the Conservation of Nature and Natural Resources (IUCN) noted that there is serious concern for the status of more than 2,000 species of birds, representing about 20 percent of the world's avifauna (Collar et al. 1995). These bird species include representatives of most taxonomic orders. Many of the species are endemic to islands or coastal areas and many are ground-nesting species. Most of the species on the IUCN list are associated with forests, scrub, and wetland or littoral habitats.

Many factors can threaten the continued existence of a species. Habitat loss and degradation are considered the main threats to most species of concern, followed by limited range or population size (Collar et al. 1995). Other factors include hunting, trapping, subsistence or commercial egg collecting, competition or predation by introduced species, natural causes, and unknown factors.

Efforts to restore endangered avian species have included: 1) legal protection from taking or harassment; 2) creation of reserves or refuges; 3) protection or restoration of habitats; 4) reduction of competition or predation; 5) provision of food or nest sites; 6) captive breeding or foster parenting; and 7) assessments of population size, recruitment, mortality, and habitat quantity and quality. Recovery plans have been developed for some endangered species. These usually are comprehensive, multiple agency/party plans or agreements that delineate specific threats, action items, designated areas, time lines, budgets and anticipated results. The plan may indicate a specific goal to be achieved, such as the number of breeding pairs in designated areas that could lead to a down-listing from endangered status. Unfortunately, only about 72 (26 percent) of the 275 listed avian species have recovery plans (USFWS 1995).

Predation

Predation is one of many mortality agents that influence populations, along with malnutrition, inclement weather, accidents, toxins, diseases and hunting by humans (deVos and Smith 1995). The significance of predation on prey populations has been widely argued. However, predators often play critical roles in the composition and function of ecosystems. The effects of predation on birds can be significant, especially with high predator densities or when predators gain access to areas they have not occupied historically. Non-native predators (feral cat [*Felis domesticus*], rats [*Rattus* spp.], red fox [*Vulpes vulpes*] and mongoose [*Herpestes auropunctatus*]) can have substantial effects on avian species, especially in localized situations or on islands (Bailey 1993, Burger and Gochfeld 1994, Welty and Baptista 1988).

Many species have been implicated in predation on endangered avian species. In addition to the species mentioned, other predators include coyote (*Canis latrans*), arctic fox (*Alopex lagopus*), feral dog (*Canis familiaris*), bobcat (*Lynx rufus*), skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), mustelids (*Mustela* spp.), ground squirrels (*Spermophilus* spp.), gulls (*Larus* spp.), ravens and crows (*Corvus* spp.), great-horned owl (*Bubo virginianus*), brown-headed cowbird (*Molothrus ater*), and brown tree snake (*Boiga irregularis*). Often, more than one species and taxonomic group of predators are involved. The egg, nestling and fledgling stages of avian development usually are most prone to predation (Burger and Gochfeld 1994). In general, ground nesters suffer highest predation levels, followed by cliff/burrow nesters, and lowest levels by tree nesters (deVos and Smith 1995). Predation may cause relatively slight to nearly complete loss of recruitment in avian species (Bailey 1993, Burger and Gochfeld 1994, Welty and Baptista 1988).

More than 30 avian species have been protected from predators as part of recovery efforts in the U.S. and its territories. These include large (Aleutian Canada goose [*Branta canadensis*], whooping crane [*Grus americana*], brown pelican [*Pelecanus occidentalis*]), intermediate-sized (light-footed clapper rail [*Rallus longirostris*], Attwater prairie chicken [*Tympanuchus cupido*], Hawaiian duck [*Anas wyvilliana*]) and small species (piping plover [*Charadrius melodus*], California least tern [*Sterna antillarum*], Kirtland's warbler [*Dendroica kirtlandii*]).

Predation Management

Many methods are available to reduce wildlife losses to predation, including physical, chemical, biological and other approaches (Fall 1990). Often, multiple methods are used to increase effectiveness and reduce hazards, in keeping with the principles of integrated pest management. Methods should be tailored to the specific situation, the target species, the locale and its laws and regulations, budget and personnel constraints, and the socio-political setting (Schmidt 1992, U.S. Department of Agriculture [USDA] 1994). Research continues to improve on existing methods and add new methods for managing predator impacts (Fall 1990).

Unfortunately, in the case of endangered avian species, many of the methods for predation management are not appropriate. For example, frightening devices and guard animals probably would be as threatening to a nesting colony as the predators themselves. The methods used most commonly include exclusion (nest or area barriers made of wire mesh and/or electric wires) or predator removal (box and leg-hold traps, snares, shooting, and toxicants). Details on the use of these methods can be found in Hygnstrom et al. (1994), Lokemoen and Messmer (1994), Robinson et al. (1993) and USDA (1994).

A plan to protect an endangered avian species must address many factors to help assure success, including: 1) identifying the problem species; 2) assessing the extent of the problem and other contributing factors; 3) stating objectives and measures of success; 4) gaining agency and landowner cooperation; 5) allowing public input; 6) defining the control area, including buffer zones; 7) defining time frames for control; 8) using integrated, diverse methods, as appropriate; 9) obeying related laws and regulations; and 10) monitoring and documenting results. Implementing predator management programs may be costly and require several years to achieve objectives; however, the use of volunteers may help to reduce costs. Publication of results may help to improve future programs.

Predator management, or the reduction of any overabundant wildlife species, is controversial even among professional biologists (Goodrich and Buskirk 1995, Robinson et al. 1993). The reintroduction of endangered species often has met with resistance because of costs and/or conflicts with other resources or land uses. Wildlife managers must take into consideration many, often conflicting, laws, policies and resource demands.

Case Histories

Multiple Predator Species Management in California

Along coastal California, numerous avian species are threatened or endangered by loss of habitat and coastal development, including the California least tern, light-footed clapper rail and western snowy plover (*Charadrius alexandrinus*). Predation on eggs, chicks and fledglings has been identified as a factor limiting the recovery of these species. In the early 1980s, biologists and nest monitors documented predation and attempted, with fencing and occasional shooting, to exclude and remove predators. When these early efforts met with limited success, the USDA Animal Damage Control (ADC) Program was consulted, then contracted, to provide predator management. By direction of the USFWS, mitigation funding from a number of sources was used to establish predator management programs. In southern California, ADC has active programs at 19 of 29 least tern nesting sites (Caffrey 1994) and 7 of 10 marshes where light-footed clapper rails occur (Zembal 1991).

The efforts have been directed at numerous species of avian and mammalian predators, including crow, raven, kestrel (*Falco sparverius*), burrowing owl (*Athene cunicularia*), barn owl (*Tyto alba*), great horned owl, loggerhead shrike (*Lanius ludovicianus*), northern harrier (*Circus cyaneus*), peregrine falcon (*Falco peregrinus*), red-tailed hawk (*Buteo jamaicensis*), bobcat (Felis *rufus*), feral cat, California ground squirrel (*Spermophilus beecheyi*), coyote, feral dog, gray fox (*Urocyon cinereoargenteus*), red fox, long-tailed weasel (*Mustela frenata*), striped skunk, raccoon and opossum (*Didelphis virginiana*). All of these species are known to prey on the California least tern and western snowy plover, whereas the coyote and red fox are primary predators of the light-footed clapper rail.

Because of this large array of predators, a strategy was developed with a goal of maintaining each nesting colony free of predators (Butchko and Small 1992). This strategy involved timing of control efforts, use of diverse methods, and communication between nest monitors and ADC personnel to assure that predation was curtailed. The principal equipment used to remove mammalian predators was cage, leghold and Conibear traps, and gas cartridges. These were used at all sites prior to the arrival of the protected species and throughout the nesting period (April 1 to August 15). In some cases, shooting was used when other methods failed. Equipment used to trap and relocate avian predators included bal-chatri, channing and pole traps. An avian toxicant, DRC-1339, was used in some cases, under a state permit, to control crows and ravens.

The results of these programs have been positive, with increased fledgling production rates documented in several cases. At Batiquitos Lagoon, predator management was begun in April, 1994. Predators identified were kestrels, owls, ravens, raccoons and long-tailed weasels. The 68 fledglings produced in 1994 represented a 100-percent increase over the previous year.

At Camp Pendleton, about 550 California least tern eggs were laid and only 56 chicks were fledged in 1987. In 1993, after six years of predator management, 522 fledglings were produced from 604 eggs—a 900-percent increase. The predators included kestrels, owls, northern harriers, coyotes, striped skunks and ground squirrels.

At the Seal Beach Naval Weapons Station and National Wildlife Refuge, the light-footed clapper rail population increased from 5 to 28 pairs from 1986 to 1991. In 1986, a predator management program was begun, directed at removal of the non-native red fox. Numbers of foxes trapped and removed increased from 60 per year (1986 and 1987) to a high of 128 (1988), then declined to 22 (1989). The reduction in foxes taken and the increase in the rail population illustrates the importance of proper identification and persistent control of the primary predator species.

At San Elijo Lagoon, where no ADC predator management program exists, production of California least terns is poor and declining. In 1992, 35 nests produced only two fledglings. In 1993 and 1994, 9 and 12 nests, respectively, produced no fledglings. The limited production in 1992 and zero production in 1993 and 1994 were attributed to predation from ravens, kestrels, coyotes and raccoons (Caffrey 1992, 1993, 1994).

After numerous years of protecting these endangered species, it appears that effective programs will have several key elements. They require adequate numbers of qualified personnel; a persistent effort, often seven days per week from sunup to sundown; and preventive control, rather than reactive control. Finally, they require that proper and diverse methods of control be available to remove specific predators once identifed (Butchko and Small 1992).

Brown Tree Snake Management in Guam

The need to control the introduced brown tree snake on Guam is highlighted by the disappearance of 9 of 11 forest bird species from the island, continued declines of both remaining species of forest birds, cessation of breeding by seabirds formerly present and significant reductions in the abundance of introduced birds (Engbring and Fritts 1988). Selection of the methods and strategies to employ in control of snakes on Guam required determination of predator population levels (Rodda et. al 1992a), assessment of sampling and control techniques (Rodda and Fritts 1992), and, ultimately, evaluation of control efforts at scales relevant to preservation of endangered species and other native vertebrate fauna (Rodda et al. 1992b).

Programs to control snake populations are not well-developed anywhere in the world. Much original research is needed to develop the control techniques taken for granted for other vertebrate groups. Important factors include the high densities of this snake (15-50 per ha), its secretive and cryptic nature, the extremely low numbers remaining of some bird species, and the movement and dispersal abilities of both birds and the snake.

High snake densities require the control or removal of large numbers of individuals to achieve measurable benefits. For example, the Mariana crow (*Corvus kubaryi*) has persisted in low numbers even after the disappearance of smaller native birds, perhaps due to special behaviors and a larger egg and body size. The discovery of a snake approximately 785 millimeters in snout-to-vent length in the process of swallowing an egg from a Mariana crow nest in March 1993 suggests that at least 76 percent of all male and 65 percent of all female snakes were of sufficient size to prey on crow eggs. Assuming a 1:1 sex ratio in a snake population of about 35 to 50 per hectare, about 25 to 36 snakes per hectare are capable of preying on crow eggs, threatening the reproduction of the species. With hand-capture rates of one to two snakes per hectare for experienced snake biologists in forest situations (Rodda and Fritts 1992) and the limitations of hand capture in high forest, other methods clearly were needed (Rodda et al. 1992c).

Control efforts relying on hand capture of snakes or capture by trapping are limited in scale and difficult to apply to areas large enough to accommodate mobile prey. Trapping experiments in 1 to 1.4 hectare experimental plots revealed that 5 to 7 percent of the snake population moved in or out of a plot per night (Rodda et al. 1992b). Thus, it is probable that large numbers of snakes will move into control sites over a period of weeks or months, and trapping efforts necessarily would be nearly continuous and extend over long time periods. The numbers of snakes that must be removed to achieve adequate protection of endangered species will be much larger than the the snake density at a point in time (e.g., 15-50 per ha). For example, 584 individual snakes were recorded in a 4-hectare plot over a 36-month interval, while the density of snakes never exceeded 60 per hectare at any point in time (E. Campbell unpublished data).

Preliminary work on snake trap efficacy suggests that the nature of the bait and trap spacing are both important. At least 30 to 40 traps per hectare are needed to assure adequate trapping rates (e.g., 6-26 percent of the population per night). Thus, a 1-square kilometer area would require 3,000 to 4,000 traps to achieve adequate control and offset re-entry and reproduction by snakes. Placing, checking, rebaiting and maintaining access to this many traps would require considerable funds and personnel, even in the relatively small area of Guam.

Snake removal and exclusion from selected control areas could produce snake-free islands of habitat where endangered species could survive and reproduce without the continual need to capture large numbers of snakes for long periods of time (Rodda et al. 1992b). In two 1-hectare plots bounded by snake barriers, snake densities were lowered essentially to zero. Once snakes were removed, an effectively snake-free environment was maintained. In two 1-hectare, unfenced plots, snakes remained abundant, plots were constantly invaded by additional snakes and snake predation rates remained high (E. Campbell unpublished data).

The necessity of combining snake exclosures with other control measures was illustrated by a trapping effort on Orote Peninsula, Guam, in 1991. About 37 snakes per hectare were present and a 26-percent chance existed of capturing any snake present each night (i.e., 26-percent snake capture success). With no snake movements, a decline of the snake population to zero would be expected after about 14 to 15 days of capture and removal effort. In practice, snake captures at the site did not decline appreciably. Remarkably, 151 snakes were removed from a 1.4-hectare plot predicted to have a population of about 52 snakes. Capture success did not even decline significantly during the last days of the study. Had the plot been isolated by barriers or major habitat features, the number of captures necessary to achieve control would have been much less.

Clearly, a variety of tools and strategies are needed to protect endangered birds adequately from brown tree snakes. Hand capture, traps, barriers and yet-to-be-developed methods (such as toxicants and repellents, modification of prey bases and habitats supporting snake populations, and biological controls) must be considered together to achieve efficient and effective control of this voracious predator.

Gull Management in New York

The piping plover is listed as a threatened species on the U.S. Atlantic Coast and as an endangered species in the State of New York, with about 1,150 nesting pairs on the U.S. Atlantic Coast in 1995. At the Breezy Point Unit of the National Park Service's (NPS) Gateway National Recreation Area in New York, herring (*Larus argentatus*) and great black-backed gulls (*L. marinus*) may affect piping plover nesting by disrupting courtship, territory establishment, chick feeding activities, and by direct predation on adult plovers and chicks (USDA 1993). In a Biological Opinion issued in 1989, USFWS identified the control of gull nesting in plover nesting areas as one of several recommended procedures for the recovery of piping plovers. Also in 1989, the NPS completed an Environmental Assessment that concurred with the USFWS finding. Beginning in 1993, ADC and NPS have conducted a cooperative gull management program at Breezy Point to reduce gull impacts (USDA 1993).

Two-phase gull management programs have been conducted at Breezy Point each spring and summer, from 1993 through 1995. Intensive harassment of gulls during the period of nest establishment (March-April) is directed at deterring gulls away from the site to reduce nesting and, ultimately, cause the site to be abandoned as a gull nesting colony. Eliminating gull reproduction through physical destruction of nests and eggs (June-July) is directed at reducing gull numbers on the site throughout the summer and, eventually, eliminating the site as a gull nesting colony. During both phases of the gull management program, ADC and NPS personnel coordinated all work activities to reduce or eliminate potential negative impacts of gull management activities on piping plovers, terns and other wildlife species of special concern.

Gull harassment activities were conducted by ADC and NPS biologists from about mid-March through mid-May during all daylight hours. Pyrotechnics and distress calls were used to deter gulls from landing on the site. A total of 27,832 rounds of pyrotechnics (screamers, bangers, 12-gauge cracker shells) were expended during the three field seasons.

Gull nest and egg treatment activities were conducted by ADC and NPS biologists from early May through mid-July. In 1993, gull eggs were punctured and physically destroyed. In 1994 and 1995, puncturing was not used because it was more time consuming and did not reduce the amount of time gulls spent loafing on beaches near plovers (relative to physical destruction). A total of 4,243 eggs (4,112 herring gull eggs and 131 great black-backed gull eggs) were destroyed.

It is difficult to determine the effectiveness of the gull management program. After three years of harassment and egg/nest treatment, the Breezy Point gull colony continues to exist. Piping plover productivity (number of fledged chicks per adult pair) has declined dramatically since the early 1990s, although the number of pairs (15-18) has remained relatively constant. Plover nest distribution has changed, with more plover nests occurring farther from the gull colony site, but closer to areas of high human use. Impacts from gulls are only one type of factor affecting piping plover success on Breezy Point. Because the degree to which gulls impact plovers and the effectiveness of gull control on improving plover productivity are unknown, NPS is initiating a research project to quantify the impact of gull predation on nesting plovers. If it is determined by NPS and USFWS that gulls are having unacceptable effects on plovers and that elimination of the gull colony is desirable, ADC would recommend that the gull colony be reduced or eliminated with the toxicant DRC-1339.

Conclusions

Comprehensive and expensive efforts usually are needed to assist recovery of endangered avian species, but often are accompanied by substantial controversy. Predators are important components of ecosystems, and control programs justifiably receive careful scrutiny by the public, concerned parties, tribes and agencies. Each predator control effort must include a careful consideration of legal mandates and regulations, the situation and species involved, the various parties with vested interests, the resources available, and the likelihood and economic cost of success. Only substantial efforts to protect or restore habitats and predator management, where appropriate, likely will stem the listing and extinction rates for avian species in North America and worldwide.

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Managing Habitat to Enhance Avian Recruitment

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Nest success lower than the 15 to 20 percent threshold levels thought necessary for population maintenance in upland-nesting ducks has been documented across most of the prairie pothole and parkland Region (PPR) of the northcentral United States and southern Canada during the 1960s to 1980s (Cowardin et al. 1985, Greenwood et al. 1987, 1995, Klett et al. 1988, Fleskes and Klaas 1991). Predation is the primary proximate cause of nest loss: predators commonly destroy 70 to 90 percent of all nests. Nest success is highly variable, both spatially and temporally, but has declined substantially in the PPR over the past 50 years (Beauchamp et al. 1996). Unlike studies of nest success, aerial surveys of duck broods have been conducted annually in a defined sampling frame over the past 45 years. The average age of duck broods observed during these surveys has decreased (Pospahala et al. 1974, Reynolds 1987), a result expected if nest success has declined and renesting has become more common.

One hypothesis posed to explain declines in duck nest success is that anthropogenic influences have caused quantity and quality of nesting cover to decline, and densities of generalist nest predators (mainly mammals) to increase (Johnson and Sargeant 1977, Cowardin et al. 1983, Johnson et al. 1989, Sargeant et al. 1993). Fragmentation and degradation of habitat, in conjunction with anthropogenically altered predator communities, also appear to be important conservation issues in a wide variety of other avian taxa and endangered species (Wilcove 1985, Johnson and Temple 1986, Terborgh 1989, Vickery et al. 1992, Böhning-Gaese et al. 1993, Garrott et al. 1993, Robinson et al. 1995), although the substantial similarities across ecosystems and taxa commonly are overlooked (Ball et al. 1994). Attempts to improve nest success (i.e., reduce nest predation) of upland-nesting ducks by improving the quality (height and density) of nesting cover at a local scale commonly have failed. Clark and Nudds (1991) reviewed published sources and concluded that cover conditions at nest sites had little influence on nest success where mammalian nest predators were common. This conclusion challenges a rather vague but firmly entrenched notion that "good" nesting cover minimizes nest predation in ducks.

In this review, I examine geographic variation in nest success among upland-nesting ducks and attempt to relate patterns in that variation to landscape composition, specifically the proportion of the landscape made up of potential nesting habitat, and to other ecological factors. I also examine the implications for conservation practice. The emphasis is primarily on upland-nesting ducks, although I suggest that the implications may extend to migratory ground-nesting birds in general. Finally, I question a popular view that connectivity among resource patches always represents a conservation benefit.

Geographic Patterns in Nest Success

Nest success of upland-nesting ducks varies widely, both temporally and at fine spatial scales, apparently in relation to local differences in habitat conditions, moisture, predator communities and alternate prey (Byers 1974, Weller 1979, Johnson et al. 1989, Fleskes and Klaas 1991, Greenwood et al. 1995, Sovada et al. 1995). Nevertheless, broad scale patterns occur in nest success estimates generated during the 1960s to 1980s (Klett et al. 1988, Cowardin et al. 1988).

Generally, nest success appears to increase from east to west on the U.S. prairies (Figure 1); the pattern in Canada is less clear. Plausible explanatory factors include parallel decreases in proportion of land that is tilled annually, density of generalist mammalian nest predators, average annual precipitation, and potential height and density of nesting cover. Note that the factors are neither independent nor mutually exclusive and that the last two imply a relationship counter to commonly presumed patterns. Across the continental divide in the intermountain valleys, nest success varies from reasonably high to extremely low.

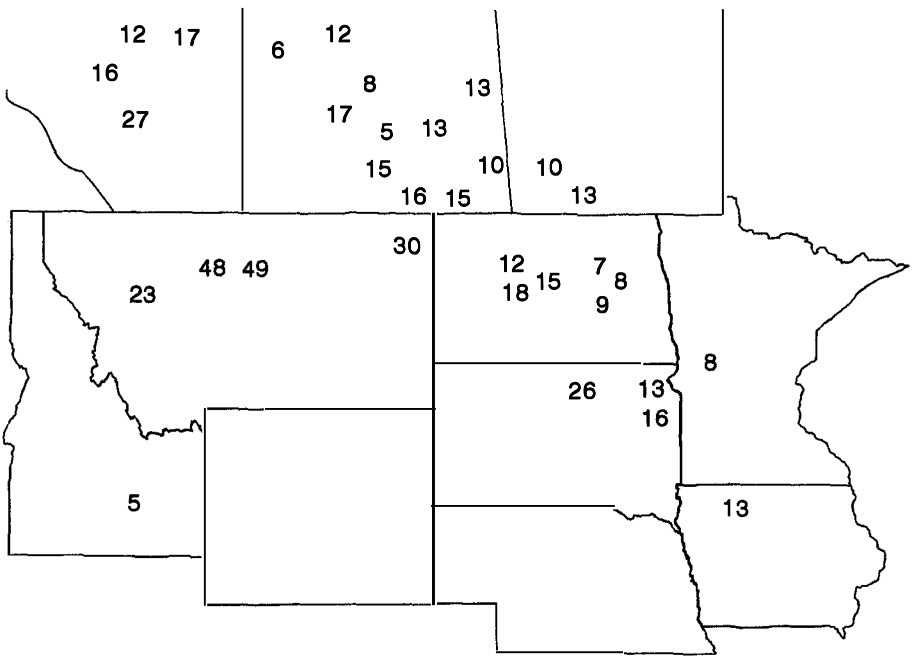

Figure 1. Geographic patterns in nest success of upland-nesting ducks during the 1960s through 1980s. Estimates for different species, years and adjacent study areas were averaged, thereby minimizing apparent variability. Data sources are: Iowa, Fleskes and Klaas (1991); North Dakota, South Dakota and Minnesota, Klett et al. (1988); Canada, Greenwood et al. (1995); Eastern Montana, Rabenberg (personal communication: 1996); Central Montana Holm (1984), Ball et al. (1995); Western Montana, Hall (1994); and Idaho, Gazda (1994). All figures are percentage nest success (Mayfield estimates) except for the 48 in Montana, which is based on broods per 100 pairs. The latter approximates nest success if broods lost prior to survey balance broods produced by renesting.

Nest Success Relative to Landscape Composition

Duck nest success does not appear to vary predictably in relation to field or patch size (Clark and Nudds 1991, Higgins et al. 1992, Gilbert et al. 1996), although little information is available for reasonably large fields (say, >260 ha). Much of the PPR, where most studies of duck nest success have been conducted, is highly fragmented by tillage agriculture (generally, 40 to 90 percent of the land base is tilled annually), and few large fields exist. However, Greenwood et al.

(1987, 1995) documented that duck nest success on the Canadian prairies was positively correlated with the proportion of 26-square kilometer study areas in potential nesting cover (i.e., negatively correlated with the proportion cultivated). Nest success declined about 4 percentage points for each 10 percentage points increase in cropland. Also, ducks on large tracts of essentially unfragmented grasslands in northcentral Montana were remarkably productive (Holm 1984, Ball et al. 1995). Similar patterns have been noted among songbirds in the Midwest, where rates of nest predation and brood parasitism were negatively correlated with the proportion of landscape forested (Robinson et al. 1995).

Overall, the pattern of decreasing duck nest success with increasing proportion of landscape cultivated seems reasonably convincing (Figure 2), although diverse interpretations are plausible. The simplest is that nesting ducks and their predators are concentrated in the remaining nesting cover and the efficiency of the predators is thereby enhanced. This scenario is intuitively pleasing in its simplicity, but considerable evidence shows the situation to be anything but simple.

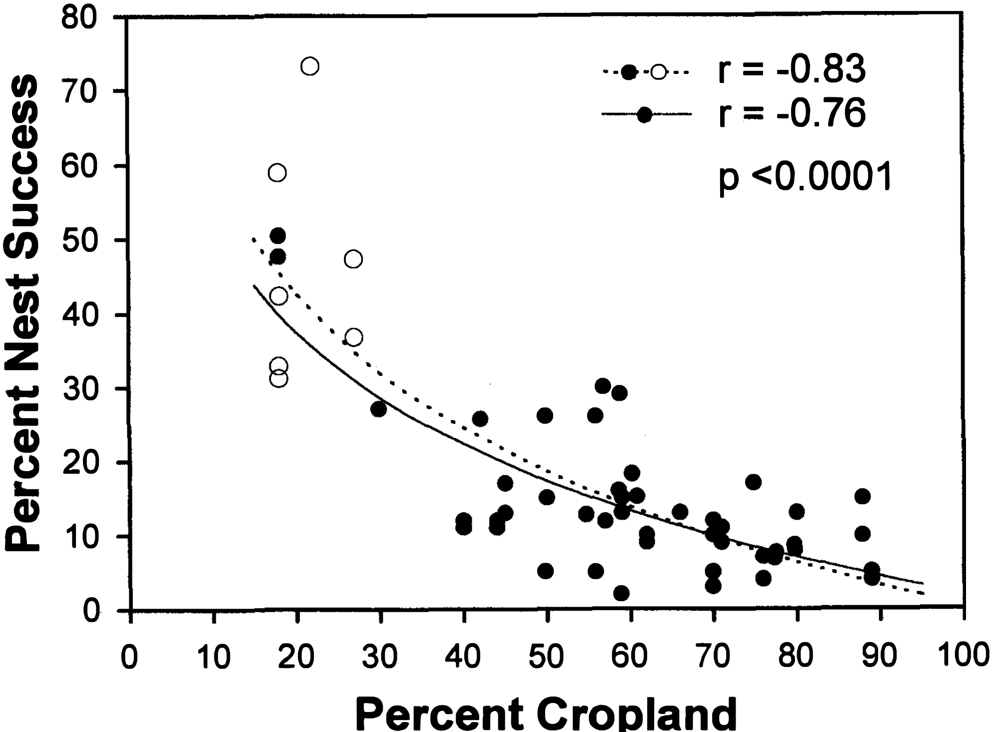

Figure 2. Nest success of upland-nesting ducks in and adjacent to the PPR during the 1960s through 1980s relative to landscape composition. Assessment scale for landscape composition was ≥26 kilometers in all cases. Estimates of nest success for different species were averaged, but variation among estimates for different time periods or adjacent study areas is shown. Data sources are: Holm (1984), Klett et al. (1988), Fleskes and Klaas (1991), Ball et al. (1995), Greenwood et al. (1995) and Rabenberg (personal communication: 1996). Solid symbols represent Mayfield estimates of nest success. Open symbols represent broods per 100 pairs, which approximates nest success if broods lost prior to survey balance broods produced by renesting. Curves represent regressions of nest success on natural log of percentage cropland. The solid curve is based on Mayfield estimates only, and the dotted curve is based on both Mayfield estimates and broods per 100 pairs.

For instance, anthropogenic changes in predator communities may cause major changes in nest success (Sovada et al. 1995), and these changes are, to some extent, independent of habitat conditions. Hence, the pattern shown in Figure 2 could derive from elements that are relatively direct (habitat ⇛ predation rate or habitat ⇛ nest density ⇛ predation rate), indirect (habitat ⇛ alternate prey ⇛ predation rate or habitat ⇛ predator populations/communities ⇛ predation rate), or some combination thereof. Furthermore, an apparent habitat ⇛ predator link could be direct or indirect (a high proportion of landscape cultivated could, in and of itself, be irrelevant to coyotes [*Canis latrans*] but expose them to high mortality inflicted by humans and, hence, result in a landscape populated by red fox [*Vulpes vulpes*] [see Johnson et al. 1989, Sargeant et al. 1993, Sovada et al. 1995]).

Managing Habitat to Minimize Nest Predation

Given the apparently strong relationship between landscape composition and nest success (Figure 2), restoration of grassland habitat at an appropriate scale (and, of course, working diligently to protect the few large tracts of relatively intact grassland systems that remain) seems to offer considerable promise. One of the most important gaps in the ecological knowledge necessary to pursue this option is that we do not know the appropriate configuration and scale at which restoration should proceed (Clark and Nudds 1991, Clark and Diamond 1993). Although much of the discussion on this issue has focussed on patch size, landscape composition in potential nesting habitat (i.e., 1 minus percent annually tilled), when addressed at an appropriately large scale (perhaps 40-65 km2) may be a more appropriate metric. Grassland systems are highly heterogenous, contrary to our common perception of them, and defining a patch becomes highly problematic. Is a shrub clump, sparsely vegetated ridge, heavily vegetated low prairie zone or heavily grazed area part of the patch in which it occurs, or is it a patch in and of itself? What anthropgenic features should be judged sufficient to divide patches: a fence line, a trail, an unsurfaced "two track" road, a gravel road or an interstate highway? Our ability to detect biological patterns is strongly influenced by the scale of assessment (Wiens et al. 1987). Individual coyotes may move over areas of up to 65 square kilometers (Johnson and Sargeant 1977), and the effect of landscape composition on the predator community and foraging strategies is certain to be a key issue.

Thus far, this paper has focused on restoring grassland habitat to increase duck nest success. Equally important, however, is the question of selecting management practices from among many options to optimize efficiency in a particular situation. Management practices can be categorized as those meant to increase nest success where it is low and those meant to attract pairs to settle where existing landscape conditions and predator communities promote high nest success (Cowardin et al. 1988). Restoring or creating wetlands in relatively intact grassland systems with high nest success can be expected to cause a net increase in nest success on a continental basis. Cowardin et al. (1988) and Reynolds et al. (1996) provide objective systems for developing and evaluating management prescriptions.

Is Habitat Management Ever Counterproductive?

I have argued here that nest success tends to vary with landscape-level habitat composition, predator communities and other ecological factors. However, settling patterns of breeding ducks are strongly influenced by distribution of surface water in spring (Johnson and Grier 1988), which may vary on a local scale and can, in some situations, be influenced by management. Just as creating or restoring wetlands in intact systems can result in increased nest success overall, doing so in badly degraded systems can cause an overall decrease. This does not mean that wetland restoration in highly degraded systems is inappropriate; clearly, though, it should not be sold to the public (or worse yet, to ourselves) as being "good" for ducks. The extent to which it is "good" for other species of wetland birds is unknown, and the question is not trivial.

Breeding ducks exist at low overall densities, but high densities per unit of wetland surface area, on relatively intact grassland tracts on the western prairies and plains, and they are remarkably successful at producing broods (Ball et al. 1995). Nesting cover in this region tends to be sparse and low, but widely dispersed nests, in conjunction with low density and diversity of predator communities, allow high productivity. Virtually all of these lands are heavily grazed by livestock, and improving cover at a broad scale through an 8,000-hectare rest-rotation grazing system appeared to increase densities of both pairs and broods (Gjersing 1975, Mundinger 1976). Conversely, nest success in small (4-25 ha) patches of dense nesting cover was less than half that in immediately adjacent, large tracts of native range (Holm 1984). The cause of this difference was unknown, but presumably included the concentration of duck nests and predators in a relatively small area. Like restoring or creating wetlands, "improving" nesting cover does not always improve nest success for ducks.

Is It Good to Have Connections?

The idea that connectivity among habitat patches often is critical has been based on the equilibrium theory of island biogeography (MacArthur and Wilson 1967) and the metapopulation paradigm (Levins 1970); it has given rise to the notion that establishing or maintaining corridors between habitat patches represent essential conservation practice. The term corridor has been used in a multitude of senses, purposes commonly are ill-defined, and empirical evidence supporting effectiveness and potential benefits is largely lacking (Simberloff et al. 1992). Nonetheless, corridors have become immensely popular (see Chadwick 1990, Mann and Plummer 1993, 1995). This popularity has given rise to proposals for implementation, varying in scale from small, site-specific linkages to a grand scheme linking remaining undeveloped areas across hundreds of kilometers (Mann and Plummer 1993). Corridors could allow for genetic interchange within a metapopulation, for recolonization following periodic extinctions and for increased access to resources in wide-ranging species (Noss 1987, Soulé and Gilpin 1991, Mann and Plummer 1995). Possible biological costs of corridors are that they could promote the spread of disease, competitors or predators (Simberloff and Cox 1987, Simberloff et al. 1992). Furthermore, if corridors eventually prove to be unnecessary, ineffective or counterproductive, but have been implemented in lieu of effective alternatives, then costs may be high in terms of scarce conservation funds, conservation opportunity and scientific credibility (see Mann and Plummer 1995).

Potential connectivity within a landscape varies among habitat types and among the wildlife species being considered (Taylor et al. 1993, Petit et al. 1995). Given that migratory birds commonly cross hundreds if not thousands of kilometers of inhospitable (in some situations, lethal) habitat and that they seem quite adept at finding and occupying isolated tracts of potential breeding habitat (see Terborgh 1989), I suggest that connectivity in general, and corridors in particular, are likely to have little if any direct benefit to breeding migratory birds. This does not, however, rule out the possibility that corridors could have indirect benefits by allowing a particular tract of potential breeding habitat to be occupied by relatively large predators, thereby reducing threats of nest predation by smaller predators (Johnson and Sargeant 1977, Sargeant 1982, Sargeant et al. 1984, Wilcove 1985, Sargeant et al. 1987, Soulé et al. 1988, Johnson et al. 1989, Sargeant and Allen 1989, Sargeant et al. 1993, Palomares et al. 1995, Sovada et al. 1995).

Consider a hypothetical but plausible scenario involving a decision about acquisition and placement of conservation areas with a primary goal of providing breeding habitat for upland-nesting ducks and other ground-nesting migratory birds. Given current landscape conditions across much of the North American prairies and plains, the areas will exist essentially as islands in a sea of intensive tillage agriculture. Strategy one calls for situating two or more units along a major riparian zone (the primary natural linear feature in grassland systems and, hence, the most likely natural corridor). Strategy two calls for situating the same number of units, of the same size, at the same distance apart; the only difference would be that the units would be located away from riparian zones and, hence, would be totally isolated by anthropogenically altered habitat rather than being connected by corridors of natural vegetation. Presume for the sake of argument that cost per unit area is equal. Which of the two strategies would be most likely to meet objectives by providing "source" (Pulliam 1988) breeding habitat? The answer is unknown, of course, but the potential advantages of connectivity in this specific example seem equivocal at best. Nest predation certainly would be a primary determinant of ultimate success or failure of the conservation effort (Klett et al. 1988, Martin 1992, Greenwood et al. 1995). Neither gray wolves (*Canis lupus*) nor coyotes (*Canis latrans*), the two major predator species that could help to minimize the effects of smaller, human-subsidized nest predators in grassland systems, appear to be directly sensitive to anthropogenic alteration of habitat (Sargeant et al. 1993, Mech 1995, Sovada et al. 1995). Hence, riparian corridors (or *any* corridors, for that matter) likely would be more beneficial to smaller generalist predators, such as striped skunks (*Mephitis mephitis*) and raccoons (*Procyon lotor*), than to larger carnivores. If so, then the disadvantages associated with riparian corridors could far exceed any advantages to ground-nesting migratory birds. Riparian areas often are diverse and obviously warrant protection for their own value as wildlife habitat (Knopf et al. 1988). Nevertheless, uncritical application of the virtually untested idea that corridors are essential does not represent progress in conservation practice.

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Altering Predator Foraging Behavior to Reduce Predation of Ground-nesting Birds

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Nesting success of many ground-nesting birds often is estimated to be lower than rates required for population stability (e.g., Klett et al. 1988, Reynolds et al. 1988, Johnson and Temple 1990, Greenwood et al. 1995), leading to much debate about causes and remedies. Because nesting success sometimes is higher on areas where predators have been removed, there is interest in determining which predator removal technique is most cost-effective (Greenwood et al. 1990, Sargeant et al. 1995, Beauchamp et al. 1996, Garrettson et al. 1996). However, killing predators may be vigorously opposed on the basis of ethical or ecological arguments (Kellert 1985, Decker et al. 1991, Goodrich and Buskirk 1995), even if effective. Thus, considerable effort has been expended to find ways of alleviating predation using techniques which are believed to be more socially acceptable than killing predators.

Here we briefly review biological concepts underlying several nonlethal methods of altering predator foraging behavior and then evaluate results of field tests whenever possible. We postulate that the success of most techniques will be influenced by variations in predator community structure and availability of alternate prey, factors which have received little attention and experimental testing, yet, ones that might be manipulated advantageously by habitat management alone.

Using Natural and Synthetic Odors to Repel Predators

Several experimental studies have demonstrated that urinary and fecal odors of predators effectively repel their prey, suggesting that aversive compounds might be used to control damage to vegetation by herbivores (reviews by Nolte et al. 1994, Epple et al. 1995). On the other hand, it has not been determined conclusively whether odors of larger predators (e.g., wolf [*Canis lupus*], coyote [*Canis latrans*]) might repel mid-sized predators (e.g., red fox [*Vulpes vulpes*], raccoon [*Procyon lotor*], skunk [*Mephitis mephitis*]) from managed areas, even though this idea seems plausible (Macdonald 1985, Sargeant et al. 1987). Distributing coyote odors might lower nest predation in areas dominated by foxes (see Sovada et al. 1995), but problems could arise if these

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odors attract conspecifics and consequently elevate predation rates. Nonetheless, the hypothesis that odors of large canids could enhance breeding success of gamebirds by repelling smaller predators from specific areas has not been evaluated.

Another possibility is to apply odors to impair predator olfaction ability, lowering predation on nesting birds and their eggs or offspring. For instance, Whelan et al. (1994) lowered predation of artificial songbird nests by olfactory-searching predators using commercial deer scent and scent shield. However, using naphthalene or other chemicals during nest visits did not lower predation on nests of red-winged blackbirds (*Agelaius phoeniceus*) (Gawlik et al. 1988) or on simulated duck nests (Hammond and Forward 1956), although each test lacked power to detect effects. A more appealing technique would involve planting mixes of aromatic vegetation, preferably composed of native plants, to block predator olfaction, but, to our knowledge, this idea has not been investigated.

Conditioned Taste Aversion

In nature, many predators exhibit learned avoidance of noxious prey, as well as potential prey that resemble noxious species (Estabrook and Jespersen 1974, Endler 1991). This natural phenomenon provided the conceptual framework for the development of conditioned-taste-aversion (CTA) (Avery 1985, Nicolaus 1987). CTA is a behavioral paradigm in which predators avoid harmless prey that mimic noxious prey; mimics are avoided after the predator is exposed to a noxious model inducing gastrointestinal illness (Nicolaus et al. 1983). In the context of predator control, some workers have suggested that conditioning predators to avoid eggs may be a potent and socially acceptable method of reducing losses to predation (Nicolaus et al. 1982, 1989a, 1989c, 1992, Conover 1990, Dimmick and Nicolaus 1990, Semel and Nicolaus 1992, Avery and Decker 1994).

Since the 1950s, research on aversion conditioning has been extensive (see Riley and Tuck 1985). Although initial taste-aversion research was conducted primarily on laboratory rats, the prevalence of mimicry and aposematism (e.g., warning coloration) in nature (Endler 1991) suggested that CTA might be applied to a variety of predators (Gustavson and Nicolaus 1987, Nicolaus et al. 1992). Early tests used lithium chloride as the aversive agent placed in baits (coyotes, Olsen and Lehner 1978, Burns and Connolly 1980, Gustavson and Nicolaus 1987; raccoons, Nicolaus et al 1982; waterfowl predators, Sheaffer 1982). Generally, results were inconclusive, probably because lithium chloride has a salty flavor, whereas effective CTA-inducing emetics must not be detected by consumers.

With appropriate aversive agents, CTA can be induced in a wide variety of animals. Carbachol (carbamylcholine chloride) is a superior aversion agent (particularly for birds) (Nicolaus et al. 1989b), because it is water soluble, colorless, odorless and difficult to detect in small doses (Dimmick and Nicolaus 1990). However, mammals are able to detect it at dose levels required to induce illness (Nicolaus and Nellis 1987). Attention recently has focused on oral estrogen (17 - α ethinyl estradiol) as an effective CTA agent in mammals (Gustavson et al. 1989, Semel and Nicolaus 1992). In field trials with estrogen, taste-aversions reportedly were established among egg-eating mammalian predators, including raccoons (Semel and Nicolaus 1992), skunks, opossums (*Didelphis virginiana*), red foxes, badgers (*Taxidea taxus*) and coyotes (Nicolaus et al. 1989c). However, consumption of chicken eggs was used as a post-treatment measure of effectiveness, and protection for natural nests remained speculative.

Because earlier studies had not adequately evaluated the efficacy of conditioned taste aversion (CTA) in reducing egg predation at natural nests, Guyn (1994) and Penner (1995) conducted field experiments to test whether CTA might be generalized to protect eggs in natural duck nests. In the first experiment (1991-1992), American crows (*Corvus brachyrhynchos*) and mammals were given eggs treated with the illness-inducing compounds carbachol and estrogen, respectively. Egg consumption subsequently decreased or ceased at egg-baits located near crow nests, but not at egg-baits for mammals. Hatching success of natural duck nests was not higher on sites where predators were treated when compared with controls. Likewise, in 1991, survival of simulated nests on crow treatment sites did not differ from controls. By contrast, in 1992, survival of simulated nests was higher on treatments than controls: (1) early in the year on sites where both crows and mammals were treated; and (2) again, later that year, on all treatments. Although we followed guidelines established from earlier research, results from this initial study provided little support for the notion that CTA is generalized to protect natural nests.

The second set of field trials, conducted in 1993 and 1994, further examined whether CTA would reduce mammalian predation of duck eggs. Survival of artificial and natural duck nests was compared between plots where predators were allowed to consume chicken eggs containing estrogen and plots where no such treatment was applied. Eight matched sets of treatment and control plots were monitored.

Overall, no difference in survival of either simulated or natural duck eggs could be detected when comparisons were made between control and treatment plots. Reasons for the apparent lack of effect provided by CTA remain equivocal, but may have included: (1) a predator community too large, diverse and dynamic to be effectively conditioned; (2) use of an aversive agent that was not noxious to all predators; (3) species-specific differences in the ability to learn and retain CTA; or (4) the inability of CTA to overcome certain innate behaviors. During 1994, additional work with captive predators revealed that the aversive agent used in field trials (ethinyl estradiol) may not be equally effective or safe with all mammalian predator species.

Although tests of CTA have produced mixed results (e.g., Semel and Nicolaus 1992, Guyn 1994, Penner 1995), it may prove to be an effective predator management technique within limited parameters. However, a safe and effective aversion agent must be developed. Furthermore, effective application will, in all likelihood, be restricted to relatively small plots with a predator community consisting of only a few species. The effectiveness of CTA in such applications requires testing.

Diversionary Feeding of Predators

Experimental testing of this idea is limited. Crabtree and Wolfe (1988) were able to lower skunk predation of duck nests by providing alternate foods early in the nesting season when natural foods were least abundant. Effectiveness of feeding diminished later in the nesting season, possibly because natural foods became more plentiful. An experimental study has just been completed to evaluate whether nest predation could be reduced by feeding skunks (R. J. Greenwood personal communication: 1995).

Diversionary feeding of bears (*Ursus* spp.) and wolves was evaluated in Alaska to determine whether moose and caribou populations would increase (Boertje et al. 1991). Preliminary results appeared promising, but, apparently, the method has not been adequately evaluated (Gasaway et al. 1992). We reviewed issues of The Wildlife Society's publications (Journal, Bulletin, Monographs and Transactions) for the period 1991 through 1995, but found no further accounts of diversionary feeding of predators. New studies may have been completed but not yet published in these sources.

Some avian predators (e.g., corvids [*Corvus* spp.], gulls [*Larus* spp.]) can be attracted easily to sites baited with food (e.g., dumps, carcasses), so it may be possible to divert them from specific areas managed for wildlife. Whether this can be done efficaciously with either birds or mammals remains uncertain. Increasing productivity, survival and population size of predators is one potential drawback of feeding.

Vegetation Management to Hinder Predator Movement, Smell and Vision

Thick cover might impede predator movements, limit detection of odors, and conceal females and eggs from visual predators, such as corvids and birds of prey. If movements of predators or odors are altered, we might expect nest success to be greater in habitat interior compared with edge. This prediction was supported with artificial duck nests in dense nesting cover (Pasitschniak-Arts and Messier 1995) and with artifical ground nests on remnant tracts of grassland (Burger et al. 1994), but not with natural duck nests (R.G. Clark unpublished data).

Bowman and Harris (1980) found that foraging efficiency of captive raccoons was poorer in areas of spatially heterogeneous vegetation, but, unfortunately, we found no similar follow-up studies. Crabtree et al. (1989) reported higher survival for gadwall (*Anas strepera*) nests placed in heterogeneous cover, a pattern found in some songbird studies (Martin 1991). Finally, some evidence is consistent with the hypothesis that dense vegetation protects ground nests from aerial predators (Clark and Nudds 1991).

Habitat Manipulations

Ball (1996) has evaluated several hypotheses and evidence concerning habitat management for enhancing avian breeding success. Reducing insularity of perennial cover (e.g., few large areas or many small ones placed close together) might enable gamebirds to disperse nests or otherwise optimize habitat choices and thereby evade predators (Clark and Nudds 1991). However, none of these hypotheses have been tested (Clark and Diamond 1993). Current work on Conservation Reserve Program areas (Reynolds et al. 1996, R. J. Greenwood personal communication: 1996, B. Batt personal communication: 1996) and on the Canadian prairies (Sankowski et al. 1995) should provide important insights concerning these ideas.

Compared with predator management involving removal or chemical controls, advantages of habitat restoration include: (1) low maintenance; (2) income to landowners; (3) benefits to a wide range of species other than gamebirds; and (4) conservation of soil and water resources. These benefits must be incorporated into cost-benefit analyses of management alternatives, including predator removal.

Role of Alternate Prey

Factors responsible for spatio-temporal variation in nesting success of gamebirds include weather, wetland conditions, nesting habitat features, structure of predator communities and abundance of alternate prey. Of these, abundance of alternate prey has received the least evaluation even though it was identified as being potentially important more than 20 years ago (Byers 1974, Weller 1979). The "alternate prey hypothesis" (APH) predicts that, other things being equal, nesting success will be greater when alternate prey are abundant. With other species and ecosystems, this relationship was proposed earlier (e.g., Darrow 1945, Larson 1960). Several studies have found a positive correlation between breeding success of ground-nesting birds and abundance of small rodents (Pehrsson 1986, Summers 1986, Summers and Underhill 1987, Sutherland 1988, Marcström et al. 1988, Ebbinge 1989, Syroechkovskiy et al. 1991, Underhill et al. 1993), although Stickney (1991) found no relationship.

Predation on females and eggs of upland-nesting ducks may be severe (Klett et al. 1988, Johnson et al. 1989, Greenwood et al. 1995); nevertheless, many of the predators inhabiting the prairie pothole region are generalists, preying on a wide variety of foods (Novak et al. 1987, Sargeant et al. 1993). Thus, the APH may account for much spatio-temporal variation in waterfowl breeding success (Klett et al. 1988, Johnson et al. 1989) and success of other birds (e.g., Marcström et al. 1988).

Conclusions

Although some methods explored seem extremely promising, our initial review revealed remarkably few field tests. This may be due to disinterest or because studies with disappointing results have not been published. It also is possible that many researchers and managers believe that lethal methods are the only viable options to effectively increase gamebird productivity.

Conditioned taste aversion might be useful for protecting eggs of target species when the predator community is relatively simple. However, in the case of mammals, we caution that some forms of estrogen may not be used safely or effectively. Furthermore, implementation of predator control (e.g., chemical, removal) likely will be site-specific, small-scale and have only limited spin-off benefits. In sharp contrast, benefits of vegetation management may be manifold.

Unfortunately, in most cases, testing the alternate prey hypothesis is hindered by a lack of data on the abundance of alternate prey, such as insects and microtines, but it remains important to evaluate whether gamebird production is related to abundance of alternate prey. For example, little is known about terrestrial food webs on the prairies, yet, changes in populations of ducks may be influenced as strongly by variations in alternate prey as by factors such as wetland numbers that traditionally have been examined. Currently, we do not fully understand how abundance of alternate prey is affected by variations in landscape pattern or habitat restoration, but we feel that this is an important topic for future research. Likewise, it is unclear whether efficacy of predator removal or chemical control (e.g., CTA) is mediated by availability of alternate foods. Answers to these questions should help to improve decision making concerning predation management.

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Special Session 2. *Conservation Potpourri*

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Characteristics of Eastern South Dakota Wetland Basins and Implications of Changes in Jurisdictional Wetland Definitions

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Hydrology, soils and vegetation currently are used to identify jurisdictional wetlands under the 1987 Corps of Engineers Wetlands Delineation Manual. Areas that are saturated or inundated during the growing season and that have evidence of hydric soils and vegetation are classified as wetlands. The Wetland Conservation Subtitle ("Swampbuster") of the Food Security Act of 1985 and the Food and Agriculture Trade Act of 1990 is the principle source of protection for wetlands in the U.S. prairie pothole region (PPR) where row crop and small grain agriculture is a primary land use. In 1994, 86 percent of South Dakota farmers received federal assistance through U.S. Department of Agriculture (USDA) farm programs (N. Kapple, USDA Farm Service Agency (FSA), personal communication: 1995). Landowners that receive subsidies from USDA programs may lose a portion of their benefits if they are determined to have illegally converted (e.g., drained) a wetland, regardless of its size or water regime.

Reaction to "Swampbuster" legislation by the agricultural community generally has been negative. Changes to definitions of jurisdictional wetlands have been proposed due to controversy concerning government regulation of private property use. The intent of proposed revisions is to eliminate protection for small wetland basins and basins that are temporarily flooded, which may impede farming or other anthropogenic landscape modifications. Proposed revisions to "Swampbuster" in the U.S. Senate (S.B. 1373) and House of Representatives (H.B. 2542) would eliminate protection for basins 1 acre (0.4 ha) or smaller in size, and for larger basins that are "frequently cropped." Proposed revisions may reflect public misperceptions of what landscape features can legitimately be called wetlands, and a lack of appreciation for the functions and values of small and temporary wetland basins. In this paper, the phrase "wetland basin" is used to indicate a surface depression in which one or more wetlands occur (Cowardin et al. 1979, Cowardin 1982).

Knowledge of the size structure and distribution of wetland basins in the PPR is improving through the use of digital National Wetlands Inventory maps. Wetland basins in the PPR that are 1 acre or smaller in size are estimated to comprise 78 percent (Wildlife Management Institute 1995) to 79 percent (Robinson 1995) of all basins. However, the magnitude of the threat to wetland resources if proposed "Swampbuster" revisions are enacted is poorly understood. We believe that surrounding land use and protection by government easement or fee-title acquisition, as well as size, influence the probability that a wetland basin will be drained. Our objective was to evaluate relationships between land use, basin protection by U.S. Fish and Wildlife Service (USFWS) easement or fee-title acquisitions, and basin size, and to estimate the number and area of wetland basins in the PPR of eastern South Dakota that are at significant risk of drainage if proposed "Swampbuster" revisions are enacted.

Methods

We determined the area, surrounding land use and protection status of wetland basins in Section 22 of 135 randomly selected townships in the Central Lowlands, Prairie Coteau and Missouri Coteau physiographic regions of eastern South Dakota. Sampling rate was 0.4 percent of the total landscape. Wetlands delineated by the National Wetlands Inventory were converted to wetland basins in a geographic information system (GIS) using techniques described by Johnson (1995). Wetland basins were classified by the most permanent wetland water regime within them. Area of each basin was determined using the GIS. Temporary, seasonal and semipermanent wetland basins completely or partially within sample plots were recorded.

Land use was categorized as cropped (annually or periodically tilled, including sites idled under the Conservation Reserve Program) or perennial grassland (no history of tillage) from FSA aerial photography. Wetland basins completely or partially in building sites were assigned to the cropped category because these basins have a high potential for drainage. Basins completely or partially surrounded by cropland were assigned to the cropped land-use category. Wetland basins completely within tracts of pasture or prairie were assigned to the perennial grassland land-use category. USFWS wetland easements and Waterfowl Production Areas (WPAs) were digitized to determine wetland basins which were protected from drainage. A wetland basin was deemed protected only when it lay completely within an easement or WPA, because drainage of basins partially under easement seldom is successfully contested by the USFWS (C. Madsen, USFWS, personal communication: 1996).

We calculated percentages of the number and area of basins by size class for land-use and protection categories. We also calculated percentages of basins by water regime at high risk for drainage as the number or area of cropped, unprotected basins by size class divided by the total number or area of basins of that water regime. These percentages were used to project potential drainage losses. Nonparametric 95-percent confidence intervals (CI) were assigned to basin sizes, and non-overlapping confidence intervals were assumed to represent a significant difference. Size structure of basins we evaluated may include a bias for larger basins because basins that fell partially within sample plots were included in analyses. Therefore, our percentages represent a conservative estimate of the number and area of basins that may be lost if proposed jurisdictional changes occur.

Results

Of the 3,199 wetland basins evaluated, 70 percent (2,222) were temporary basins, 26 percent (843) were seasonal basins and 4 percent (134) were semipermanent basins (Table 1). Approximately 10,000 acres (4,046 ha) of wetland basins were evaluated. Of the total area, 17 percent (1,692 acres: 685 ha) were temporary basins, 19 percent (1,949 acres: 789 ha) were seasonal basins and 64 percent (6,356 acres: 2,572 ha) were in semipermanent basins (Table 1).

Of all wetland basins evaluated, 70 percent (2,234), comprising 65 percent of total basin area (6,523 acres: 2,640 ha) were in the cropped land-use category. These included 77 percent (1,703) of temporary basins and 76 percent (1,283 acres: 519 ha) of temporary basin area, 54 percent (457) of seasonal basins and 55 percent (1,073 acres: 434 ha) of seasonal basin area, and 55 percent (74) of semipermanent basins and 66 percent (4,167 acres: 1,687 ha) of semipermanent basin area (Table 2).

Table 1. Size structure of all temporary, seasonal and semipermanent wetland basins.

	0-0.5	>0.5-1.0	>1.0-2.0	>2.0-5.0	>5.0-10.0	>10.0	Total
Temporary							
Number	1,475	358	223	124	32	10	2,222
Percentage	66.4	16.1	10.0	5.6	1.4	0.4	100.0
Area in acres	293.1	252.8	313.1	374.4	216.2	242.2	1,691.6
Percentage	17.3	14.9	18.5	22.1	12.8	14.3	100.0
Seasonal							
Number	318	148	146	142	55	34	843
Percentage	37.7	17.6	17.3	16.8	6.5	4.0	100.0
Area in acres	74.4	110.0	208.8	450.2	367.2	737.6	1,948.6
Percentage	3.8	5.6	10.7	23.1	18.8	37.9	100.0
Semipermanent							
Number	14	14	11	37	22	37	134
Percentage	10.4	10.4	8.2	27.6	16.4	27.6	100.0
Area in acres	4.7	9.4	16.6	118.4	159.1	6,053.0	6,356.2
Percentage	0.1	0.1	0.2	2.0	2.5	95.2	100.0

Table 2. Size structure of temporary, seasonal and semipermanent wetland basins with cropped land-use classification.

	0-0.5	>0.5-1.0	>1.0-2.0	>2.0-5.0	>5.0-10.0	>10.0	Total
Temporary							
Number	1,114	286	176	98	22	7	1,703
Percentage	65.4	16.8	10.3	5.8	1.3	0.4	100.0
Area in acres	232.3	201.9	245.1	51.9	152.0	152.7	1,283.2
Percentage	18.1	15.7	19.1	23.3	11.8	11.9	100.0
Seasonal							
Number	147	77	94	80	39	20	457
Percentage	32.2	16.8	20.5	17.5	8.5	4.4	100.0
Area in acres	36.8	56.8	134.7	251.1	261.4	332.1	1,072.9
Percentage	3.4	5.3	12.6	23.3	24.4	31.0	100.0
Semipermanent							
Number	5	6	7	25	14	18	74
Percentage	6.7	8.1	9.5	33.8	18.9	24.3	100.0
Area in acres	1.5	4.0	11.4	79.8	99.1	3,976.6	4,167.3
Percentage		0.1	0.3	1.9	2.4	95.4	100.0

Of all wetland basins evaluated, 24 percent (761), comprising 12 percent (1,224 acres: 495 ha) of total basin area, was protected by USFWS easement or fee-title acquisition. These included 21 percent (470) of temporary basins and 22 percent (370 acres: 150 ha) of temporary basin area, 31 percent (262) of seasonal basins and 30 percent (584 acres: 236 ha) of seasonal basin area, and 22 percent (29) of semipermanent basins and 4 percent (271 acres: 110 ha) of semipermanent basin area (Table 3). The small percentage of semipermanent basin area protected by USFWS easement or fee-title acquisition was due to their relatively large size and our exclusion of basins from the protected category when they were only partially encompassed by easements.

Of all wetland basins evaluated, 56 percent (1,803), comprising 60 percent (5,986 acres: 2,422 ha) of total basin area, was categorized as having both cropped land use and unprotected status. These included 63 percent (1,398) of temporary basins and 66 percent (1,118 acres: 452 ha)

Table 3. Size structure of all temporary, seasonal and semipermanent wetland basins protected by USFWS easement or fee-title acquisition.

	0-0.5	>0.5-1.0	>1.0-2.0	>2.0-5.0	>5.0-10.0	>10.0	Total
Temporary							
Number	325	76	45	14	6	4	470
Percentage	69.1	16.2	9.6	3.0	1.3	0.9	100.0
Area in acres	60.3	52.9	63.3	46.2	41.0	106.5	369.7
Percentage	16.3	14.3	17.1	12.5	11.1	28.8	100.0
Seasonal							
Number	81	46	47	59	22	7	262
Percentage	30.9	17.6	17.9	22.5	8.4	2.7	100.0
Area in acres	18.8	33.6	67.2	194.2	150.5	119.1	583.7
Percentage	3.2	5.8	11.5	33.2	25.8	20.4	100.0
Semipermanent							
Number	1	6	2	6	10	4	29
Percentage	3.4	20.7	6.9	20.7	34.5	13.8	100.0
Area in acres	0.2	4.0	2.7	16.8	70.9	176.2	270.8
Percentage	0.1	1.4	1.0	6.2	26.2	65.1	100.0

Table 4. Size structure of temporary, seasonal and semipermanent wetland basins unprotected by USFWS easement or fee-title acquisition and with cropped land-use classification.

	0-0.5	>0.5-1.0	>1.0-2.0	>2.0-5.0	>5.0-10.0	>10.0	Total
Temporary							
Number	893	238	151	89	21	6	1,398
Percentage	63.9	17.0	10.8	6.4	1.5	0.4	100.0
Area in acres	188.3	168.3	211.3	267.9	146.5	135.7	1,117.6
Percentage	16.8	15.1	18.9	24.0	13.1	12.1	100.0
Seasonal							
Number	119	54	70	58	28	15	344
Percentage	34.6	15.7	20.3	16.8	8.1	4.4	100.0
Area in acres	29.4	40.5	100.8	181.9	187.1	251.3	791.0
Percentage	3.7	5.1	12.7	23.0	23.6	31.8	100.0
Semipermanent							
Number	4	5	7	22	7	17	61
Percentage	6.5	8.2	11.5	36.0	11.5	27.9	100.0
Area in acres	1.2	3.2	11.4	70.4	49.2	3,946.4	4,076.9
Percentage		0.1	0.3	1.7	1.2	96.8	100.0

of temporary basin area, 41 percent (334) of seasonal basins and 41 percent (791 acres: 320 ha) of seasonal basin area, and 46 percent (61) of semipermanent basins and 64 percent (4,077 acres: 1,650 ha) of semipermanent basin area (Table 4). We assumed that unprotected wetland basins in cropland are at the greatest risk for drainage if proposed regulatory changes are enacted because landowners may perceive that they will receive an economic benefit from draining and farming basins in cropland, or that they are a hinderance to field operations (Leitch 1989).

Of the total sample of wetland basins evaluated, 73 percent were 1 acre or smaller in size, and most small basins had temporary or seasonal water regimes (Table 1). Of all basins evaluated, 83 percent of temporary basins and 55 percent of seasonal basins were 1 acre or smaller in size. Of all semipermanent basins evaluated, 10 percent were 1 acre or smaller in size. Temporary wetland

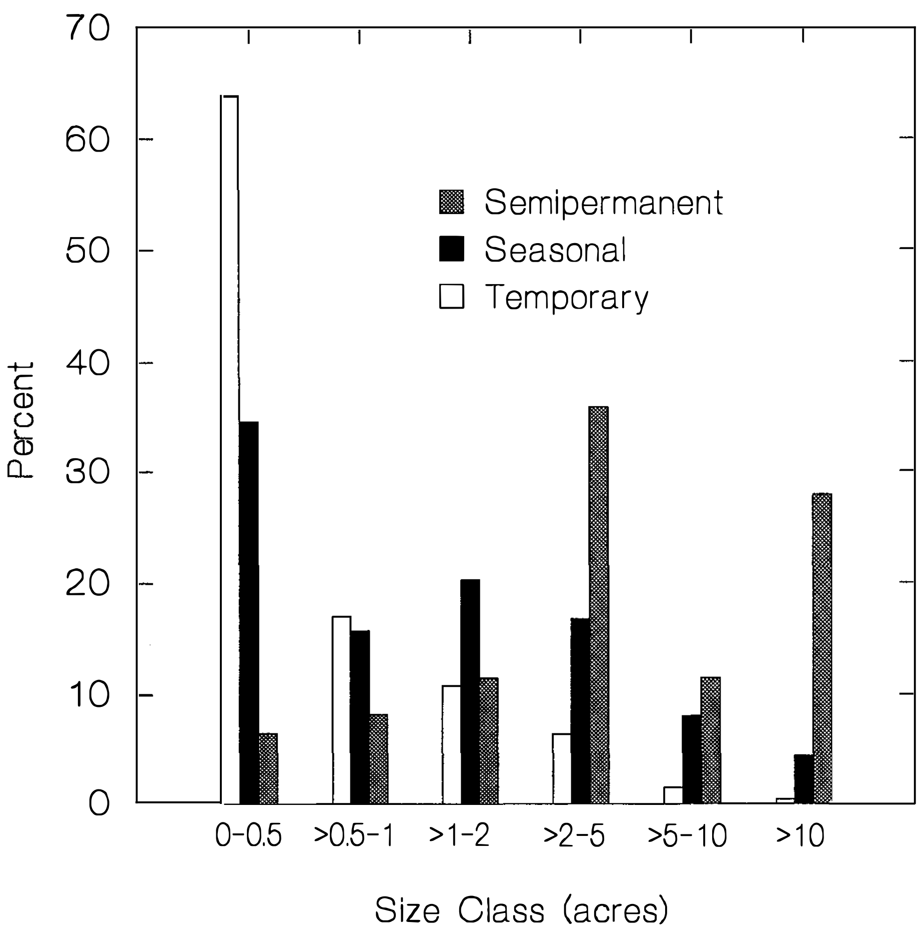

Figure 1. Percentage frequency of cropped and unprotected temporary, seasonal and semipermanent wetland basins by size class.

basin median size (0.30 acres [0.12 ha], CI = 0.30-0.32 acres) was smaller than the median size of seasonal (0.86 acres [0.35 ha], CI = 0.72-0.96 acres) or semipermanent basins (3.71 acres [1.50 ha], CI = 2.89-5.31 acres) (P < 0.05) which also differed from each other (P < 0.05).

Wetland basins categorized as both unprotected and in cropland had a size structure that was similar to the size structure of the total sample of basins (Table 4) (figures 1 and 2). Unprotected basins in cropland that were 1 acre or smaller in size (calculated as number or area of cropped, unprotected basins by size class [Table 4] divided by total number or area of basins by water regime [Table 1]) comprised 51 percent of all temporary basins and 21 percent of temporary basin area, 20 percent of all seasonal basins and 4 percent of seasonal basin area, and 7 percent of semipermanent basins and less than 1 percent of semipermanent basin area.

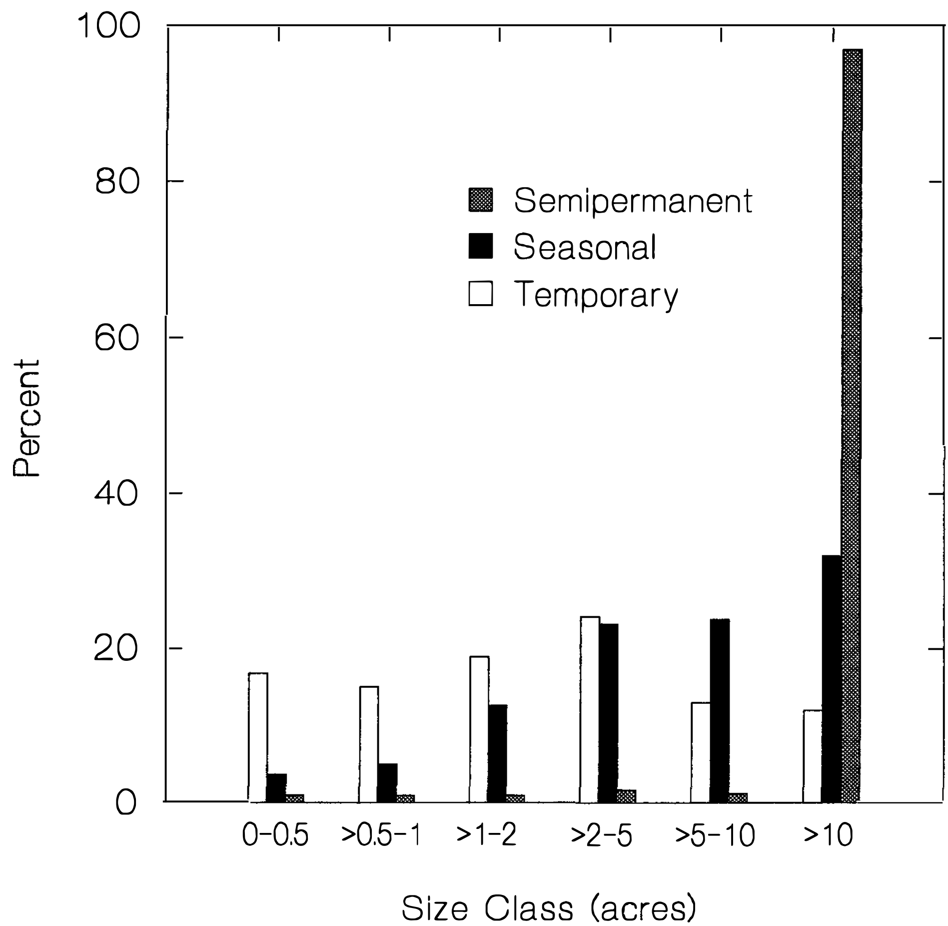

Figure 2. Percentage area of cropped and unprotected temporary, seasonal and semipermanent wetland basins by size class.

Discussion

Landowners are likely to view wetlands as nonproductive acreage or as operational nuisances. Economic issues are most commonly cited as justification for wetland drainage, including perceived potential for increased crop production, increased land valuation and financial gains to offset taxes. However, Leitch and Danielson (1979) found that farmers were willing to drain wetlands to eliminate the need to till around them even when drainage was uneconomical. Recent wet conditions in eastern South Dakota have limited the ability of farmers to plant, cultivate and harvest their crops. Because of economic issues, poor field conditions and frustration about prohibitions on drainage since 1985, interest in draining wetlands in eastern South Dakota is high.

To project potential wetland losses if proposed "Swampbuster" revisions are enacted, we assumed that unprotected basins located in cropland were at high risk of drainage, and that basins in perennial grassland were at low risk of drainage because the potential for economic gain from draining them is lower. We recognize that these are simplistic assumptions, but believe that they reflect drainage patterns that may occur. Johnson (1995) presented estimates of the number and area of wetland basins by water regime in eastern South Dakota based on a census of basins delineated by the NWI. We multiplied proportions (presented as percentages in this paper) of unprotected basins in the cropped land-use category, by size class, times the number and area of basins by water regime in eastern South Dakota (Johnson 1995) to estimate of the number and area of eastern South Dakota wetland basins at high risk for drainage under three deregulation scenarios if all or some of the proposed "Swampbuster" revisions in S.B. 1373 or H.B. 2542 are enacted.

Scenario 1: Deregulation of Temporary Basins

Temporary basins in eastern South Dakota are most abundant in low-relief terrain (Johnson 1995) where the landscape is intensively cultivated. Temporary wetland basins in cropland, regardless of size, have a high probability of drainage. We estimated that 63 percent (327,319 basins) of temporary basins are at high risk for drainage, representing 35 percent of all eastern South Dakota wetland basins. We also estimated that 66 percent (257,827 acres: 104,341 ha) of the total area of temporary basins in eastern South Dakota may be drained, representing 12 percent of the total area of all eastern South Dakota wetland basins.

Scenario 2: Deregulation of Basins 1 Acre or Smaller in Size

Using the percentage of cropped, unprotected basins by water regime which were 1 acre or smaller in size (i.e., number or area of basins 1 acre or smaller divided by the total number or area of basins for that water regime), we estimated that 51 percent (264,873) of temporary basins, 21 percent (68,614) of seasonal basins and 7 percent (1,641) of semipermanent basins, totaling more than 35 percent of all eastern South Dakota wetland basins, are at high risk for drainage. We also estimated that 21 percent (82,302 acres: 33,307 ha) of temporary basin area, 4 percent (19,926 acres: 8,064 ha) of seasonal basin area and 1 percent (12,676 acres: 5,130 ha) of semipermanent basin area, totaling more than 5 percent of all wetland basin area in eastern South Dakota, are at high risk for drainage.

Scenario 3: Deregulation of Basins 1 Acre or Smaller in Size and Frequently Farmed Basins

Most temporary basins in croplands may be "frequently farmed." When defined liberally, "frequently farmed" also may be applied to seasonal basins in cropland. Using estimates from the above scenarios, we estimated that if only temporary wetland basins are defined as frequently farmed, up to 42 percent (397,574 = 327,319 temporary basins + 68,614 seasonal basins + 1,641 semipermanent basins [all temporary basins, and seasonal and semipermanent basins 1 acre or smaller in size, that are unprotected and in cropland]) of eastern South Dakota wetland basins, comprising 14 percent (290,429 acres [117,535 ha] = 257,827 acres of temporary basins + 19,926 acres of seasonal basins + 12,676 acres of semipermanent basins) of basin area, are at high risk for drainage. If temporary and seasonal basins qualify as frequently farmed, we estimated that 49 percent (465,517 = 327,319 temporary basins + 136,557 seasonal basins + 1,641 semipermanent basins [all temporary and seasonal basins, and semipermanent basins that are 1 acre or smaller in size, that are unprotected in cropland]) of wetland basins are in jeopardy of drainage, comprising 22 percent (497,444 acres [201,313 ha] = 257,827 acres of temporary basins + 226,941 acres of seasonal basins + 12,676 acres of semipermanent basins) of the area of all wetland basins in eastern South Dakota.

Possible Impacts of Revisions to "Swampbuster"

Our estimates of potential wetland drainage demonstrate that from 35 to 49 percent of eastern South Dakota wetland basins are at high risk for drainage if proposed "Swampbuster" revisions are enacted. The negative impacts of draining 300,000 to 450,000 wetland basins on the biology, hydrology and economy of eastern South Dakota may be enormous. The rural economy of South Dakota depends heavily on expenditures for outdoor recreation and tourism, including expenditures by nonresident hunters. Dietz (1990) reported that 99 percent of South Dakota residents enjoyed wildlife-related activities. In 1991, 347,000 South Dakotans spent $231 million on these activities (USFWS 1991), many of which involved wetland-dependent species. Economic costs to the citizens of South Dakota due to draining small wetland basins and the associated loss of wildlife habitat may be substantial.

Many wildlife species in South Dakota, including waterfowl, shorebirds and neo-tropical migrants, require wetlands for reproduction, and many game and nongame species, including ring-necked pheasant (*Phasianus colchicus*) and white-tailed deer (*Odocoileus virginanus*), require wetlands as wintering habitat. Biota in the PPR are adapted to exploit patchy, dynamic habitats, and have evolved mechanisms to remain dormant during unfavorable periods, or to disperse between patches of available habitat. Assuming a limited dispersal capacity (e.g., 1 km) between basins, the PPR of eastern South Dakota may act as a single, contiguous wetland complex for most species (Johnson 1995). Although most basins that may be drained following deregulation are small, the integrity of the PPR wetland complex may depend on their existence. Because wetland basin density still is high, it may not currently be possible to evaluate the effects of habitat isolation on wetland-dependent wildlife in the PPR of eastern South Dakota; however, draining small basins may fragment the PPR wetland complex, resulting in reduced biodiversity (Dinsmore 1981, Brown and Dinsmore 1986). The Wildlife Management Institute (1995) estimated that, by exempting wetlands 1 acre or smaller from protection, duck production would decrease by 50 percent and the fall flight would be reduced by 9 percent in the short term.

Wetland basins also provide hydrologic values. Basins impound runoff and moderate the effects of flooding. Whittmier and Mack (1982) reported that 87 percent of drained wetland basins contributed to streamflows in the Yellowbank River watershed of eastern South Dakota. Wetland drainage has increased flooding frequency and intensity on many rivers in North Dakota (Malcom 1979, Rannie 1980, Brun et al. 1981, Vining et al. 1983). In 1993, extensive flooding occurred in the Vermillion River watershed in eastern South Dakota, where approximately 30 percent of remaining basins showed evidence of partial drainage (R. Johnson unpublished data). The flooding caused damages of $204 million to agriculture, $12 million to public facilities, $10 million to private residences and $2 million to businesses (Monday 1994). Wetland basins also are the site of most groundwater recharge in eastern South Dakota (Lissey 1971). The impacts of reduced groundwater levels on agriculture and residential water supplies remain poorly understood.

The biotic, hydrologic and economic values of wetlands are well established (Hubbard 1988). Negative impacts on wildlife in the PPR, and the socioeconomic effects of draining wetlands to put up to 500,000 acres (202,300 ha) of additional marginal farm land into production during a period with consistent agricultural commodity surpluses makes enacting proposed "Swampbuster" revisions appear a poor choice for most South Dakotans. Admittedly, the least-studied types of wetland basins are small temporary basins, exactly the type of basin for which farmers find protective legislation the most onerous. Management strategies that are mutually acceptable to the agricultural and natural resource publics must be developed for these basins. We propose that long-term studies, encompassing various agricultural systems and hydrologic conditions, need to be conducted to identify accurately and objectively the costs and benefits of preserving or draining small and temporary wetland basins.

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Minimizing Controversy in Wildlife and Livestock Grazing Management

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Wildlife managers in the United States are learning that synergy between ranchers and the public is a necessary component of effectively managing wildlife and livestock grazing. Increasing public involvement on a variety of environmental issues has created increasing restrictions and policies for grazing management, especially on public lands. Resource managers have conducted research concerning wildlife and livestock relationships but, often, this research focuses on a negative impact one has on the other (Cory et al. 1985, Kothman 1984, Bernardo 1994, Lacey et al. 1988). This often leads to management decisions which restrict the use of an area or impose an either-or strategy. This research is effective in identifying situations that are detrimental to agriculture or to wildlife, but it also leads to confrontational situations.

Various strategies for managing livestock and wildlife in the Intermountain West have been developed. Some of these strategies do not involve reduction of grazing animals to reduce negative impacts. The purpose of this paper is to describe current practices that effectively manage grazing without restricting livestock use. Some of the practices involve people management and some involve resource management.

Advisory Groups

Advisory groups, when properly composed, provide an opportunity for managers to identify concerns, strategies and issues that might enhance decision making (Roberts 1992). In southcentral New Mexico, a multi-interest advisory team developed a grazing management plan as part of the Negrito Ecosystem Project (Wondolleck et al. 1994). The team was composed of ranchers, environmentalists, sportspersons, county commissioners and loggers. Representatives of the Gila National Forest and the New Mexico Department of Game and Fish have worked with the group to develop the management plan.

One of the unique aspects is the selection of members on this team. In order to satisfy National Environmental Policy Act (NEPA) requirements, it was necessary that all interested organizations be allowed to provide input. Invited representatives however, were selected based on being widely recognized as a representative of a particular interest group and also for their reputation as seeking solutions rather than promoting controversies. The process allowed participation and attendance by those not specifically selected as a part of the team. This strategy worked exceptionally well because the invited members of the team worked in a positive manner and this attitude influenced others to provide positive, constructive input.

Utilizing this process, the team has been successful in developing concensus support for management strategies. Needs associated with ranching, endangered species management, timber harvest, riparian management and community economics have been accommodated. The Negrito Ecosystem team illustrates that multi-interest advisory groups can be utilized successfully if individuals making up the groups are oriented toward solutions rather than toward perpetuating controversy.

Riparian Management

Controversies over wildlife and livestock grazing often revolve around livestock damage in riparian areas (Smith et al. 1992). Strategies that involve fencing of riparian areas often lead to controversy because this practice excludes an important grazing component of the ranch (Bryant 1982). Several strategies can be considered to manage riparian areas while not eliminating their use by livestock.

Fencing of a riparian area so that it can be managed as a separate pasture may provide the necessary care riparian areas need (Thomas 1991). If a rancher is able to graze the riparian area for one or two weeks per year, the impact to the vegetation and water quality could be acceptable, and this minimal use might provide benefits to the rancher. For example, the riparian pasture might be used as a place to hold cattle just prior to shipping to increase body condition and reduce roundup costs. Proper grazing of the pasture may enhance the value of the area for wildlife (Sedgwick et al. 1991). If the riparian area is an important wintering range or an important fawning or calving area, livestock grazing can be scheduled at a time that will not pose a conflict (Chaney et al. 1990).

Several new strategies are being tested for managing riparian areas that involve non-exclusion techniques. A project in Montana is investigating the effect of cross riparian drift fences to encourage livestock to utilize upland areas (A. Carter personal communication: 1995). The cross riparian drift fences are placed perpendicular to the stream and ascend to mid-slope on both sides. The idea behind cross riparian drift fences is to prevent livestock from utilizing the bottoms as travel corridors (Mueggler 1965). Livestock will encounter the fence, pass along the fence to go around, but actually end up halfway up the side. In many cases, livestock will continue traveling toward the ridge rather than dropping back down into the bottom. This technique is especially effective when the upland area provides sufficient forage (Ganskopp et al. 1987).

Other methods of attracting livestock to the upland areas involve the use of off-site watering and fertilized plots in those areas (Miner et al. 1992). These strategies make the uplands more attractive and make it unnecessary for the livestock to utilize the riparian areas for water or more lush vegetation. When livestock utilize riparian areas for water, quite often they will loaf in the area and damage may occur. By providing water on a ridge, livestock often will stay in the upland areas. The use of fertilized plots in the uplands will create a small area of highly palatable vegetation (Smith 1958).

Excessive damage to fences can occur in areas where elk (*Cervus elaphus*) migrate or are in high numbers. Certain fence designs can reduce maintenance required because of damage by elk (Jepson et al 1983). In the past, fence damage areas were protected by using poles across the top of the fence. In many situations, the use of these poles caused elk to use adjacent fence crossings that did not have poles. A recent study has tested different fence designs and monitored which were most preferred by elk (Knight et al. 1996). Results indicated lowering of the top wire on a standard four-wire fence proved to be the most effective way to reduce maintenance and provided a crossing which the elk did not avoid.

Grazing for Wildlife Enhancement

In western Montana, several landowners are cooperating with the U.S.D.A. Forest Service and the Montana Department of Fish, Wildlife and Parks to use livestock grazing to enhance elk winter range on state Wildlife Management Areas (WMAs) (Frisina 1992). It has been found that WMAs can be grazed to a level that maximizes the palatability of grasses and forbs. Historically, landowners adjacent to WMAs received the most use by elk during winter and early spring. This posed a livestock management problem because these areas were needed for livestock grazing in early spring. It was determined that elk used the grazed private land more than the ungrazed WMAs. Livestock removed the older and more decedent grasses and allowed easy accessibility to the more nutritious and palatable young shoots. Ongoing studies are investigating the effect of grazing on forb production. Elk may be attracted to the grazed areas because of removal of the dense overstory which allows sunlight to stimulate forb production (Singer 1975).

Conservation Easements

Public and private wildlife management organizations have long recognized the need to preserve wildlife habitat. In the past, wildlife habitat has been preserved through purchases of critical areas to prevent them from being developed. More recently, conservation easements are becoming an acceptable way of ensuring maintenance of wildlife habitat by attaching land-use restrictions to deeds (Knight 1995). Conservation easements can be developed that allow grazing and other agricultural practices and still provide for wildlife habitat. Many of the interests of the landowner are compatible with the interests of the wildlife habitat manager. Many landowners, however, do not realize the significance of payment that can be made for entering into a conservation easement, nor do they realize the flexibility that can be incorporated into the agreements.

The amount of payment normally is dependant on the value of the land as wildlife habitat and, to a certain extent, the potential for that land to be developed in the near future. The starting point for payment for a conservation easement usually is the difference between the value of the land as agricultural land and the value of the land to developers. In Montana, one situation resulted in a land area of 5,000 acres (2025 ha) being placed into a conservation easement for $1.6 million (Montana Department of Fish, Wildlife and Parks 1994). In areas where the wildlife habitat values are not as significant, the payments may be significantly less. The highest payments are for large portions of land providing critical habitat in areas sought for development.

A conservation easement is attached to the deed and provides for certain restrictions as to how the land is utilized in the future. Most conservation easements are designed to keep the land from being subdivided. Many conservation easements not only allow but encourage present agricultural practices to continue. For some landowners, the attractiveness of a conservation easement is that the land will be guaranteed to stay in the use that it is in today. Traditional ranchers who have been on a ranch for many years are sometimes attracted to a guarantee that the ranch will stay in one piece.

Some landowners are concerned that a conservation easement will devalue their land. The value of the land as agricultural land is not decreased if restrictions are not placed on agricultural practices. The value of the land as developed land, though, would be decreased.

Hunting Access

Increasingly, hunting access on private land is a point of concern and controversy. While access to wildlife populations is necessary for the general hunting public, landowners have been increasingly discouraged by demands for access and, in some situations, poor behavior of hunters. This has resulted in the closure of many private lands that were open to hunting in the past. Several programs are being implemented to address private land access for hunters (Teer 1981, Knight 1984). California, Colorado, Montana and New Mexico have implemented programs that provide incentives for landowners to allow public access.

In Montana, a program known as Block Management has been used to provide incentives to landowners to keep their land open to the public (Montana Department of Fish, Wildlife and Parks 1996). This program provides funding to offset expenses incurred by landowners who allow public hunting. Legislative action in 1995 established a fee of up to $8,000 per landowner to offset potential impacts. Program funding comes from license fees.

Landowner/Hunter Relationships

Much of the concern ranchers have over hunter use of land revolves around perceived problems between landowners and hunters. A study in Montana has identified two of the top three problems perceived by hunters and ranchers as identical (Swensson 1996). Both the hunters and the ranchers concluded damage to private land and too many hunters were major problems. The hunters added that a major problem was too little access, and the ranchers added that a major problem was driving off roads. Both groups also shared two of the top three solutions to hunter/rancher problems. Both responded that better communication between the two groups and a greater appreciation for the contribution of the other group would help solve conflicts. Hunters also indicated better identification of property lines would be important, and ranchers said that stiffer penalties would reduce some of the problems between hunters and ranchers. A similar study in New Mexico (Knight et al. 1987) indicated that, while hunters and ranchers have differences, both groups have a common desire to mend these differences.

Conclusions

Across the West, there is an increasing interest in minimizing controversy in wildlife and livestock grazing management issues. Interest groups that are striving to identify win/win situations, rather than prolonging controversies, are more likely to be invited to problem-solving sessions. Conservation groups, land-management agencies and state wildlife agencies recognize the contribution of agriculture and are trying to develop ways to enhance cooperation. Habitat management practices that consider needs of agriculture are more likely to be implemented by landowners. Conservation easements and hunter access programs are examples of win/win strategies that address the needs of landowners while accomplishing objectives important to wildlife management. Finally, identification of perceived problems and perceived solutions will allow wildlife managers to focus on issues most likely to have impact.

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A Quarter Century of American Falconry Regulation: An Example of Management/User Cooperation

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During the 1995 North American Wildlife and Natural Resources Conference, Michigan State University Professor R. B. Peyton presented an in-depth examination of the American falconry community (Peyton 1995 et al.). He concluded an oral presentation with comments on the development of specialist groups of hunters and fishermen within the recreational community. Peyton indicated that such groups have developed their own ethics and strong attitudes concerning the stewardship of the natural resources with which they are associated. According to Peyton, specialist groups not only accept many forms of regulation, but often lobby for more restrictive regulation of their sport and associated resources. He stated these groups can be powerful allies for management agencies. Conversely, when alienated, they can prove demanding, competitive or even obstructive. Peyton continued that management agencies are beginning to realize the significance of this specialization process and the usefulness of cooperating with groups that possess unique skills and information. He further indicated that falconers exhibit many of the characteristics of such a highly specialized recreational group and recommended that state and federal agencies explore their relationships with American falconers as a small but unique group of such specialists.

We agree that falconers are a specialized group of sportsmen adhering to the Peyton concept. There has been a constructive and cooperative relationship between wildlife managers and falconers throughout the last 25 years. We feel this relationship can serve as a model for both managers and sportsmen.

This paper provides a chronology which explores significant events in the history of this relationship including: a description of how falconers were allowed to provide input to management agencies—enabling them to develop insight into the falconers' unique needs; how wildlife managers judged falconers' proposals based on biological merit; and how this cooperative relationship resulted in increased recreational opportunities, decreased administrative burden and successfully "partnershipped" conservation efforts, including the restoration of an endangered species.

Falconry: Definition and Description

In order to understand the sport and the unique regulatory burdens that allow a specialist group to undertake such activities, several key points about falconry must be understood: 1) we define falconry as the taking of wild quarry in its natural state and habitat with trained raptors; 2) as one of man's oldest field sports, falconry has great historical credibility. From circa 2000 BC until the expanded use of firearms in the seventeenth century, falconry was widely practiced and literally was "the sport of kings." In North America, falconry can be traced to a hawk caught at the direction of Montezuma for training by one of Cortez's captains (Aguilar Rivera 1995). However, the majority of the sport's practice on this continent took place after 1920 and was virtually unregulated until the 1950s; 3) among hunting sports, falconry almost alone utilizes one form of wildlife (raptorial birds) to pursue others (traditional game or unprotected species). In doing so, falconry necessitates unique regulations allowing take and possession of otherwise protected wildlife (raptors); 4) falconry has been called "a special form of bird-watching" (Cade 1982). It is among the least efficient means of hunting and its effect on game species is insignificant. The attraction to its followers lies in the spectacle of the "chase" rather than the harvesting of animals. In this respect, it is much like flyfishing. Similarly, as in flyfishing, knowledge of the quarry and the manufacturing of one's own equipment are significant components of its enjoyment and success. Because it is so ineffective, falconers seek and are granted additional time in the field for their activities; 5) because of the massive time demands and even life-style changes necessary to train and care for a raptor successfully, falconry has been a self-limiting, slow-growth hunting activity. Regulations to limit numbers of participants, such as license quotas or drawings, remain unnecessary; and 6) of particular significance, regulations that falconers have proposed to management agencies reflect a strongly held hierarchy of ethical concerns including: first, the well-being of the individual raptors possessed; second, the sport; and, only last, the falconer. In other words, falconers support regulations designed to protect individual raptors possessed at the expense of the sport and even of the falconers, if necessary. Current falconry regulations, as championed by the falconry community, ensure that only individuals who demonstrate the knowledge and possess the equipment and motivation to possess raptors safely are allowed to do so.

A Chronology of Falconry Regulations

Despite falconry's 4,000-year history, the intensive regulatory interaction of falconers with U.S. wildlife agencies dates back only a quarter century. Prior to that time, federal involvement with raptors was virtually nonexistent outside the Bald Eagle Act, and there were few state falconry regulations. Those state regulations that did exist most often reflected isolated efforts of a few motivated individuals or small clubs. By 1971, there were only 2,200 licensed falconers in the U.S. Probably more than half of those individuals did not actively practice the sport as we have defined it. In many states, falconry was illegal, not because it was prohibited by regulation, but because it was not specifically allowed as a means to take game—it simply never had been considered. Of the seventeen states where the sport was not illegal, most had accepted it on faith since there was little information available to wildlife administrators on its practice (U.S. Fish and Wildlife Service [USFWS] 1976a). Based on a similar lack of information and experience, opposition to the sport was widespread among private conservation organizations (Graham 1992).

In that same year (1971) the senior writer appeared on behalf of the North American Falconers Association (NAFA) at a special session of the North American Wildlife and Natural Resources Conference in Portland, Oregon. The purpose for NAFA's participation was to begin a dialogue leading to consensus among falconers (users) and the various management agencies for an appropriate set of "model" regulations to uniformly govern our sport (Carnie 1971a).

That "North American" session, sponsored by the National Audubon Society, was occasioned by the precipitous decline in populations of the peregrine falcon in the preceding decade. Despite the absence of any clear evidence then as to the cause of this decline, falconers often were blamed for it. Of particular concern to falconers was the atmosphere generated by an Audubon-proposed moratorium on the take of any peregrines or gyrfalcons (telegram, Roland C. Clement, Vice-President, National Audubon Society to Directors of the Canadian Wildlife Service and selected state conservation agencies, October 1, 1968). The model regulations which NAFA proposed to the 1971 Conference were very restrictive in nature (NAFA 1971a). This early attempt by falconers to propose rules for our sport clearly reflected Peyton's concept of ethical motivation in a specialized group and closely adhered to the falconers' hierarchy of ethical concerns for the well-being of captive raptors noted above.

As a result of that conference, the Wildlife Management Institute recommended that NAFA present its proposed regulations to the International Association of Game, Fish and Conservation Commissioners (International) meeting in Rhode Island in September of that same year (Morse 1971). The proposal NAFA then presented to the International included changes solicited from the states following our proposal at the North American (Carnie 1971b, 1971c, NAFA 1971b). The pattern of cooperation between falconers and managers developed at the North American in Portland continued during this subsequent meeting of the International. That association established a special subcommittee of wildlife administrators and falconers to develop model regulations for state administration of falconry. The subcommittee essentially endorsed the set of regulations proposed by NAFA. Cooperation between falconers and the International Association of Game, Fish and Conservation Commissioners, at the recommendation of the Wildlife Management Institute, thus, produced a model for uniform (albeit restrictive) regulation of falconry throughout the United States.

Before it was possible for the states to consider implementation of this model, however, the Migratory Bird Treaty Act was renegotiated in 1972, placing all raptorial birds, and therefore falconry, under federal jurisdiction—a move supported by the falconry community. The federal government suddenly was challenged to understand falconry's impact, both on quarry populations—with which they were familiar—and on populations of raptorial birds, with which they had little experience. This challenge was exacerbated by the ravages wrought on some raptor populations by what we now know were the metabolites of DDT.

Development of federal regulations commenced with meetings in March and May 1972. Those meetings built on what had been, originally, the International's special subcommittee, and included representatives from USFWS, state agencies, NationalAudubon Society and NAFA (Carnie 1972a, 1972b). The regulations which had been the final product of NAFA's International presentation were reconsidered on a national, rather than individual state, basis. The new regulators (USFWS) approached the sport within the concept of use management, appropriately controlled by adequate regulation. Among federal biologists were those with sufficient understanding of the sport to be able to keep the protestations of the protectionists in perspective. In the course of its deliberations, the USFWS produced an Environmental Assessment to examine the potential impact of the sport (USFWS 1976a). While the USFWS concluded that falconry offered no significant threats either to quarry species or to the raptors themselves, it recognized that legalization of falconry would impact wildlife administrators most. Additionally, falconers themselves were requesting regulatory activities more involved than those required for any other type of hunting.

Consistent with Peyton's model of an ethics-motivated group and our own hierarchy of needs for captive raptors, falconers proposed regulations that mandated passage of a test on falconry, a detailed inspection of facilities and equipment, and, for novices, two years of apprenticeship under a previously licensed falconer before independent license could be granted. Mindful that this proposal carried a considerable administrative burden, falconers worked with administrators to develop means by which that burden could be lessened. Where examinations were proposed, NAFA provided sample tests. Where facilities and equipment inspections were necessary, NAFA provided guidelines to help with such inspections. NAFA produced generic falconry regulations to facilitate state compliance with the intricacies of the proposed federal regulations. By working with conservation organizations and wildlife administrators, falconers were able to develop a set of regulations which insured both the protection of the sport and the raptors possessed. An additional benefit was that the rigor of the falconers' proposal aided federal regulators in assuaging some of the concerns of the protectionist community.

Federal falconry regulations were published in 1976 (USFWS 1976b) and closely resembled the proposals falconers originally proffered at the 1971 meeting of the International. Within eighteen months, 25 states had adopted falconry as a legal hunting means. With the advantage of a national agency to establish basic standards, falconers were able to achieve several subsequent regulatory goals. Included were federal regulations covering captive propagation of raptors and the exemption of certain propagated raptors from provisions of the Endangered Species Act (USFWS 1983).

While we enjoyed the benefits of single-point federal negotiations, we learned that such also had their problems. As an example, in 1972, Congress passed legislation allowing falconers to use depredating golden eagles that had been marked for destruction by federal animal control agents. Federal regulations to allow such use were not promulgated until 12 years later (USFWS 1984a). Subsequent law enforcement regional autonomy within the USFWS also further diluted that earlier "single-point" advantage.

NAFA's policy is to support local falconers with technical information, rather than becoming directly involved in state issues. Because the new federal regulations required the states to conduct the majority of the administration of the sport, the dialogue between local falconers and state agencies increased. NAFA also encouraged falconers to approach their respective state agencies to promulgate regulations dealing with some of the more unique needs of the sport or issues not federally controlled. The result has been numerous state regulations allowing extended falconry seasons, reasonable permit fees, protection from prosecution for inadvertent kills and nonresident take of raptors.

Many early state regulations were restrictive even beyond what was requested by falconers or mandated by the federal regulations. This situation was understandable, given agency inexperience with the sport and concerns for then declining raptor populations. Some of those regulations, however, reflected political rather than biological concerns or pressures from protectionists and antihunting groups. As understanding of raptor populations and falconry has improved, many states streamlined their regulations within the federal standards. Some still have not.

Another cause for the continuation of overly complex regulations has been a trend for managers—having once examined and accepted falconry—to turn administration and subsequent revision of regulations over to law enforcement personnel. The principal focus of law enforcement has, in some cases, been the regulations themselves, rather than management of the activity or resources involved. While falconers recognize enforcement as an essential tool of management, there has been an inclination in some jurisdictions for the enforcement "tail" to wag the management "dog."

Culminating in 1984, a three-year covert investigation of the falconry community by the USFWS Law Enforcement Division purported to uncover large-scale, profit-motivated illegal activities by falconers. Despite early news releases to the contrary (USFWS 1984b), this "Operation Falcon" did not produce evidence of major wrong-doing by falconers. The falconry community subsequently was exonerated by the USFWS itself. The Service went on record as "supporting falconry," indicating that, in its experience, "the overwhelming majority of falconers practice their sport in full compliance with Federal and State Regulations." It further stated that "...most falconers are conservationists who have a deep and abiding love for the migratory bird resources" (USFWS 1989).

In the long run, however, this federal law enforcement action proved to be a significant event in the relationship between falconers and the USFWS and produced significant erosion in the spirit of cooperation with federal authorities that had guided the production of regulations and administration of our sport until that date (Shor 1994). As predicted by the Peyton model for specialized groups, this highly publicized "sting" resulted in a degree of alienation in the falconry community toward the Law Enforcement Division of the USFWS, an alienation the community perceives as mutual.

Despite that eventual Service exoneration, the USFWS Law Enforcement Division explicitly cited "Operation Falcon" as the basis for an extensive revision of falconry regulations commenced in 1985 (USFWS 1987). The regulations developed by the Law Enforcement Division in the name of the USFWS (1987) put forth changes not only to the falconry regulations but to the general permit procedures for all migratory birds. The proposed regulations increased prohibitions and penalties and essentially granted judicial authority to enforcement personnel. The Service proposed establishment of new, separate, parallel state and federal permit systems requiring a new federal permit and fee, and mandated new reporting procedures and forms. Some portions of the regulations which falconers had championed since 1971 were to be eliminated. Gone would be the testing, inspection and apprenticeship programs that were in place specifically to protect birds held in captivity.

The Law Enforcement Division proposed these regulatory changes for public comment a half-year before a second Environmental Assessment addressing the subject and undertaken by the USFWS Office of Migratory Bird Management was made public (USFWS 1988). That assessment had been prepared as a "part of the decision making process in analyzing regulatory changes" (letter, USFWS Director to International Association of Fish and Wildlife Agencies [IAFWA] President, May 21 1986). It addressed the effect of falconry, including the findings of "Operation Falcon," over the previous 12 years of federal regulation. Its findings included that falconry was a "small scale activity having little or no impact on raptor populations" and that "most raptor populations have increased from lows reached during the early 1970's." The assessment findings for proposed regulatory changes were that "the degree of regulation imposed by the federal regulations governing falconry appears to be unnecessary."

The states, with a decade of experience implementing federal regulations, already had begun to voice concerns about their unnecessary complexity and enforcement (letter, Larry R. Gale, Director, Missouri Department of Conservation to William P. Horn, Assistant Secretary of Interior, December 31, 1985). In 1986, the IAFWA formed a special subcommittee to re-examine falconry regulations. In expressing his pleasure that IAFWA would be providing the USFWS with the results of that review, the Director, USFWS wrote to its President that the IAFWA's views would "be carefully and thoroughly considered" (letter, Frank Dunkle to Gary T. Myers, May 21, 1986). Based on recommendations of its subcommittee (Brohn et al. 1986), the IAFWA "strongly encouraged" the USFWS to "simplify such [regulatory] requirements to the fullest extent consistent with appropriate protection of raptor populations" (IAFWA 1986). "The Association's recommendations and the [its] resolution were all but ignored by the Fish and Wildlife Service" (memorandum, Jack H. Berryman, Executive Vice-President, IAFWA to state governmental members, February 11, 1988).

The Law Enforcement Division (in the name of the USFWS) was proposing massive increases in regulation, the Office of Migratory Bird Management was recommending decreases in regulation and the states, through the IAFWA, were recommending simplification in regulation. The falconry community was caught squarely in the middle.

While this series of events decreased cooperation between the federal Law Enforcement Division and falconers, the relationship between the states and falconers had grown as a result of 10 years of interaction during the implementation phase of the federal regulations. The states, the IAFWA and falconers collectively succeeded in blunting some of the more onerous aspects of the proposed federal regulations (USFWS 1989). It is ironic that the above-cited USFWS support for falconers and falconry was so explicitly stated in the preface to regulations originally intended to "crack down" on the sport.

Important to falconers was the fact that the states continued to agree that testing, inspections and apprenticeship prior to further licensing were significant and should be preserved. In recognizing the necessity for these time- and labor-consuming portions of the regulations, the states essentially had recognized the importance of the safety of captive birds and their own role in the hierarchy of ethical concerns our group holds.

Some simplification did result from those regulatory changes and the process itself provided an opportune basis for states to further revise their own regulations, putting into effect lessons learned in 13 years of experience administering falconry. While a few states remain unchanged, we see continuing progress in elimination of unnecessary control and administration. That progress is a direct reflection of increasing understanding and cooperation between state administrators and their local falconry communities.

Today, while the number of falconers has remained minuscule in relation to other hunters, the number of states where falconry is recognized legally has expanded to virtually the entire nation. Opposition now is limited for the most part to those who oppose all forms of hunting. We have created regulations respected and commended internationally, even by the sport's detractors (Robinson 1991).

Falconers and Conservation

Cooperation and understanding have been the focal points of the successful regulation of falconry. Falconers also have provided managers with their special knowledge and skills in raptor biology. Falconers have studied, understood and loved raptors for thousands of years. In the U.S., the activities of falconers as advocates for raptor protection began in times when such species were considered bountied "vermin."

In Idaho, long-time falconer Morlan Nelson was the major instigator for establishment of the federal Snake River Birds of Prey Natural Area. Wisconsin falconer Robert Rosenfield, more recently, has found, banded and studied more Cooper's hawks than were thought to exist in that state. While John and Frank Craighead are most famous for their work on grizzly bears, it was falconry and their subsequent study of raptors in Michigan that excited them and led them into a lifetime dedicated to wildlife.

The most successful marriage of wildlife professionals and falconers for conservation purposes undoubtedly is re-establishment of the peregrine falcon. In 1965, Joseph Hickey was planning the first conference to study the decline in peregrine populations. He assembled all the biologists known to him to be experts on this species. It is said that, in the final planning stages, he asked Frances Hamerstrom, "Shouldn't we invite some falconers to sit in on this meeting?" That biologist (and falconer) pointed out to Professor Hickey that many of the biologists invited were active falconers. In point of fact, 8 of the 11 presentations on North American peregrine populations delivered at that historic Madison conference were provided by falconers (Hickey 1969).

The demise of the peregrine falcon from the face of the earth, simply stated, was an option totally unacceptable to falconers. In the early stages of the peregrine restoration project, conceived and developed by Tom Cade of Cornell University's Laboratory of Ornithology and aided by several other individual falconers, the techniques, vocabulary, personnel, breeding stock and, to a large extent, the funding, originated with falconers. To date, nearly 5,000 peregrines leave been released into the wild (Peregrine Fund 1995) and the USFWS has filed notice of intent to delist this species under the provisions of the Endangered Species Act (USFWS 1995)

The techniques developed by falconers for breeding and hacking (releasing) peregrine falcons now are being applied in restoration efforts involving Mauritius kestrels, aplomado falcons, bald eagles, California condors and even the Hawaiian crow. The success of the peregrine program is a direct result of cooperation between management agencies, private foundations, educational institutions and private individuals, but, at each stage, falconers have been there with the knowledge, motivation and specialized skills unique to their group.

Conclusions

The history of falconry regulation offers lessons to both sportsmen and wildlife administrators. While some aspects of this history are unique to falconry, most will be useful in creation or revision of regulations for any sport. The falconers' campaign for legal recognition and sensible administration was facilitated by assumption of jurisdiction over raptorial birds at the federal level. Falconers, at least at first, had a single agency with which to deal nationwide. Falconers were able to participate in regulatory development from its inception and were met with open minds. This specialized group of sportsmen responded with regulatory proposals that were reasonable, stringent and biologically sound. Where their recommendations were labor consuming, falconers actively provided tangible assistance to alleviate the administrative impacts of those proposals.

After a quarter century of regulation and analysis, managers have confirmed that falconry has no negative impact on game or raptorial species. Conversely, agency biologists and managers have made use of the specialized knowledge and skills falconers possess which has resulted in positive impacts on raptors and aided in the recovery of some populations.

Simply put, regulation and, indeed, the recognition of falconry in the United States has been a success based on the biological merits of the sport itself and cooperation between the sportsmen and managers who were willing to allow a specialist group to participate in both the process and the outcome. We both have come a long way in the past 25 years and look forward to similar progress in the coming quarter century.

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Illinois Fur Hunting and Trapping Project: A Case Study in Facing Reality

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Maintaining support for fur hunting and trapping as viable management tools has challenged wildlife managers in recent years. In 1992, the Illinois Department of Natural Resources initiated the development of a comprehensive fur hunting and trapping education program to address this issue in Illinois. The education program was designed for Illinois residents who do not hunt or trap, with the goals of increasing positive opinions toward trapping and fur hunting, and gaining informed consent that fur hunting and trapping are legitimate and beneficial activities for American society.

Biological and ecological research are the foundations of successful wildlife management programs. Planning and social science research are the foundation of successful education programs. If planning, social science and market research are not utilized in the development of educational programs and products, wildlife educators risk espousing the wrong messages, rendering educational programs ineffective and wasting valuable resources. For example, three of the most common messages used today in justifying fur hunting and trapping to the public—tradition, recreation and economics—were determined to be ineffective in gaining informed consent for fur hunting and trapping in Illinois.

The Illinois fur hunting and trapping education program is based on a solid foundation of comprehensive planning, social science, market research and product testing. The project was multi-phased and consisted of a telephone survey and a series of focus groups to provide the basis for product development. The survey was administered to Illinois residents to determine current opinions on and attitudes toward fur hunting and trapping, as well as gauge reactions to various fur hunting and trapping messages. Based on the survey results, a pilot video on fur hunting and trapping was developed. Next, the effectiveness of the video was tested in a series of focus groups where respondents were asked what they liked and did not like about the video and if they experienced changes in opinions and attitudes toward trapping. Based on the focus groups, the video was edited to strengthen concepts that worked and delete sections that did not work. The final education program and products, a video titled "Fur Hunting and Trapping in Illinois," corresponding brochure, table-top display, slide program, media relations plan and leadership workshops were based on this full range of market research and will be more effective in changing attitudes, gaining informed consent and maintaining support for fur hunting and trapping as viable management tools in Illinois.

Telephone Survey

A telephone survey was conducted to quantify Illinois residents' opinions on and attitudes toward trapping, fur hunting and furbearer management. Results of the statewide telephone survey are based on a random-digit dialing, computer-assisted telephone survey of adult Illinois residents. Telephones were selected as the preferred sampling medium, since nearly all Illinois residents have access to a telephone. In addition, a central polling site allowed for rigorous quality control. The random selection procedure used within each household was the "last birthday" procedure. This means that when someone answered the phone, the interviewer asked to speak to the person over 18 that had the most recent birthday. This procedure is easy for the respondent to understand. Randomly generated telephone numbers, coupled with the "last birthday" method, ensure that the survey results can be projected to the adult, resident population of Illinois. The sample population demographics closely matched U.S. Bureau of Census demographics.

Awareness of Trapping, Fur Hunting and the Illinois Department of Conservation

A majority of respondents were aware that people participate in trapping and fur hunting in Illinois, as well as the fact that the Illinois Department of Natural Resources (Department) regulated trapping and hunting. However, a majority of respondents reported that they knew a little bit or nothing at all about these activities. Few respondents (6 percent) said they were very familiar with the Department, while almost half (44 percent) said they were somewhat familiar and the remaining half said they were not at all familiar with the Department.

These findings point out that, although residents were aware that trapping and fur hunting occur in Illinois and are regulated by the state, there was little knowledge about the activities themselves.

General Opinion of Fur Hunting and Trapping

Overall, when asked initially about fur hunting, 27 percent of respondents approved while 64 percent disapproved. Overall, when asked initially about trapping, 22 percent of respondents approved while 71 percent disapproved. Notably, for either activity, most of the support was moderate, but, on the other hand, most of the disapproval was strong. Specifically, 40 percent of respondents reported strong disapproval for fur hunting and 50 percent of respondents reported strong disapproval for trapping. Fur hunting was defined to all respondents as hunting wild animals for the primary purpose of obtaining their fur. Trapping was defined to all respondents as capturing wild animals in traps for the primary purpose of obtaining their fur.

Many different reasons were given for respondents' opinions of trapping. For supporters of trapping, reasons ranged from population control, tradition, economic, utilitarian, as well as if it's regulated then it's okay. For opposers of trapping, reasons ranged from those related to animal welfare and cruelty, trapping is unnecessary due to other alternatives like synthetics, animal rights, the perception that trapping is wasteful, as well as the fact that it endangers animal populations.

At the end of the survey, respondents again were asked what their opinion of trapping was, based on the interview—after several messages on fur hunting and trapping were delivered. Overall approval increased from 22 to 46 percent, while disapproval decreased from 71 to 46 percent.

Opinions Regarding Trapping in Specific Circumstances

Next, respondents were asked for their opinion of trapping under several different circumstances. The circumstance that received the most approval was trapping for animal damage control (71 percent approved), trapping for animal population control (70 percent) and as part of a biological study (63 percent). Circumstances that received the least approval were as a way for individuals to make money (27 percent), to be close to nature and experience the outdoors (18 percent), and for recreation or sport (16 percent).

Opinion of Animal Welfare and Rights

The next three questions presented respondents with statements to which the respondent was instructed to agree or disagree. The statements addressed topics of animal welfare, animal rights and human rights. Fifty percent of respondents agreed that regulated trapping is okay if the animals die quickly and without undue pain. Forty-four percent disagreed with this statement.

Fifty-two percent of respondents agreed that regulated trapping is wrong because animals have the right to live independently of people and should not be used or harmed in any way. Forty percent disagreed with this statement. Thirty-three percent of respondents agreed that regulated trapping is okay because people should have the right to participate if they want to. Fifty-nine percent disagreed with this statement. Again, as in general opinions toward fur hunting and trapping, the pro-trapping opinions were mostly moderate, while the anti-trapping opinions were more strong than moderate.

Message Testing

Nine messages were tested to see what messages made respondents more likely to find trapping acceptable. To minimize bias, the order in which the messages series was administered was randomly selected. The message receiving the highest percentage of opposers[1] indicating that the message would make them more likely to find trapping acceptable was: "State laws require daily trap checks, limit trap sizes, and prohibit certain type of traps which ensure that trapping is as humane as possible given current technology." One-third of opposers said that this message would make them more likely to find trapping acceptable.

Thirty-one percent of opposers reported knowing that seasons are structured in autumn and winter for many reasons, including to help ensure that newborn animals are not trapped or left helpless, would make them more likely to find trapping acceptable. Thirty percent of opposers reported knowing that wildlife biologists monitor furbearer populations and conduct scientific studies to ensure that trapping and fur hunting do not remove too many animals would make them more likely to find trapping acceptable. Twenty-eight percent of opposers reported knowing that trappers buy licenses and pay other fees that are used for wildlife habitat protection and other conservation programs that benefit a wide variety of wildlife would make them more likely to find trapping acceptable. Twenty-five percent of opposers reported knowing that state, national and international laws make it illegal to trap endangered and threatened species would make them more likely to find trapping acceptable. Twenty-four percent of opposers reported knowing that the Illinois Department of Natural Resources and wildlife biologists support regulated trapping as an ecologically sound method of harvesting most furbearers would make them more likely to find trapping acceptable. Twenty-four percent of opposers reported knowing that people under the age of 18 must pass a special course sponsored by the Department before they can purchase a trapping license would make them more likely to find trapping acceptable. Twenty-two percent of opposers reported knowing that most trapping in Illinois occurs only during 60 to 65 days of the year would make them more likely to find trapping acceptable. Finally, 10 percent of opposers reported knowing that the sale of furs from wild animals adds an average of $5 million per year to the Illinois economy would make them more likely to find trapping acceptable.

Sources of Information on Trapping

Respondents were presented with several different sources of information on trapping and were asked to report which source they would consider to be the most credible. Overwhelmingly, the Illinois Department of Natural Resources was selected as the most credible source for information about trapping (64 percent). Following the Department were animal rights organizations, with 15 percent of respondents reporting them as the most credible. Respondents also were asked where they had received their information about trapping. Responses varied from friends and family, magazines and other publications, such as newspapers, television, life experience in general, the Department and the survey itself, as being their source of information on trapping.

[1]An opposer was defined as a respondent who reported moderate or strong disapproval to trapping in general at the beginning of the survey.

Video Development

Telephone survey data was used to select spokespersons, key messages and supporting facts which were most likely to result in increased positive opinions on fur hunting and trapping in Illinois. The major implications of the telephone survey for the video included:

- Positive opinions on trapping and fur hunting can be increased with appropriate messages.
- Trapping for animal damage control, population control and as part of a biological study should be highlighted in educational programs and materials in Illinois. Trapping as a way to make money, being close to nature and for sport would not be effective arguments in attempts to increase positive opinions toward trapping and fur hunting in Illinois.
- Issues that should be stressed in educational materials must include: (1) laws require daily trap checks, limit trap sizes and prohibit certain types of traps to help ensure that trapping is as humane as possible; (2) seasons are structured in autumn and winter for many reasons, including to help ensure that newborn animals are not trapped or left helpless; (3) wildlife biologists monitor furbearer populations and conduct scientific studies to ensure that trapping and fur hunting do not remove too many animals; and (4) fur hunting and trapping do not cause wildlife to become endangered—animals hunted and trapped are abundant.
- An Illinois Department of Natural Resouces employee should be spokesperson in the video.

Focus Groups

Two focus groups were conducted to test the effectiveness of the video, "Fur Hunting and Trapping in Illinois." The focus groups contained 8 to 10 people recruited to represent urban Chicago residents to gauge reaction to the video and provide new insights, new hypotheses and understanding through the interaction process. The use of focus groups is an accepted research technique for qualitative explorations of opinions, attitudes, motivations, and behavioral predispositions and practices.

Focus groups are group-depth interviews, in that a small group of participants is interviewed at length about a single subject. Focus groups are widely used in market research and political science, especially applied politics, for exposing attitudes, values and responses to policy issues. The technique has been used by several state fish and wildlife agencies to uncover public opinion and attitudes toward a variety of fish and wildlife management-related topics.

The method of conducting the focus groups used in this study was to have the moderator conduct a two-hour discussion on the video, and opinions on and attitudes toward fur hunting and trapping based on viewing of the video. First, the video was played in its entirety for focus group participants. Participants then were asked for their opinions on the video, including what they liked and did not like, the credibility of the spokesperson, and how the video changed their opinions on fur hunting and trapping.

The role of the moderator was to keep the discussion within design parameters, but not to exert a strong influence on the content of the discussion. In this sense, focus groups are non-directive group discussions and expose spontaneous attitudes of small groups. A focus group facility was contracted to provide a suitable location, pay participants the cash incentives and serve refreshments to participants and observers. The focus groups were video and audio taped and observed unobtrusively through one-way mirrors. Analysis was based on firsthand observation, discussion with other observers and the moderator, comparison with independent analysis and repeated reviewing of the discussion tapes.

Development of Final Video

Overall, focus group respondents reacted positively toward the video and positive opinions on trapping increased. Respondents reacted positively to the video's host, Bob Bluett of the Illinois Department of Natural Resources. Respondents found Mr. Bluett likeable and credible. Respondents reacted positively to the "man on the street" concept and felt that fur hunting and trapping were treated fairly. Respondents also were impressed with a segment stating that the Illinois Department of Natural Resources supported regulated fur hunting and trapping. A few segments, however, were not well received. A section that highlighted a furrier pointing out that the whole animal is used, not just the fur, was not considered credible. This section was deleted.

Conclusion

Comprehensive planning, telephone survey and focus group research were invaluable in developing an effective education program to increase positive opinions toward trapping and fur hunting and to gain informed consent that fur hunting and trapping are legitimate and beneficial activities for American society.

Acknowledgments

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"Wildlife is About as Exciting as Recycling" and Other Viewpoints from the "Uncommitted Public"

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For years, state fish and wildlife agencies have monitored the behavior, attitudes and beliefs of people who hunt, fish and trap. Agencies also have researched attitudes of a small, vocal minority that opposes hunting, fishing and trapping. The purpose of this research was to collect information about the majority of North Americans who do not hunt, fish or trap, or actively oppose these activities—known as the "uncommitted public." The uncommitted public is commonly cited as representing 80 percent of the North American citizenry. Relatively little is known about this population's attitudes and beliefs when it comes to fish and wildlife.

The International Association of Fish and Wildlife Agencies (IAFWA) and its member state and provincial fish and wildlife agencies seek a better understanding of this uncommitted public because it represents a key constituency for agencies, both politically and as identified in most agency mission statements. Agencies also need a better understanding of the uncommitted public to ascertain their expectations and determine how best to meet their needs.

In 1990, IAFWA began a major effort called the Proactive Strategies for Fish and Wildlife Management Project (Proactive Strategies Project) to help agencies maintain public support in the face of anti-management opposition (Race et al. 1991). The project's goal is straightforward: "To provide effective strategies to maintain and increase support for professional fish and wildlife management and long-term conservation programs." A key component of the Proactive Strategies Project is stakeholder analysis—identifying groups and individuals with an interest in fish and wildlife management and analyzing their perceptions about fish and wildlife issues. Many groups were analyzed, both in favor of and opposed to wildlife management. To add another dimension to the stakeholder analysis, a series of four focus groups with the uncommitted public was held in March and April 1994.

Focus Group Methodology

The focus group technique was developed by Merton and Kendall (1946, Merton et al. 1956) in the 1940s as an outgrowth of research on extended interview techniques. Focus groups are used frequently in market research and applied political science to expose attitudes, values and responses to new products or policy issues (Templeton 1987). Unlike surveys, focus groups are "qualitative" rather than "quantitative" research. Focus group results cannot be quantified like results of surveys using scientific random samples. Instead, focus groups allow researchers to determine the reasons behind initially stated opinions and perceptions. Particular attention should be paid when focus group participants reach widespread consensus.

For each focus group in this study, a moderator, Bob Stein of Fleishman-Hillard Research, facilitated a two-hour discussion on wildlife and wildlife management. The moderator's role was to keep the discussion within design parameters, but not to exert a strong influence on the content of the discussion. A topic guide to help the moderator focus the discussion was developed in advance by Mr. Stein and staff of the Proactive Strategies Project. Standardized methodology, fee schedule and rules of ethical conduct were observed (Krueger 1988).

Four focus groups were held: one each in the Midwest (St. Louis, Missouri), West (Phoenix, Arizona), Northeast (Cherry Hill, New Jersey) and Southeast (Atlanta, Georgia) to correspond with the regional associations of fish and wildlife agencies. All focus groups were held in large metropolitan areas to coincide with the 80 percent of the North American public that lives in urbanized areas. Telephone recruiting of participants was coordinated by Fleishman-Hillard as a standard service offered to their clients.

The objective for the focus groups was to talk to people who are not involved in hunting, fishing or animal rights, but who are at least minimally informed about other areas of public life. Accordingly, telephone respondents were screened for individuals who are registered to vote and either regularly read the newspaper or watch the news on television. A total of 51 individuals (12 to 15 per focus group) participated in the focus groups. Group participants had household incomes greater than $15,000, were between the ages of 21 and 70, and were equally balanced between men and women.

An important component of the research design was the presence of observers from fish and wildlife agencies. For each focus group, local fish and wildlife agency representatives watched and listened to the group, concealed by a one-way mirror. Participants were informed of this presence, but could not see or hear the observers or be distracted by them. Feedback from observers was captured during debriefing sessions immediately following the focus groups. Analysis of the focus groups was based on firsthand observations by the moderator, discussions with observers and review of audio tapes made of each session.

Results

The Uncommitted Public Reminds Us of the Breadth of the Animal Kingdom

To set the stage for discussion of fish and wildlife topics, focus group members were asked to name the animal they find most interesting. Participants in all groups except Phoenix were more likely to name a domestic animal as a wild one. Dogs were the animal most often considered interesting, followed by cats. The reasons given for interest in these animals often were anthropomorphic in nature: dogs were described as friends, monkeys as almost human, raccoons as cute. Perhaps even more revealing was that so few participants named animals that are actively managed by state fish and wildlife agencies.

When asked to define "wildlife," participants in all groups named "deer" and either "ducks" or "birds." All groups except Phoenix mentioned fish and opossum. Phoenix participants mentioned a slightly different array of wildlife than the other groups: they alone mentioned rodents, lizards, scorpions, javelina, bighorn sheep and elk.

Man is the Primary Threat to Wildlife

The uncommitted public viewed man as the primary threat to wildlife. Man is encroaching on animal habitats, polluting the environment and has removed natural predators. Only in the St. Louis group was natural disaster mentioned, largely due to the highly publicized impact of the 1993 flood on displaced deer. Basically, this public was sympathetic to wildlife and encroachment issues.

Wildlife is About as Exciting as Recycling

The uncommitted public accidentally encounters wildlife; they do not seek it out. Their day-to-day image of wildlife is based on what they see—squirrels and songbirds and occasional rabbits. They see deer occasionally along the road. They may see a wild animal peripherally while cruising down the highway at 60 miles per hour, or drive around a road kill. They may see wildlife while walking for exercise or through a parking lot. Encounters with wildlife during outdoor activities such as biking, horseback riding or picnicking were considered bonuses but not fundamental to the activity. One of the more memorable depictions of wildlife was the hospital worker who enjoyed seeing the squirrels and birds as she left her job each day. This was meaningful, enjoyable wildlife appreciation for her. Casual backyard bird watchers expressed the same type of satisfaction. Their encounters with wildlife typically were fleeting and an adjunct to some other activity. One person explained that her concern about wildlife was equal to her interest in recycling. While recycling is socially acceptable, it is "nothing to get excited about" and represents a rather mundane activity. This characterizes how many in the focus groups felt about wildlife—they support it, but don't miss it if they don't see it. Interestingly, for many participants, some of their most intense exposure to wildlife was watching nature programs on television. Most of their understanding of endangered species seemed to come from this type of programming.

When asked to name outdoor recreational activities that involve wildlife, all groups mentioned fishing, hiking and camping, and all but Cherry Hill mentioned hunting. At the same time, hunting and fishing were discussed by all groups as natural and appropriate recreational activities. Significantly, none of the participants used the terms game/nongame or consumptive/nonconsumptive to describe different categories of outdoor activities.

Hunting Game for Food is Acceptable

Focus group participants repeated messages about hunting as a means of population control, but did not appear to place much stock in this explanation as a motive for hunting. Participants felt that hunting for food is acceptable, however, they believe that many hunters are involved primarily for sport, not food. Hunting purely for sport and trophy hunting were viewed negatively. When asked to name the benefits of hunting, participants named social benefits, food, animal population control, and funding for conservation and animal reserves.

"Guns" and "bow and arrow" were the weapons most often named as used for hunting. Some participants were uncertain of the difference between a shotgun and a rifle. Archery was acknowledged as the most sporting way to hunt, and archers were accorded the most respect. No objections were noted to hunting on public lands. Some safety concerns were mentioned—such as a concern for people hiking or camping during hunting seasons.

Several people emphasized that hunting is a tradition passed down from father to son. Opinions about hunting as a tradition varied from "a positive intergenerational bonding" to "a negative male bonding experience, where beer drinking is more important than respect for the game, safety, or the environment." A key determinant of attitude toward hunting appeared to be experience. As one participant pointed out, "It comes down to exposure; if you've done it, it's okay."

Hunters Receive a Mixed Review:
To Some, the Stereotypical Hunter Drinks Beer and Kills Indiscriminately

Hunters themselves received a mixed review. The dominant stereotypes of hunters tended to emphasize the negative—"redneck" and "beer drinking" were common descriptors of hunters. Some participants said that hunters can be respectful of nature, quiet and unassuming, skilled, and only kill for food. A few participants appeared to view hunting as detrimental to family life (focusing on hunting rather than family).

As with hunters themselves, hunting ethics were thought to vary. Some participants realized that hunters contribute to conservation through their license fees. Other participants felt that some hunters respect wildlife and the environment, while others do not. Overall, participants recognized that there is a spectrum of hunters that like any other group includes responsible and irresponsible elements.

Trapping is Not Socially Acceptable

Focus group participants exhibited mostly negative views toward trapping. They described trapping as something practiced in colonial times rather than as a modern practice. While a few acceptable uses were noted (i.e., moving animals without harming them or trapping pests), most participants said they consider leghold traps to be cruel. Surprisingly little concern was shown for animals raised commercially for their fur.

Attitudes toward Fishing are Positive

Fishing was viewed as much more benign than hunting and attitudes toward fishing were positive overall. Compared with hunting, fishing was considered more relaxing, safer, more of a family pastime and more socially acceptable. One participant said that fishing doesn't impact the environment like hunting. Several people pointed out that a fish makes the decision to take bait, whereas a deer has no choice about being shot. Focus group participants had no negative feelings toward killing fish. Comments included, "fish aren't cute; people don't bond with fish" and "people don't form emotional attachments to fish." Negative comments regarding fishing were that "it's expensive" and "the rewards are small for the work involved." Not surprisingly, while focus group participants' personal experiences with hunting was very limited, many had fished at some point in their lives.

Anglers are Perceived as Kind, Introverted, Family Men

Overall, focus group participants saw the typical angler as less macho than hunters and described anglers using adjectives such as "kind," "patient" and "caring." Only one person made a negative comment that anglers can be sloppy about beer cans. The St. Louis focus group alone pointed out that the same person can be both a hunter and an angler.

Overall Familiarity with Agencies Responsible for Fish and Wildlife was Low

Focus group participants were largely unfamiliar with the state agencies responsible for managing fish and wildlife. When asked what agency is responsible for wildlife in their state, most people outside of Missouri could not name their state fish and wildlife agency. St. Louis participants were aware of the Missouri Department of Conservation and have a high opinion of it. Those Phoenix participants who are aware of the Arizona Game and Fish Department hold a positive opinion of it, however, most participants knew nothing about the agency. Cherry Hill participants appeared to have limited knowledge of the New Jersey Division of Fish, Game, and Wildlife, and one participant suggested that the agency must be doing a poor job since he had never heard of them. Most Atlanta participants could not name the Georgia Department of Natural Resources, but those who could believe that the Department is doing a good job but needs additional manpower and funding. Overall, there was a willingness to support state fish and wildlife agencies for protection of wildlife, preservation of wildlife areas and education about wildlife. However, there was limited awareness of what agencies are doing in these areas, with the notable exception of Missouri. Many participants stated that state fish and wildlife agencies need to do a better job promoting their programs so the public knows what they're doing; however, at least one individual felt strongly that agencies should spend money on doing the job rather than building an image.

The Ideal Fish and Wildlife Agency would Preserve Wildlife and the Environment, Enforce Rules on Use of these Resources and Educate the Public on Proper Use of the Wildlife Resource

Participants believed that government's role in fish and wildlife management is to safeguard and control the use of wildlife and the environment. Participants felt that the ideal fish and wildlife agency would be responsive to the needs of both hunters/anglers and non-hunters/non-anglers. They believed the ideal fish and wildlife agency would preserve wildlife and the environment, enforce rules on the use of these resources and educate the public about proper use of the wildlife resource. The uncommitted public said they wanted their state agency to provide them with more information on agency activities, to educate the public through outreach programs and the media, and to keep them informed on recreational opportunities and programs.

Discussion

This research represents, to the best of our knowledge, the first attempt to sit down and discuss wildlife issues in depth with the uncommitted public. As such, we consider our findings preliminary and hope that more research will be done on this group of constituents. Nevertheless, we feel that our results have significant implications for fish and wildlife management, and would like to draw some broad conclusions.

Diverse Values

Decker et al. (1991) caution wildlife professionals that wildlife management is a value-laden enterprise and that managers need to be aware of differences between our personal values and those of various segments of society. Based on our research, the wildlife values of the uncommitted public are very different from those of agency employees and other more "typical" agency constituents. The uncommitted public held essentially positive values toward wildlife and most wildlife-related activities, but did not consider wildlife a high priority in their day-to-day lives or as an important component of their outdoor activities. Fish and wildlife agency employees, on the other hand, tend to possess an almost fervent devotion to wildlife, as do many hunters, anglers, bird watchers, animal rights activists and other constituent groups with whom agencies routinely interact.

The lesson to be learned is that, as professional resource managers, we cannot assume that we know what people want. We must actively seek information on different publics' needs and wildlife values. Because the resource is so important to us personally, many in our profession believe that the vast majority of Americans actively support wildlife programs. Focus group participants displayed what best could be described as tacit support for wildlife—they were glad that somebody was protecting and managing wildlife, but their support was secondary to other interests/activities in their lives. Their concern for wildlife is analogous to public concern for efficient highways or clean air—it is important to them to know that somebody is taking care of it, but not important enough to get personally involved.

They Don't Know Who We Are

Two recent studies conducted by Responsive Management corroborate our finding regarding the public's overall lack of awareness of their state fish and wildlife agencies. In a recent update to an earlier survey of Floridians, only 23 percent of telephone respondents could correctly name the Florida Game and Fresh Water Fish Commission as the state agency with management responsibility for wildlife; 78 percent either answered incorrectly or did not know (Duda and Young 1995). When asked specifically to identify who was responsible for managing and protecting wild animals in Maryland, 74 percent of Maryland residents said they did not know (Duda and Young 1993). The uncommitted public knew that *somebody* was protecting and managing their wildlife, they just couldn't say *who*.

Is this a problem as long as hunters and anglers know who we are? We think so. Demographic changes across North America are impacting public perceptions about fish and wildlife management and participation in wildlife-related recreation (Applegate et al. 1984, Celente and Milton 1990, Miller 1991, Witter 1991). In the not-so-distant future, traditional supporters of fish and wildlife agencies, white male hunters and anglers, will make up a smaller proportion of the population. Fish and wildlife agencies will be less able to rely solely on this shrinking group of strong supporters to sustain programs, and will need broad support from other groups of constituents and the public at large. If they don't know who we are, then how can we expect them to support us?

The antihunting debate has forced most fish and wildlife agencies to realize that not enough attention has been given to our more "nontraditional" publics. Granted, this has been due largely to the fact that agencies' funds come from the sale of licenses, and agencies are appropriately committed to putting those monies back into programs for consumptive users. We would argue, however, that one of the reasons animal rights activists are able to impact wildlife agencies is because agencies don't have the outspoken support of the majority of their constituents, nor are these constituents aware of how the agency benefits wildlife. If they don't know what we do, someone else can easily convince them that we are not doing our job.

We face competition from sources other than animal rights groups for our "customers." Who else provides wildlife-oriented programs to the uncommitted public—numerous organizations, such as The Nature Conservancy, National Audubon Society and National Geographic; media sources including the Discovery Channel, USA Today, Reader's Digest and Time magazine; and companies such as The Nature Company, to name just a handful. Many of these groups do not market a program, *per se*, but they market ideas or messages. Many we would agree with—they tend to stress conservation and sound resource management. However, there are other groups whose message is completely counterproductive to professional fish and wildlife management. Focus group participants told us that some of their most intense exposure to wildlife was watching nature programs on television—if nature programs on television emphasize African gorillas or dolphins, how does this affect support for or knowledge about local fish and wildlife? Are people more likely to be concerned with habitat loss affecting the mountain gorilla than with habitat loss affecting the peregrine falcon? Do people send their charitable contributions to the World Wildlife Fund or Greenpeace instead of the Nongame Checkoff Program in their state?

Focus group participants believe that the ideal fish and wildlife agency would preserve wildlife and the environment, enforce rules on the use of these resources and educate the public about proper use of wildlife resources. State fish and wildlife agencies routinely do these things, and do them well. The uncommitted public also said they wanted their state agency to provide them with more information on agency activities, to educate the public through outreach programs and the media, and to keep them informed on recreational opportunities and programs. State fish and wildlife agencies also provide these services, but they evidentally are not apparent to everyone interested in them. Fish and wildlife agencies do good things for wildlife and people; we need to find a way to ensure that the majority of our constituents believe it as much as we do.

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Diversity: Maintenance Tips for a Double-edged Sword

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A *Practitioner's Instant Diversity Kit* is what many wish they had to help them deal with this complex issue—or, a simple, quick, politically correct fix. Unfortunately, the challenges of workforce diversity are complex and delicate, requiring change processes that often are labor intensive and costly. Committing to diversification of the workforce and implementation of diversity programs demands dedication to the concept and its attendant issues; it also may require paradigm shifting from viewing diversity programs as "extras" to thinking of them as organizational "necessities." But *how can directors and managers be expected to commit to a concept that is propelling forward from its own popular inertia within a dearth of empirical support?*

Part of the problem is that there is no widely held agreement among academicians and practitioners as to a construct for diversity—no clear understanding of what diversity is. Natural resource agencies can benefit from borrowing expertise from other professional fields such as organizational and human resource development. The bottom-line is that where diversity is concerned, quick-fix approaches don't work; bandwagon jumping can be lethal (Baytos 1992, Rice 1994).

Fish and wildlife agencies may have three choices related to diversity. One, they can do nothing, pretending this whole diversity thing will just go away on its own or get lost in the increasing heap of more urgent priorities; or, two, they can "knee-jerk" to political pressures, select an attractive bandwagon and jump aboard, hoping that the megabucks invested in the consultants, trainers or organizational development interventionists will do the trick. A third choice is that fish and wildlife agencies can be proactive, choosing to invest in the long-term commitment with sincerity and the systemic changes necessary to their strategic operations that will sustain an effective workforce diversity program optimizing their human resource capital.

This paper briefly examines some dimensions of workforce diversity in organization transformation and some implications for fish and wildlife agencies. A metaphor and a model for diversity are presented to stimulate more realistic thinking about an issue that many nod their head to but in reality very little real commitment is given.

A Dangerous Metaphor

Like *leadership*, diversity as a concept remains elusive. In this paper, the metaphor of choice for diversity is a sword—a sharp, double-edged sword: one edge seeing diversity as a necessary and eminent organizational development step for fish and wildlife agencies; the other side representing diversity as a potential block to agency progress. Intuitively, diversity sounds good. Particularly for many of today's fish and wildlife agencies finding themselves in the midst of reinventing and re-engineering, the idea of a collaborative mix of perspectives from employees of differing cultures, ages, ethnic origins and genders *sounds* attractive.

It dangles like bait, offering itself as a potentially powerful source of synergism for creative problem solving. According to Harris and Moran (1993) this is the basis for the popular view of workforce diversity: *diversity equals positive synergy.* The term, synergy, reflects the equally popular notion that the "whole is greater than the sum of the parts." However, there is no empirical evidence to support the idea that diversity *always* equals positive synergy. In other words, synergy could be analogized as 2 + 2 = 5 instead of 4, but, given various cross-cultural barriers such as age, gender, ethnicity or religion, for example, cultural synergy may be the equation of 2 + 2 = 3. Harris and Moran further suggest that progress is made as long as the sum is positive. A more comprehensive consideration of synergy gives rise to hints of a "double edge." For example, a negative result of synergy may imply barriers to progress, such as obstacles to effective communication within the group, personality conflicts or inability to reach consensus causing the group to be less productive/ creative than more.

Overall, synergy is perceived positively. This positive view depicts diversity as capitalizing on work team member differences as a source of innovative and fresh perspectives—precisely what fish and wildlife agencies facing transition need.

A different picture is revealed by the sword's other side. When organizations jump on the politically correct bandwagon and initiate diversity programs without first doing the necessary needs assessment and systems readjustments, often substituting a touchy-feely sensitivity awareness training for a diversity *program*, the proverbial "can of worms" can be opened. Differences between people can be exacerbated, creating a worse situation than before. Diversity is viewed by some as divisive, and deservedly so.

The workforce of fish and wildlife agencies is changing, perhaps more slowly than organizations in business or the private sector, but changing nevertheless. The former fish and wildlife state agency cookie-cutter mold employee, i.e., a white male biologist from a rural setting who hunts and fishes and graduates from a land-grant college later sharing many of his very same professors with agency peers, is giving way to employees coming from a wide variety of educational and demographic backgrounds. They may or may not hunt or fish. They may represent agency member counterparts to the diverse watchable wildlife recreationist constituents emerging in the public.

Also impacting workforce composition is the predicted gradual entry of women into the workforce (Johnston and Packer 1987). This shift in internal demographics brings with it not only a change in the way a fish and wildlife agency workforce looks, but also a differing set of values and skills than workers of past decades. For example, in a nationwide study of fish and wildlife agencies, Angus (1996) found that male and female managers have significantly different perceptions about a number of agency issues, including job satisfaction needs, supportiveness in the work environment, sexual harassment, discrimination and unmet job needs.

In addition, as many long-term employees retire or opt for early retirement, they are replaced by new professional types, ranging from computer technicians, planners, public relation specialists, marketing experts, sociologists, trainers and human resource development specialists. Diverging from the cookie-cutter mold employee, workforce diversification can create a manager's nightmare. In other words, without diversity *management*, comprehensive and dynamic, diversity by itself can put the organization in jeopardy

Thus, a double-edged sword emerges—a dangerous metaphor for diversity. But, diversity is not unlike a handwoven tapestry, depending on which side you're looking at, the threads form a very different picture. While the potential may exist for a diversity program to act as a double-edged sword, an *effectively managed* diverse workforce, nevertheless, continues to offer great potential, a compelling promise for fish and wildlife agencies having to compete today with other agencies and organizations for funding, constituents' support and recreationists' leisure time.

A Model for Diversity

The absence of empirical studies and consequential agreement as to a construct for diversity has contributed to the difficulty of launching diversity programs. Current approaches to diversity basically fall into three categories: 1) the *traditional approach*, an affirmative action increase-the-numbers model which assumes that a melting pot assimilation of differences will occur; 2) the *understanding diversity approach*, a model which enhances employees' abilities to accept, understand and appreciate differences among individuals; and 3) the *managing for diversity approach*, an emerging model which combines some of the traditional approach with the kind of systems changes in the second model that effective diversity programs might require in order to be successful. According to one rare, recently conducted empirical study by Rynes and Rosen (1995), organizations that embrace a broader, more *holistic* definition of diversity are more inclined to see success regarding their diversity training initiatives.

This author views *managing for diversity*, as the most promising. Such a view would see the objective of managing diversity as creating an environment that fully taps the potential of all individuals, in pursuit of organization objectives, without giving advantage or disadvantage to any person or group of persons (Thomas 1990, Gardenswartz et al. 1995). This approach also comes closer to the more holistic definition recommended by Rynes and Rosen (1995).

Gardenswartz and Rowe (1993) suggest distinct stages in the evolution of diversity within an organization. The integral parts of *affirmative action, valuing differences* and *managing for diversity* overlap both in philosophy and practice. In addition, Gardenswartz and Rowe see these stages or diversity components as types of *openers*: affirmative action opens doors, valuing differences opens minds (changing attitudes, beliefs), and managing for diversity opens systems, affecting managerial policies and practices. They further suggest that each of these aspects of diversity may have a different driver: affirmative action driven by legal considerations, valuing differences in employees driven by ethical considerations and managing for diversity being driven by organizational strategic plans and goals.

In a diversifying workforce, the human dynamics of social interaction are too complex to be handled adequately by one model (Miller 1994). This paper proposes a hybrid or composite model to facilitate a more comprehensive consideration of the subject. Drawing from the three approaches to diversity: traditional, understanding and managing for diversity, combined with a consideration of evolutionary stages of diversity, as suggested by Gardenswartz and Rowe (1994), the new model emerges, facilitating a more holistic way to look at this complex subject (Figure 1).

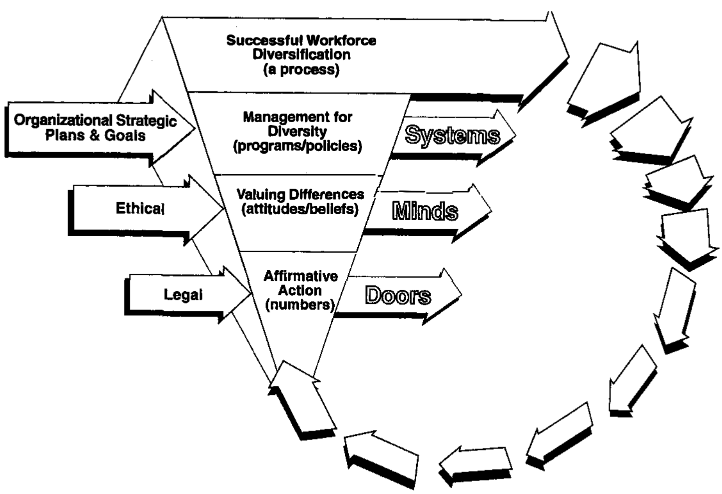

Figure 1. A proposed composite or hybrid model for diversity.

Seven Cs for Diversity Sharpness

While recognizing that a "sword" with a double edge can cut and do damage, dullness can be even more dangerous. Actively choosing to keep one's "sword" sharp can be thought of as choosing to have a better tool, an *effective* agency diversity initiative. The following are seven suggested tips for agencies to consider in the process of developing an effective and successful diversity program:

- choose rather than coalesce to diversity;
- cultivate your own current work culture;
- create an environment of freedom and respect;
- counter conflict with congruence of differing values;
- codify calmness and courage;
- commit to the long-term with champions; and
- celebrate the smallest of diversity victories and achievements!

Choose rather than coalesce to diversity. Make it a matter of good decision making, planning and foresight; select the high road. Choose to develop a diversity program because it fits the organization's philosophy and values, rather than as a result of perceived peer pressure or some bandwagon with easy jump-on access promising to make you look smart.

An agency may want to consider doing some organizational identifications, i.e., identifying organizational barriers to diversity initiatives, the real costs of implementation, where the fears may be toward hiring diverse individuals, what the merit system is *really* like (does it favor any individuals or groups, or need changing?).

Cultivate your own current work culture. While diversity may be a theoretical construct having no widely held agreement, that doesn't mean an organization should stand still and do nothing while it's workforce continues to change gradually, emerging with it the required different forms of management. Whatever an agency does with regard to diversity needs to be part of the organization's overall planning linked with programs and outcomes, not piecemeal. Agencies may find that they need to conduct surveys to assess values and needs. They may need to recruit in very different ways in order to attract a more diverse applicant pool. To facilitate this type of recruiting, an agency making the paradigm shift from an affirmative-action view of diversity to seeing it as a value-added organizational program necessity also will need to put forth an effort to inform their external constituents of this significant change in organizational attitude.

An agency may want to address the misperceptions of some that diversity would inadvertently dismantle everything accomplished so far, i.e., the development of a new agency culture by trashing all of the former.

Agencies may need to invest in establishing dynamic mentorship programs and/or work study arrangements. Training may need to be conducted with feedback and tie-in to policies and programs and individual professional development plans. Managers and leaders may need to do a lot of listening and a good deal of asking.

Create an environment of freedom and respect. The hallmark of an effective and enduring diversity program is one built on awareness and respect of one another's differences and the consequential trust in one another to be free to self-express, however differently.

Counter conflict with congruence of differing values. Expect conflict to emerge, but know that conflict is not always a bad thing. This is normal when there are differences between individuals and/or between individuals and the organization. Conflict, managed effectively, can be an effective catalyst for creative thinking. Remember, ***not all groups an effective team will make***! If the agency is serious about teams, care and time must be given to their selection and development. Managers may need to learn *how* to do this.

Codify calmness and courage. As a workforce diversifies and evolves, as individuals move from awareness of differences to acceptance, a certain degree of discomfort is inevitable. For example, some agency members may fear that diversification of the workforce within their agency will increase grievances filed, increase incidences of sexual harassment or result in others not liking them anymore. Resistance can come from fearing change itself. Some may fear the possibility that they will suffer reverse discrimination. Others may misunderstand diversity in general as only affirmative action. Still others may feel that diversity will be of advantage to certain groups, the exact opposite of its ideal intent. Finally, others may look at the dollar costs and worry about costs to benefits for the agency overall. These are all legitimate concerns warranting explanations.

Courage is needed to keep the initiative moving forward even when it doesn't feel good and to institutionalize the processes for employees working together amidst differing values. An effective diversity program will nurture calmness, like islands in a storm, as the organization in transition moves steadily forward in spite of inevitable emotional disagreements.

Commit to the long term with champions. Fish and wildlife agencies often are influenced by political appointments and elections. Particular leadership often is of short duration. Therefore, of necessity, no particular leader or style of leadership can be counted on to ensure a lasting diversity program within an agency. Consideration may need to be given to these political constraints and a strategy adopted that will enable the program efforts to endure changes in leadership at the top of the agency.

This paper suggests that efforts to gain the buy-in from management necessary for program survival be adjusted by using a continuously visible "third line down" strategic approach. Such an approach targets those in the organizational line below the deputy director level to obtain iron-clad commitment from management while allowing changes of leadership above with minimal disturbance to the diversity initiative in the organization overall. Then, add the additional step of melding the commitment of such third-line champions with citizen participation input and approval for a powerful insurance strategy.

Celebrate the smallest of diversity victories and achievements! Diversity in the workforce essentially is the organizational culture, evolving through its own inertia or by design. As an issue, diversity has moved past emphasis solely on getting in the numbers. Today, in addition to demographics, diversity will need to address the underlying values and needs. While the predictions of the *Workforce 2000* (Johnston and Packer 1987) report are a reality in many places, human resources experts estimate that only 3 to 5 percent of U.S. corporations are diversifying their workforces *effectively*. Unlike much of the work that fish and wildlife agencies do, which typically produces a product within a defined time line, managing for diversity is a process that is without an end; it's labor-intensive, being productive only after many positive little steps (Gardenswartz et al. 1993, Rice 1994, Sheinberg 1994, Thomas 1990).

Conclusion

The long-term effort of changing culture is important work, since it is culture, according to Sheinberg (1994), that creates meaning in any organization. As suggested by Thomas (1990), perhaps managing for diversity is a *process* rather than a solution, *enabling* rather than controlling, and perhaps it is *broad* in dimensions rather than limited to race, gender or ethnicity. But, such a diversity management approach *assumes* and *requires* that both the organization and the individual do some adjusting.

Has the historical, characteristic missionary zeal unique to fish and wildlife agencies insulated agency leaders from the need to manage for cultural and value differences between employees? Considering the demographics and attendant value shifts within and outside fish and wildlife agencies, informed management is important at this time when agencies are in critical need of optimizing their human resource capital. Managers proceeding forward with cultural and systemic interventions and initiatives at the individual and interpersonal levels, without the requisite research base and/or level of necessary commitment, may make costly decisions without achieving the potential benefits. Handle a double-edged sword with care.

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Beyond Rhetoric: Facing the New Realities in Fish and Wildlife Agency Management

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Had they possessed the means to do so, the dominant life forms in North America might have had a meeting such as this about 200 million years ago. They would have booked a nice hotel somewhere in the middle of a Mesozoic forest, with lots of great places to eat and drink nearby. They would have sent only the best and brightest of their various species. Indeed, it would have been a great honor to be selected to attend. Perhaps they would have had committee gatherings a couple of days beforehand, with separate committees for carnivores and herbivores in order to avoid unpleasant events involving velociraptors or tyrannosaurs. They would have had, no doubt, splendid orations by renowned saurians. Perhaps after some opening remarks by their esteemed leaders, even some dino-politicians would have graced the podium. Then might have come a seemingly endless parade of technical papers: "Impacts of Predation on *Triceratops*," "Food Habits of Northern Pterodactyls" and "The Effects of Lightning-caused Fires on Stegosaur Foraging Habitat." A few days later, after some heavy-duty foraging and schmoozing, they would have picked up their briefcases and headed out, each for his or her own habitat and all ultimately for extinction. They might have had a tremendous meeting, but they couldn't deal with change. Despite their successes dating back millions of years, they failed to grasp the emerging realities of their own environment.

Wildlife managers in 1995 are in a similar situation. Despite a record of successes going back a full century, we find ourselves harried by a host of special interests, constantly competing and conflicting. We find ourselves a force staffed and lead by baby-boomers, children of the "environmental age" and veterans of Earth Day. Yet, we are faced with a fierce attack on our most hard-won victories, like the Endangered Species Act and the Clean Water Act. We sometimes feel "out of synch" with America, out of step with much of society, and we sense the righteous fire of our youth being replaced with a sense of discomfort and even cynicism. This is not the mid-life crisis of a generation inspired by Aldo Leopold and Rachel Carson. It is much more than that. The waning years of the 20th century are chaotic times for fish and wildlife managers. One of our colleagues describes the chaos in his agency as "trying to change a flat on a car that's going 100 miles per hour." Truly, this paints a picture of managing in chaos. He goes on to say that only after considerable thought did he realize that the car had to be stopped somehow in order for the flat to be fixed. Unhappily, it's usually a wreck that brings the car to a halt, and then a lot more than the tire needs fixing!

We two authors admit to being change junkies, stimulated by the opportunities that change brings, neither afraid nor reluctant to embrace change. But we also are unerringly dedicated and committed to the fish and wildlife business. We wouldn't do what we do for Sears, Microsoft or General Motors. We care enough about the future of this business to talk somewhat directly about the things we think need improving. We speak candidly because we think that therein lies the only hope for the future of fish and wildlife resources and those who care about them.

The Big Problem

The theme of this North American Conference is "facing realities in resource management." That's a good theme, but it isn't the realities in resource management that give our profession the most trouble. It's the realities in resource *agency* management that need to be dealt with! Three years ago, in another session on agency management (Dubrock and Amend 1993), we sounded a warning. We said that unless agencies took on a concerted effort to increase their effectiveness, there were troubled waters ahead. Many of you have tested these waters. We find ourselves now sounding that warning again—louder, shriller and with more concern than ever. *We have a problem,* and you all know it: we have failed to grasp the emerging realities of the 21st century. To wit:

We have failed to recognize our role, or the role of fish and wildlife, in the hearts and minds of America. Despite the fact that we're a big deal to ourselves, the fish and wildlife business is a small business in society's terms. Consider that most leaders in the business probably are in this building somewhere today and you see what we mean; we aren't really a very big piece of the overall puzzle. It is important to remember that fish and wildlife are luxury items in the grand scheme of civilization. It also is important to remember that, just because we see ourselves as the leaders in the fish and wildlife business, it doesn't mean others see us that way. Many people who have a vital interest in fish and wildlife conservation see us as part of the problem, not the solution.

We are a business, and we are in competition with other businesses. The fish and wildlife business has to realize that it is part of a much larger business—the recreation business—which competes for people's time and money with still other uses of leisure time, like museums and concerts. And that leisure time—seemingly illogically, but truly—is becoming more scarce, not more abundant.

We have failed to deal with the social, economic and political realities of fish and wildlife conservation. As we prepared this paper, we reviewed a pretty good cross-section of the research being done on fish and wildlife today. We found that some of the same studies we personally did decades ago are continuing today; we're not moving ahead on what we've learned. For example, one of our favorite college debates is continuing: do a researcher's responsibilities end when she completes her research, or does she have an obligation to get involved in the messy business of public policy development, using her research results? This, folks, is not progress.

We have said it before (Amend 1993) and we will say it again: *The truly big decisions facing resource managers are settled more on the basis of economic, social or political concerns, rather than biological or technical concerns.* It is these socioeconomic and political issues that cause most of our agency disasters. We know this. To illustrate the concept, we've developed a crude risk analysis for looking at fish and wildlife agency agendas—and it isn't a pretty picture.

This risk analysis process was first developed several years ago by Jack Gross and some of our other colleagues at the Systems Applications Group. The technique requires classification of programs, projects or activities as to whether they are focused on the economic, social, political, biological or institutional aspects of management, and then creating an index of risk for each data set. The indices represent the ratios of each of the other components to the biological component for that data set. An overall index for each data set was calculated as the ratio of the total of all other components to the biological component. Numbers then were converted to the same scale and scaled such that higher numbers indicate higher risk (Table 1). For this paper, we looked at five data sets representing a cross-section of the fish and wildlife business: (1) The Wildlife Society's (TWS) 2nd Annual Conference; (2) the last five North American Wildlife and Natural Resource Conferences (NAM), including this one; (3) an issue identification/strategic planning session at the last mid-winter meeting of the International Association of Fish and Wildlife Agencies (IAFWA)

Executive Committee; (4) Chapter 6 in the IAFWA history book (Belanger 1988); and (5) the agendas from the last four Business Meetings and Executive Committee Meetings of the IAFWA.

Table 1. Risk analysis for fish and wildlife agencies. High figures indicate higher risk.

	N	Economic	Social	Political	Institutional	Biological	Overall risk factor
TWS	519	0.97	0.93	0.96	0.98	0.0	0.96
NAM	561	0.93	0.88	0.85	0.88	0.0	0.89
IAWFA (issues)	81	0.48	0.86	0.45	0.41	0.0	0.55
History	65	0.50	0.55	0.35	0.35	0.0	0.44
IAFWA (meetings)	238	0.58	0.80	0.48	0.53	0.0	0.59

Comparing relative scores can help determine weaknesses. As shown in Table 1, risk is lowered by either (1) having a balanced interest across all components, or (2) not being preoccupied with strictly a biological or technical focus. Clearly, the issue analysis being done by the IAFWA as part of their strategic planning has more security than either the focus of the TWS conference or the North Americans. Interestingly, the IAFWA history showed a strong sense of relevance and reality. We don't want to use this simple tool to single anyone out for criticism, but it appears that there are some huge holes, at least in the places we looked.

We have failed to be effective in managing our own agencies. This may be the worst failing of all. Our sins are many, but a brief summary might include:

1. we don't focus specifically on the need for good management science skills and, as a result,
2. we lack good internal agency management processes, and continue to "wing it." For example:
    - we are terribly weak at evaluating what we do;
    - we focus on activities rather than accomplishments;
    - we don't allocate our fiscal and personnel resources to the top priorities;
    - we don't accurately account for where and how we spend our resources; and
    - we aren't good at strategic thinking; we worry about the urgent, rather than the important.
3. we continue to behave (as individuals and agencies) with the cavalier attitude of "we know what the right things are... just give us the money and go away!";
4. we don't manage process. Even when we're right, which happens fairly frequently, we often still find ourselves in trouble by doing the right things the wrong way;
5. we don't do very good public involvement;
6. we are poor at communicating internally and worse at communicating externally;
7. we don't take advantage of the benefits of working together—teamwork; and, finally,
8. we are absolutely terrible at dealing with change.

We have failed to gain adequate funding for fish and wildlife conservation. The funds from traditional sources are no longer adequate. The demands and opportunities for the products and services provided by fish and wildlife agencies are not slowing down, but the traditional funding sources are. This does not portend good things in the future unless we do something, now. There are two possible things that can happen when funding starts to get tight. First, we can cut back programs to the level of the existing funding base. Several fish and wildlife agencies currently are in this mode. The second option is to expand the funding base. Many people are working hard to make this a reality, especially in the area of funding for biodiversity. Paradoxically, many people in the same agencies are working hard to make sure it doesn't happen because they don't want nontraditional users in their camp. We simply cannot afford this attitude—financially or politically.

We have failed to be an effective political force. Politicians are using the fish and wildlife business as a whipping post, accusing us of being obstructionist in the face of development; and sometimes we deserve this label. Given the current pro-development attitude in the political arenas of the country, those who would conserve wild places and wild things are being called out as standing in the way of "progress." We may be only a few days or a couple of Congressional votes away from losing a significant portion of the existing funding base. Do we really think Federal Aid funding is safe? We have potential funding dilemmas on both ends: in the worst case scenario, we could lose all or part of what we now have in the way of a funding base, while, at the other end of the spectrum, most of our agencies are ill-prepared for a funding influx if "Teaming With Wildlife" were to be funded tomorrow.

We have failed to take the political offensive. We have failed to advance our own political agendas and endure the slings and arrows of political fortune because we have worked so long and hard at "taking the politics out of wildlife conservation." We cannot afford to be politically ineffective. We must mobilize the active support of our constituents. If we fail to do this, our enemies simply will overrun us.

We have failed to put our own house in order. A colleague of ours likens his agency to a collection of divisional "smokestacks," each functioning independently of the other divisions, and each competing with the others for resources and belching forth its own "smokescreen" of self-promoting messages. This deplorable internal scrapping and competition within our own agencies wastes entirely too much energy and sends the wrong message to our constituents. It angers and sickens us to hear of the "smokestack mentality" between parts of the same agency competing with open hostility for the favor of the politicians. We must grow up and learn to hang together before we all hang separately!

We have failed to do effective marketing. "If you build it, they will come" may work well for backyard baseball stadiums, but it is dead wrong insofaras fish and wildlife is concerned. Participation and enjoyment of fish and wildlife have to be marketed to the customers. We are the stewards of truly one of the best, most marketable products on the face of the earth. We all love that experience, but we fail to take advantage of the opportunity to truly market it. If the people responsible for Pepsi or Tide had the opportunity to market competing fish- and wildlife-related experiences, we'd be out of business in a week. Marketing simply is finding out what your customers want, providing it and making it continually better. We are terrible at it.

We continue to delude ourselves into thinking that, like the dinosaurs, the same adaptive skills that got us here will ensure our future. They won't. In fact, some of the very same skills that were advantages in the past now are disadvantages. As a result, most fish and wildlife managers share a feeling that things are out of control. They don't have enough time to get everything done that needs doing. They know the job never has been bigger or more urgent. And so, they work harder for longer hours, seek fewer outside/family distractions, and wonder why they feel dissatisfied. That feeling of dissatisfaction and newfound cynicism is a huge danger signal that the whole system is about to have a nervous breakdown. We have a real problem.

None of us wants to stand by, watching fish and wildlife conservation grow impotent. We were drawn to this field by a spirit of activism and a desire to make a difference for wild things and wild places. If we are to be successful in dealing with the realities of the future, we must acknowledge that a problem exists. What is the problem? The problem is that fish and wildlife agencies have not yet developed the strategic skills that will enable them to be effective in the future. The fish and wildlife business is never going to be the same—as it is or as it was—as when most of us got started in it. We can quit reminiscing about the good old days, except to the extent it makes the swill sweeter, and get ready for some changes.

The Consequences

One consequence of losing control of our agencies, or suffering "hostile takeovers" where others take over authorities long thought to be the exclusive domain of our agencies, will be our loss of credibility. This loss may come with our customers, other stakeholders, such as legislatures, or even with our own employees. Credibility, as we have found through hard experience, is priceless. It must be earned and maintained through years of hard work. But it can be lost instantly by dealing poorly with a single situation or issue. There are a number of ways to destroy agency credibility (Bleiker 1995). These include (1) allowing someone else to be the first or best source of information; (2) dismissing legitimate concerns or dealing with them as if they were silly or phony; (3) letting others bring up the big, controversial, painful issues—and then getting defensive about them; (4) becoming unavailable for people, including the press; and (5) pretending to know more or less than we really know. We see fish and wildlife agencies doing these things with alarming regularity.

How do we lose control? We fail to adapt. Drucker (1995) and Senge (1990) talk about organizational learning. In ecological terms, this "organizational learning" may be compared with the natural adaptations or evolution that species or populations go through. And, just as with populations or species, organizations that are incapable or unwilling to learn and adapt will become extinct. This is the biggest consequence of all.

The Solutions

Revolutionary changes almost never occur in the public sector. Yet, revolutionary changes are what we think are needed: change in defining agency missions, in empowering dedicated fish and wildlife professionals, in radical decentralization of authority and responsibility, and in development of protocols for dealing with constant change, uncertainty and chaos. We have to get beyond the talking, hand-wringing and table-pounding stage as fast as possible. No one is going to do these things for us. These are not things we can contract out to consultants or entrust to the universities. Only we can develop the skills we need to cope with the emerging realities of the 21st century. Our future does not hinge on doing better biology or better research. It does not rest on doing the same things for the same people. It relies on a new course, and we are the only ones who can steer that course.

The good news is that we can do all these things. We can, and have begun, to develop the skills that we will need to meet the challenges of the 21st century. We have begun to chart the new course for fish and wildlife conservation. Some signs of this include:

We are learning to pursue effectiveness. McMullin (1993) provided eight benchmarks for fish and wildlife agency effectiveness. They are:

- proactive action on issues;
- closeness to citizens;
- autonomy and empowerment;
- valued employees;
- missionary zeal;
- biological base;
- stable, respected, enlightened leadership; and
- political/nonpolitical.

These benchmarks did not come from management theory, nor were they taken from the private sector. They were identified in real live fish and wildlife agencies. There are agencies out there right now working consciously to improve their own effectiveness. Amend et al. (1994) cite dozens of agency "success stories" that range in scope from funding to training and originate from states as diverse as South Carolina and Minnesota. We can all learn from their examples and their successes. None of our agencies is as effective as it could be or as effective as it should be. We simply cannot afford to be performing at less than our full potential in the coming years.

We are beginning to nurture the leaders of the future. Leadership is one of the areas offering the most hope for the future. Fish and wildlife agency leadership includes a variety of factors associated with leadership in private business, but it includes some unique factors, as well. Our understanding of fish and wildlife agency leadership is growing thanks to The Leadership Project, which Virginia Tech is conducting and the Management Assistance Team is sponsoring. So far, working with some of the recognized top leaders in our business, they have identified the main features of fish and wildlife agency leadership, including the following:

- being a good communicator, including being a good listener;
- being fair, balancing justice and compassion;
- leading by example, commonly referred to as "walking the talk";
- motivating and facilitating people to excel;
- being committed to continuous improvement;
- vision—not just having it, but developing the shared vision; and
- integrity, including always being open and totally honest.

Nurturing the future leaders in the fish and wildlife business is one of the biggest challenges we all face (S. Wolff and S. McMullin personal communication: 1996). Academia, the professional societies, regional and national associations, and our individual, respective agencies must all join together in a commitment to develop and nurture the future leaders in our business.

For too long, we have taken a *laissez faire* approach to leadership in our agencies. We have rewarded good researchers, field biologists or habitat managers by placing them in positions of leadership, with only minimal training and almost no idea of the characteristics that made them good at what they did. Some succeeded, most failed, and a great deal of personal and professional grief was suffered on the way. If luck was with us, the right person was in the right position of leadership at the right time and things went very well. If luck was absent, then things went poorly. We cannot entrust the leadership of our agencies to luck. We must begin now to identify the future leaders of our agencies. We must train them and nurture them. We must give them opportunities to grow in stature within the environment of our agencies. And we must embrace the idea that good leadership is important at all levels of the organization, not just the front office.

We are beginning to evaluate what we do. The International's Proactive Strategies Project is a good example of moving a project from the hand-wringing/table-pounding stage to the point of doing something positive and constructive. This important project has produced a number of useful products for fish and wildlife agencies, and now is moving into a phase of training and technical assistance that should result in even greater benefits.

The Proactive Strategies approach works like this. In issue analysis, all agency employees participate in an effort to identify programs and policies which make the agency vulnerable to challenge, litigation or other civil action. In risk assessment, agency management is involved in answering a series of questions designed to identify "chinks in the agency's armor" and developing strategies to lessen or eliminate the risk associated with these weak spots. The two processes unite in a proactive plan, custom-built for the agency to deal with the most potentially difficult issues *before* they become controversial. The process was successfully pilot-tested in agencies as diverse as New Jersey, Manitoba and Utah, and has been implemented in a variety of states, including Wyoming, Colorado and Florida.

We must keep to the moral or ethical high ground. No matter how badly we are abused in the press or at some legislative hearing, we cannot stoop to the level of the abuser. This can be awfully hard to remember sometimes. But the harder it is to remember, the more important it is not to forget. It is an absolute imperative during times of high stress, but it also applies when making personnel selections, program decisions—indeed, virtually all the time.

We are involving more people. This issue has two faces. The first is internal, and it is the part we do poorly. Angus (1995) concluded that, to agency staff, diversity within agencies was a significant issue. But in most agencies, diversity is treated as a non-issue: it is not happening because it simply isn't important to us. It will become important as we begin to consciously consider developing the potential of our agencies. We must pursue diversity. We must get more women in our ranks. We must actively recruit minorities. We cannot hope to be successful in the future as a white, male bastion in a multi-cultural world. We must pursue the development of multi-disciplinary agencies. Our business has evolved beyond its ecology and law enforcement roots. We must recruit and keep not only the best biologists and game wardens, but the best social researchers, marketers, telecommunications experts, computer wizards and educators. But it is not enough to get more and different people involved internally in wildlife conservation.

We must involve society at large in wildlife conservation, especially those who have not been involved in the past. This is a formidable challenge. The real power, and perhaps the ultimate key to our success or failure, is in getting more people actively involved in wildlife conservation. When as many people know about "Teaming With Wildlife" as know about the Contract with America, we will have begun. When wildlife issues begin to drive grassroots politics in America as much as jobs and the economy, we will be well on our way. When we elect a president based on his or her stand on wildlife/environmental issues, we finally will have achieved something.

We are starting to "think outside the box." We are beginning to learn from other businesses. We are even beginning to pay attention to what's going on in the world. The business of business is many times bigger, older and more mature than the fish and wildlife business. We must learn to steal ideas from anyone, anywhere, if it will help fish and wildlife agencies be more successful in pursuing their missions. In Wisconsin, for example, fish and wildlife managers are actively networking with corporations and other organizations to identify and deal with future trends.

This sort of idea sharing is testimony to the adage that we cannot hope to solve new problems with old ways of thinking. We must begin now to form new networks with people outside our traditional sphere of influence. We must begin to share information with other professionals in disciplines far removed from fish and wildlife conservation: physics, psychology, business, computer science, philosophy, sociology and economics. We have much to learn about how these disciplines can help us understand our organizations and our customers. Perhaps we have some lessons to teach, as well.

We are beginning to reward creativity and innovation. Senge (1994) discusses the importance of building a "learning organization," where people are committed to nurturing new patterns of thinking and continually learning how to learn together. Doing so in a state agency bureaucracy is a challenge. Doing so in a state agency involved in the chaotic world of fish and wildlife conservation is an even bigger challenge. But agencies are doing it. For example, in Arizona, the agency makes a conscious effort to provide rewards that are meaningful to its people. In Montana, efforts to identify specific rewards that are important to agency personnel netted more than 40 different ideas that could be implemented. We must identify these rewards.

We must become self-renewing, learning organizations by continually rewarding creativity and innovation. These characteristics are the lifeblood of any organization faced with continuous, rapid-fire change. Unfortunately, most of us work in government, the traditional antithesis of creativity and innovation. We must change that—at least in our agencies. We must find ways to tap into the boundless creativity and energy of people inside and outside our agencies.

We are learning to deal with change and become comfortable with chaos. In what is perhaps the most important recent work on organizations, Wheatley (1992) likens the organizations of the future to a stream. The stream shifts course, adapts and shifts configurations in response to terrain, but the mission remains simple: to move to the sea. In organizations, so, too, should the forms change, but the mission remain clear. Divisions, programs and even products emerge as temporary solutions that facilitate but do not interfere. There is no reliance on artificially imposed answers, forms or past practices. This fluidity and adaptability coupled with singleness of mission is scarce among wildlife conservation agencies, but it is not unknown. The Organization of Wildlife Planners and the National Educational Training Center offer courses aimed at helping agencies prepare for the uncertain future.

It isn't ever going to be easy again. Maybe it never really was. The world of fish and wildlife conservation will grow even more chaotic, a strange and troubling place. Change will accelerate. We must become comfortable with this pace. We must begin to see change as something we can work with, not against. We must begin to see new ways of working as positive stimuli, not as threats. Our hope for the future lies in becoming comfortable with uncertainty, not with trusty old tools and techniques.

Beyond Rhetoric

We don't want to sound like doom-sayers. Indeed, we're very optimistic about the future, given some of the changes and approaches we've talked about. Given those changes, the future of fish and wildlife and those who care about it is more solid than ever. People like fish and wildlife and the images these resources evoke. Even people who are hungry will forgo some of their own comforts to maintain healthy fish and wildlife populations. Not just in this culture, but in cultures around the globe, maintaining healthy fish and wildlife populations is a common cultural value. As the nominal stewards of these resources, we have a very exciting opportunity to turn this cultural value into a healthy future.

Much of this should come as no great shock to those of us who live in fish and wildlife conservation agencies. Certainly, the problems are evident to us all. We are uncomfortable and frustrated because we perceive that the solutions of the past will not work on the problems of the present, much less those of the future. We have identified some potential ways that agencies can deal effectively with those problems. We have even illustrated some examples of agencies taking the first steps toward developing into the agencies of the future. But we must go beyond this. We must go beyond talking about it and begin consciously developing agencies with the skills for the future. To do that, we must be willing to let go of our past. We must be willing to drop our defenses and cultivate a culture of openness. We must be willing to go beyond rhetoric and beyond our comfort zone. We must become comfortable with uncertainty, at peace with confusion.

We must look to our values—our individual values and our "corporate cultures." One of the best places to begin working on the future is to articulate what we believe and what we believe *in*. All the rest is based on these. And, ultimately, we can't get anybody or any organization to change in some way that is not congruent with their own beliefs, values or culture.

Thousands of years ago, someone somewhere sailed a dugout canoe or reed boat out to sea. At some point, they lost sight of land. They faced the uncertainty of travel and the peril of strange waters with a great deal of trepidation, no doubt. There were no charts and only the most primitive sorts of navigational aids—the stars, mostly. But they went, relying on faith, courage and the best compass they knew. And they found a new world. This story could apply to Polynesian seafarers, Sumerian sailors or even our own northern European ancestors. But it also applies to fish and wildlife agencies. We must be willing to lose sight of the comfortable old world in which we have lived. We must be willing to set forth on a sea full of unfamiliar currents and rocky shoals with faith in ourselves and a damn good mission statement as a compass. We must open ourselves to uncertainty, discovery and wonder.

Acknowledgments

We would like to acknowledge a number of people who contributed to making the preparation of this paper extremely satisfying. First of all, we'd like to thank the session cochairs for inviting us to share some of our experiences and biases. We thank Pat Metcalf for her work with the early organizing and support. It was a pleasure to receive the benefits of critical thinking and conversation from MATites Verlyn Ebert, Bob Hays, Mary Hall and Juliette Wilson at a variety of stages. Sheila Cage deserves our gratitude for assuming the large chore of trying to get our disorganized material into presentable shape at the last minute. And, finally, we'd like to thank each other—we had fun throughout the adventure, and we think we make a pretty good working tandem.

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Special Session 3. *Prescribed Fire and Its Effects on Wildlife Habitat and Populations*

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Stillwater

Cochair
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Introductory Remarks

Champe B. Green

Good morning. My name is Champe Green and I like to prescribe burn! I am the chair of this session and, together with cochair Ron Masters, would like to welcome you to this session, only the second session in the history of the North American Conference to focus specifically on the effects of prescribed burning on wildlife.

As I look around at the number of you who are showing interest in this session, I am reminded of Arlo Guthrie's famous line in his satirical song, *Alice's Restaurant*, when he sang "Friends, they may think it's a movement!"

And indeed, folks, it is a movement with a long history. I've been reading Curt Meine's biography of Aldo Leopold recently and noted Leopold's early evolution of thought as a young forester. In 1920, about 10 years out of the Yale School of Forestry, he believed, like many foresters of that day, that fire was evil, that fire was to forest what wolves were to game and livestock. But by 1923, Leopold had started to change his thinking as he pondered presettlement vegetation patterns and the frustrating encroachment of brushfields on the Prescott and Tonto national forests of Arizona. Though he still regarded fire as the scourge of all living things, he is recorded as ruefully acknowledging that fire sometimes caused an increase in vegetation beneficial to game. He was willing to "let the fire devil has his due." In 1924, as his ecological reasoning matured, in his inspection report titled, "Grass, Brush, Timber and Fire in Southern Arizona," which later appeared in the *Journal of Forestry*, Leopold advanced that there indeed was a significant role for fire in the evolution of the southwestern U.S. forests, and cautioned of the great danger of accepting and applying European forestry traditions uncritically to the American landscape. By 1939, Leopold's thinking on prescribed burning had converged with that of Herb Stoddard and he urged the Soil Conservation Service to examine Stoddard's prescribed burning techniques as a way to restore U.S. coastal plains forestland for combined forest and wildlife benefits.

In more recent years, other notable scientists have further demonstrated the value of prescribed burning to wildlife, among others, individuals such as S.W. Green, Biswell, Heyward and Barnette, Wright, Bailey, Komarek, Pyne, MaCleery, and, indeed, several of our presenters here today. But the journey of this evolving concept of prescribed burning and its effect on wildlife habitats and populations is far from complete. While we now have a wealth of knowledge and prescribed burning rightly is at the forefront in the discussion of what constitutes forest and rangeland health, we need more knowledge and more experience. But we must remain alert to other issues that affect our ability to use fire to manage the wildlife resource and not rest on our laurels, myopic and naive, and allow our interests in prescribed burning to focus only on wildlife. We must recognize the public's sensitivity to issues such as the right to clean air and how our management of smoke, when burning for whatever reason, will affect our ability to continue to use this wonderful tool. Already, slogans meant to attack the practice of prescribed burning, such as "We need healthy people, not healthy forests," are emanating from an otherwise Mom-and-apple pie organization like the American Lung Association.

Yes, there still is plenty to learn, but equally as important, there is plenty of outreach work needed if we are to retain the privilege of burning on private and public lands. And here to make further comments on this issue is the cochair of this session and a prescribed burn researcher and practitioner, as well as a colleague at Oklahoma State University, please make welcome Dr. Ron Masters.

Ronald E. Masters

Thank you, Champe. We need to be thinking about fire at the wildland/urban interface; this is a problem that people in Florida and California have been dealing with for sometime. Along with it come the questions of air quality Champe alluded to.

Few natural phenomena elicit such diametrically opposed emotions—from comfort and well-being by the fireplace to the intense fear and awe of a crown fire. Although the outcome and feedback from the Yellowstone fires has been positive, fire is not tolerated at the wildland/urban interface. People are establishing residences adjacent to national parks, forests, wildlife refuges and other natural areas. Results can seriously hamper management efforts. residences also create unique problems and/or opportunities for landscape-level prescribed burns.

Prescribed burning policies will continue to be questioned as long as the media covers fires. Flames make excellent video for local stories. We must have our ducks in a row when we burn. We must have appropriate training and follow procedures. For risk assessment, we often look at biological effects, fire parameters, plan for smoke management and have a back-up plan, but we need to assess the risk in terms of effects on policy that could emanate from an escaped fire when numerous residences are in the area. If you need to burn, be sure of parameters, then burn. To administrators: get your people trained, then let them do their jobs. However, be prepared in advance for public concern. Above all, don't dismiss their concerns, because they are real and often deal with personal fears—whether founded or not. Don't push the burning window to the extent that you lose fire as a management tool. It is a fascinating time to be involved in fire research and management. In different time and context, it has been said, "These are the best of times and these are the worst of times." The more we learn about fire ecology, the greater the challenge we uncover. Perhaps our greatest challenge is dealing with an undedicated public.

Fire is recognized by most in the scientific community as a natural disturbance and important ecological process. It has become a valuable tool in the new and fast-growing field of restoration ecology. It long has been important in wildlife, forestry and range management. From Herbert Stoddard's early seminal work with fire and quail as a foundation, fire research and management have slowly evolved. In the 1960s and '70s, there was a plethora of workshops and conferences on fire, with much focus on site-specific and species-specific research. In the 1990s, fire research has moved to that next level. More research is focused on the community, landscape and ecosystem levels.

That is not to say that we don't need site- and species-specific studies. We do, but they need to be set up with broad-based perspectives and tight experimental designs that help us answer community- and landscape-level management questions.

Tools such as GIS-based fire behavior models and other computer-based fire behavior models help land managers to define appropriate burning windows and even extend those burning windows when administrators allow. With such tools, we finally can look at landscapes in the context of historic fire influence, and approach some landscape- and ecosystem-level questions essential to dealing with some species and community existence and management for biodiversity.

Monitoring the Long-term Effects of Prescribed Burning on Non-game Wildlife in a Grassland Ecosystem in Central British Columbia

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The goals of the British Columbia Ministry of Environment Wildlife Program have evolved to manage for the diversity of all native wildlife (Wildlife Program 1994). In British Columbia, as in other parts of North America, there is growing concern over the declines in populations of grassland species (Knopf 1994, Hooper and Pitt 1995). Thirty-eight percent of the provincial wildlife species at risk occur in the Cariboo-Chilcotin grasslands (Hooper and Pitt 1995). Presently, just more than 5 percent of the grassland ecosystem (bunchgrass zone) within the Cariboo-Chilcotin and less than 8 percent of provincial grassland has any form of protection (K. Lewis personal communication: 1996). Grazing by livestock, contemporary fire management, and recreational use have altered the structure of almost all of the Cariboo-Chilcotin grasslands (Hooper and Pitt 1995). As a result of this recognition, a habitat enhancement project for the natural grasslands within the Cariboo-Chilcotin region was initiated (Hooper and Pitt 1995). The Junction Area has not been heavily grazed by livestock since 1976 and it offers unparalleled opportunities for grassland management and research.

Historically, fire is believed to have played an important role in shaping the vegetation structure, and plant and animal composition of the Cariboo-Chilcotin grassland communities of British Columbia (Mitchell et al. 1975, Eastman 1978). Prior to 1920, 124,000 to 185,000 acres (50,000-75,000 ha [1 percent]) of the Cariboo-Chilcotin region was burned annually. These fires were ignited by lightning or First Nations people attempting to improve hunting grounds (Youds and Hebert 1988, Tisdale and McLean 1957). Since the arrival of European settlers, grazing by livestock resulted in reduction of potential ground fuel (Mitchell et al. 1975), so that fires seldom burned in the grasslands. During the past two decades, the average annual amount of burned grassland in the Cariboo-Chilcotin region has been less than 300 acres (120 ha or 0.25 percent) of the historical amount (Youds and Hebert 1988).

The Junction area was established as a Wildlife Management Area[1] in order to protect and manage the traditional range of the resident herd of 500 California bighorn sheep *(Ovis canadensis californiana)*. In 1975, the British Columbia Fish and Wildlife Branch, in cooperation with the USDA Forest Service, began a program of prescribed burning in the grasslands of the Junction. The burning was prescribed to increase California bighorn sheep forage quantity and quality by releasing nutrients from accumulated dead matter in bunchgrass clumps, and to eliminate big sagebrush to increase forage potential (Eastman 1978). The prescribed burning covered a total of 3,840 acres (1,555 ha) between 1975 and 1987 (Youds and Hebert 1988). The management plan for the Junction is in the process of being revised to fully incorporate conservation objectives at the species and ecosystem levels (Hooper and Pitt 1995). A monitoring plan was devised to de-

[1]The Junction was reclassified as a Provincial Park in July of 1995.

termine the effects of the prescribed burns on wildlife and their habitat in the Junction Wildlife Management Area (Thompson et al. 1993).

The objective of this study was to measure the effects of the prescribed burns on non-game wildlife. We conducted field research from April through August 1995 to compare species presence and relative abundance between burned and non-burned areas. The monitoring plan suggested the research focus on species at risk and grassland songbirds. Accordingly, we conducted breeding songbird, long-billed curlew (*Numenius americanus*), sharp-tailed grouse (*Tympanuchus phasianellus*) and bat surveys according to standard methods proposed by the Resources Inventory Committee (1994) of British Columbia.

Study Area Description

The Junction is located north of the confluence of the Chilcotin and Fraser Rivers (51° N, 122° W), 31 miles (50 km) southwest of Williams Lake, British Columbia (Figure 1). This protected area covers approximately 11,470 acres (4,600 ha) from 1,200 to 3,300 feet (360 to 1,000 m) elevation. The protected area is surrounded by private ranch land on its northern boundaries. The climate of the Junction is typified by hot, dry summers with average daytime temperatures of 73 to 81 degrees Fahrenheit (23 to 27° C) and cold winters with relatively little snowfall (Meidinger and Pojar 1991). The area is in the rain shadow of the Coast Mountains, and snow tends to melt sooner than in adjacent areas (Mitchell et al. 1975). The vegetation of the Junction is mainly grasslands (comprised of bluebunch wheatgrass [*Elymus spicatus*], junegrass [*Koelaria macrantha*] and needlegrass [*Stipa* spp.]) on rolling slopes and southerly exposures. Some unburned steep slopes and benches are dominated by big sagebrush (*Artemesia tridentata*). Aspen (*Populus tremuloides*) groves occur in dips or in areas of higher moisture. Douglas-fir (*Pseudotsuga menziesii*) are scattered throughout the area and Douglas-fir forests occur on northerly slopes. Wetlands are uncommon in the management area, however, eight ponds occur in the study area. Within the management area, we examined four habitat types with burned and unburned status.

Lower Grassland/Shrub Benches. This habitat type occurs on lower valley terraces below 2,000 feet (600 m). Big sagebrush dominates the unburned benches. Grasses, such as bluebunch wheatgrass, needle-and-thread grass (*Stipa comata*) and Sandberg's bluegrass (*Poa sandbergii*), are common here. Burning generally eliminated the big sagebrush in this habitat type.

Steep Grassland/shrub Slopes. This habitat type is characterized by steep (up to 80-percent slope) topography on south-, west- and east-facing slopes at elevations between 2,000 and 2,600 feet (600 and 800 m). Percentage bare ground is relatively high due to erosion. Big sagebrush and occasionally rabbitbrush (*Chrysothamnus naseosus*) occur on unburned slopes. Bluebunch wheatgrass is the dominant grass. However, sand dropseed (*Sporobolus cryptandrus*) and Sandberg bluegrass occur on the lower slopes.

Steep Forested Slopes. This habitat class is dominated by open Douglas-fir forest on steep north-facing terrain between 2,000 and 2,600 feet (600 and 800 m) elevation. These slopes hold more moisture than the grassland slopes. Bryophyte ground cover is high, and understory vegetation is characterized by pinegrass (*Calamagrostis rubescens*) and a variety of forbs. Burned areas in this habitat type had Douglas-fir patches interspersed with bluebunch wheatgrass openings.

Upper Grasslands. The upper grassland habitat type forms a wide and extensive rolling plateau above the steep slopes at elevations between 2,600 and 2,950 feet (800 and 900 m). Dominant vegetation is bluebunch wheatgrass, junegrass, needle-and-thread grass and pasture sage (*Artemesia frigida*). Balsam root (*Balsamorhiza sagittata*) grows on some slopes. Hollows with snow accumulations are characterized by spreading needlegrass (*Stipa richardsonii*).

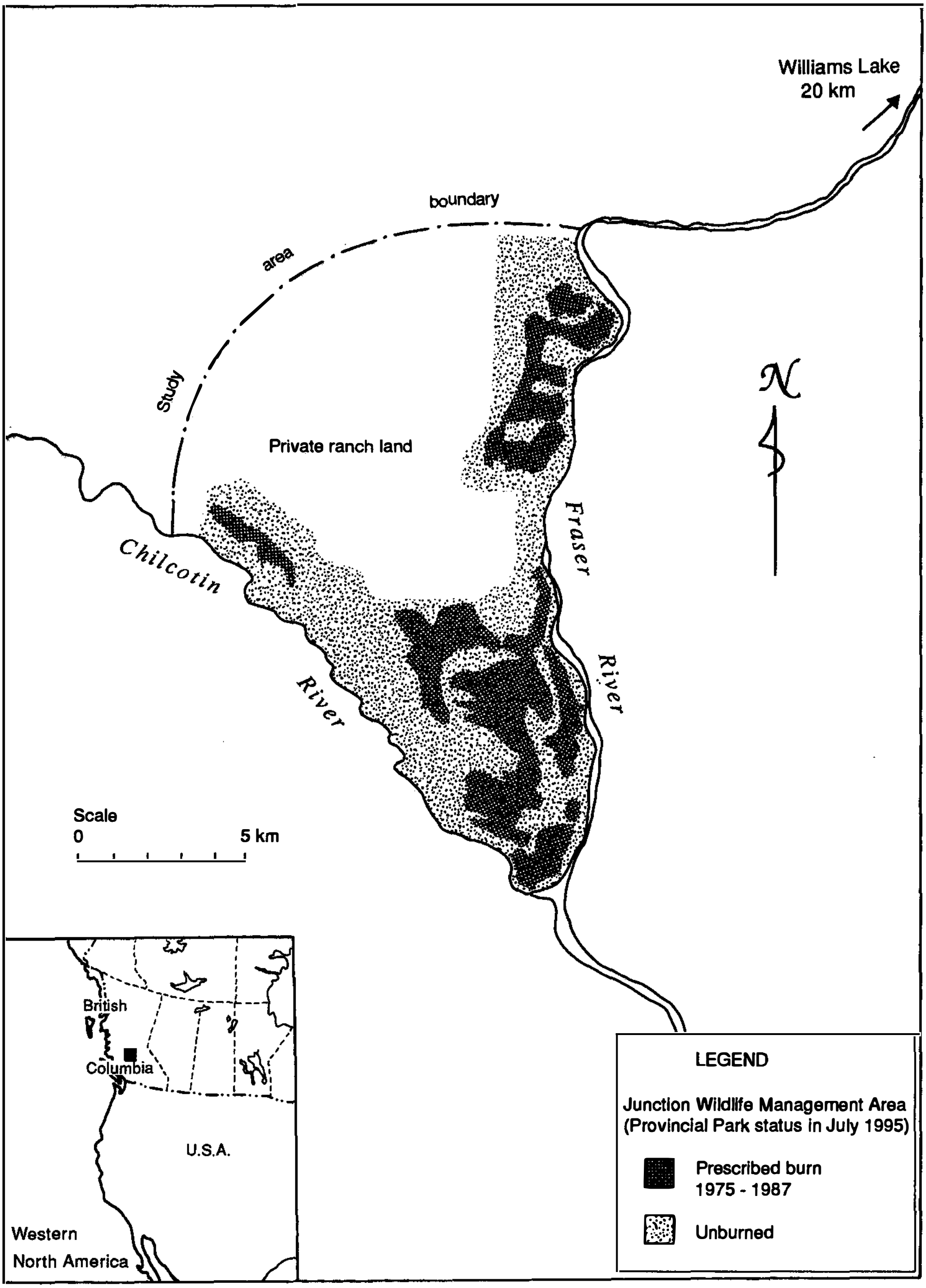

Figure 1. Location of the Junction study area in central British Columbia at latitude 51 degrees 49 minutes North and longitude 122 degrees 27 minutes West.

Survey Methodologies, Results and Discussion

Songbirds

Breeding bird surveys were conducted to determine differences in bird density and diversity between burned and unburned sites. Attempts were made to establish as many points as possible, with equal numbers within each habitat type and treatment. However, due to limitations of burned areas on the steep forest slopes and grassland/shrub slopes, the study design was uneven. We established 158 permanent monitoring points; 67 in burned areas, 91 in unburned areas. Bird surveys were conducted using the point count method (Resources Inventory Committee 1994) between April 30 and June 20, 1995. All bird detections in a 164-foot (50 m) radius were recorded for 10 consecutive minutes.

Shannon diversity indices were calculated to compare bird communities between habitat types (Krebs 1989). Forested slopes and burned, steep grassland/shrub slopes were withdrawn from the comparisons, as there were too few points in these habitats. Bird density was measured as the number of birds recorded per point, per census. Significant differences in bird density and species richness in burned and unburned treatments in the four habitat types were examined in an unbalanced Anova design. Contrast tests were performed to determine if habitat classes were distinct, and to determine if significant differences existed within a habitat class, between burned and unburned treatments. The probability of a Type I error (α) was set at 0.05. Sources that had a Type I error probability greater than 0.2 were pooled into the error term.

A total of 991 individual bird observations of 50 species were counted in 364 surveys between April 30 and June 20, 1995. The Junction bird density values (0.6 to 2.8 birds per acre: 1.6-7.0 birds/ha) and the Shannon diversity indices (1.6-2.7) were higher than other Cariboo-Chilcotin bird density values (0.6 to 1.0 birds per acre: 1.6-2.5 birds/ha) (Hooper 1994) and diversity (0.71-1.38) estimates, and other North American grassland densities (0.4 to 1.6 birds per acre: 1.0-4.0 birds/ha) and diversity indices (0.44-1.43) (Weins 1973, Cody 1985). These higher values reflect the diversity of the Junction landscape. The mosaic of grassland, aspen groves, Douglas-fir forest, big sagebrush shrublands and cliffs of various sizes, combined with elevation, slope and aspect variability, provides breeding opportunities for both grassland and forest bird species.

Burned areas of the Junction had lower Shannon diversity indices (D = 1.6-1.9) than unburned areas (D = 2.4-2.7). After burning, species distribution may have been altered (Figure 2). Vesper sparrows (*Pooecetes gramineus*) and western meadowlarks (*Sturnella neglecta*) together comprised 27 to 40 percent of the observations in unburned areas. In burned areas, they dominated the bird community with 49 to 70 percent of the observations. Throughout North American grassland, two species tend to dominate the bird community, comprising 75 to 88 percent of the observations (Wiens and Dyer 1975). The dominance pattern after prescribed burning appeared to be more similar to typical North American grassland bird communities than those areas that weren't burned.

Although relative proportions of certain songbird species were different between burned and unburned habitats, the overall density of birds was not significantly different between treatments. This concurs with Bendell's (1974) findings in a sage/grass ecosystem. In our study, species richness was significantly higher in burned habitat and diversity was lower in these burned habitats. Low diversity indices in burned habitats are due to low evenness as two dominant species comprised the majority of the observations.

There were significant differences between the four habitat types in bird density and species richness. The contrast tests demonstrated that the steep forested slopes were significantly more dense and had greater richness than the three other grassland habitat types. As responses to

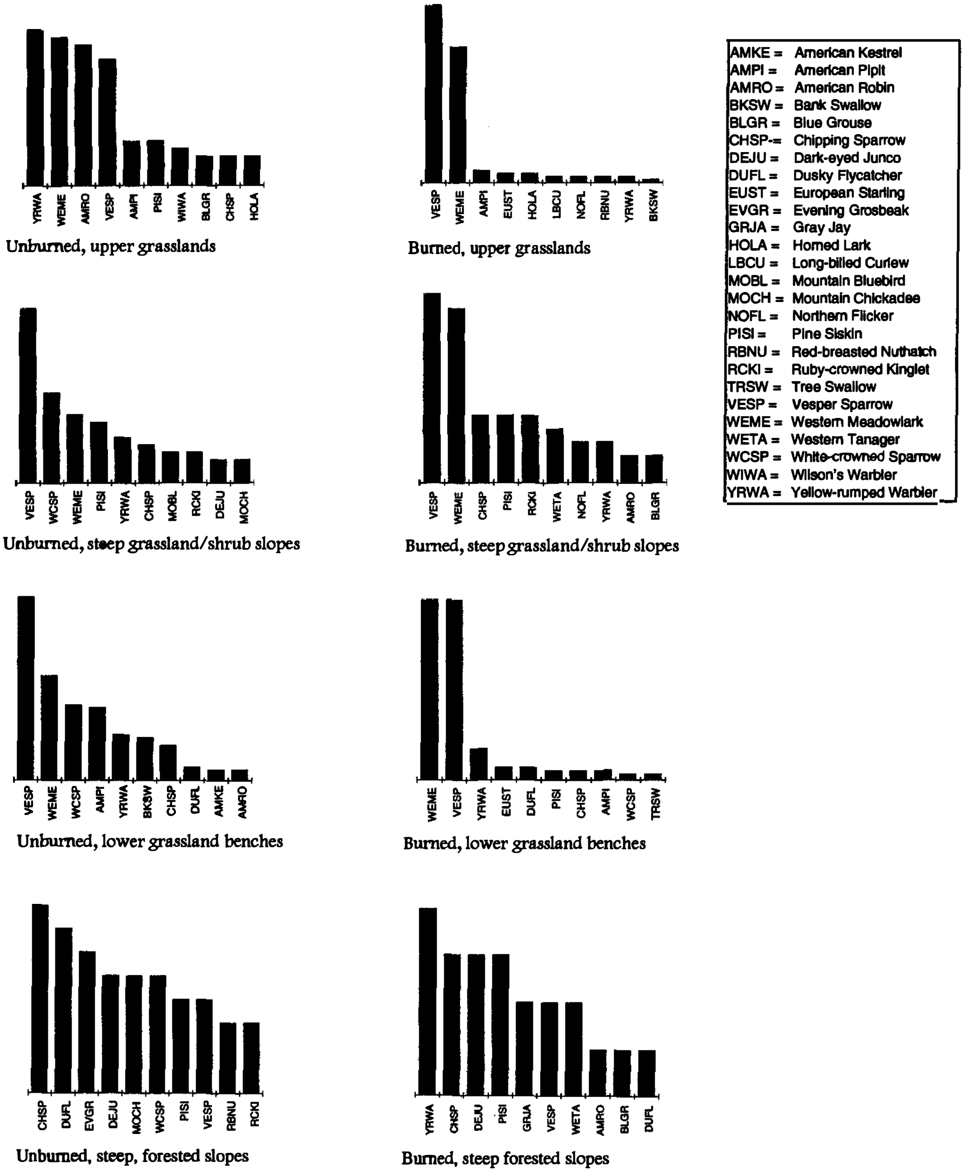

Figure 2. Relative abundance of the 10 most common bird species observed between April 30 and June 20, 1995 in the burned and unburned habitat types of the Junction Wildlife Management Area.

the burn treatment appeared to be dependent on habitat type (Figure 3), each habitat is discussed separately.

Upper grasslands and steep grassland/shrub slopes. Density and richness of birds in the higher elevation steep grassland/shrub slopes and upper grasslands did not differ significantly between burned and unburned habitat. As the upper elevation grasslands are believed to be adapted to a fire frequency of approximately every nine years (J. Parminter personal communication: 1995), and bunchgrass ecosystems recover within three years (Blaisdell 1953), differences in bird community were not expected.

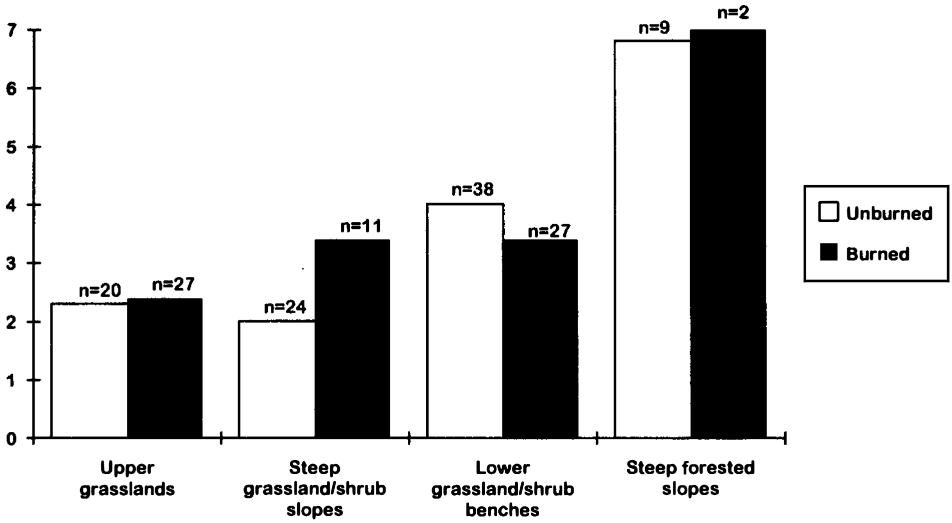

Figure 3. A comparison of mean bird density (birds per acre) in burned and unburned habitat types of the Junction Wildlife Management Area between April 30 and June 20, 1995.

Lower grassland/shrub benches. Burned lower grassland benches showed lower bird diversity and density. Natural fire frequency in the lower benchlands of the Junction is expected to be once in 50 to 65 years (Wright and Britton 1976). Big sagebrush can take up to 30 years to recover from fire effects (Harness and Murray 1973). Big sagebrush provides vegetative structure for birds as cover and singing perches. Decreased structure in the grasslands often is negatively correlated with bird diversity (Weins and Rotenberry 1981, Hooper 1994). Burning these lower grassland/sage benches may negatively affect the bird community.

Steep forested slopes. The steep forested slope bird community had significantly higher density and higher diversity of birds than the three grassland habitats. The structural and compositional complexity of snags, trees and shrubs provides habitat niches for more and different species of birds. The dominant grassland species, vesper sparrow and western meadowlark, were replaced by forest species such as chipping sparrow (*Spizella passerina*), yellow-rumped warbler (*Dendroica coronata*), ruby-crowned kinglet (*Regulus calendula*) and blue grouse (*Dendragapus obscurus*). Despite the increased bird richness in the forested areas, there is concern about Douglas-fir encroachment in the grasslands, and the negative effect on the grassland bird community over the long term (Wildlife Program 1991). If forests continue to invade grasslands, declines in western meadowlarks, vesper sparrows and horned larks, as well as long-billed curlews and sharp-tailed grouse, are to be expected. Fire should continue to play an important role in suppressing forest encroachment in the grasslands in the Cariboo-Chilcotin (Strang and Parminter 1980, Youds and Hebert 1988).

Long-billed Curlews

Long-billed curlews were selected for monitoring in the habitat enhancement monitoring plan, as they were perceived to be an "indicator" species in grasslands and are declining across

North America (De Smet personal communication: in Hooper et al. 1990). We surveyed long-billed curlews according to a modified Finnish line transect method proposed by Redmond et al. (1981). As higher numbers of long-billed curlews occurred outside the boundaries of the Junction, we surveyed 13 square miles (34 km2) in the Junction and in upper grassland of the adjacent private lands. Long-billed curlews were first observed during the 1995 breeding season in the Junction on April 9th. During the courtship and incubation period, we counted a maximum of 17 adult birds on any one survey, and estimated six long-billed curlew territories. Only two occupied territories were in the protected Junction area. Of these territories, one was in a combination of burned and unburned grassland. The other territory was in unburned grassland. The long-billed curlew data were inconclusive in regards to the effect of prescribed burning. Since long-billed curlews select nest sites that provide good visibility, they tend to avoid thick patches of grasses and big sagebrush (Campbell et al. 1990). They probably would not be adversely affected by burning before territory establishment.

Sharp-tailed Grouse

The Junction represents the largest protected area in British Columbia that is suitable for sharp-tailed grouse (Ritcey 1995). Inventory and management of sharp-tailed grouse are priorities in the Cariboo-Chilcotin. Ritcey (1995) reports that "sharp-tails respond positively to fire," as fire removes forest cover. Sharp-tailed grouse have distinct breeding, nesting, brood-rearing and wintering habitat. Forest ingrowth, due to lack of fire, is cited as being responsible for near extirpation of Columbian sharp-tailed grouse in southeastern British Columbia (Ohanjanian 1990).

Our study involved searches for breeding grounds or leks in the upper grasslands. We surveyed for sharp-tailed grouse leks within the Junction and on the surrounding private land from April 9 until May 15, 1995.

A total of five leks were found. Two of the leks were in the Junction in burned habitat, and three leks occurred on private ranch land in upper grasslands with unknown burn status. Although we did not conduct a nesting survey, one sharp-tailed grouse nest was found in a grassy hollow approximately 1 kilometer from the lekking site. Tall, dense needle-grass surrounded the nest.

As our data were limited, we could not be definitive regarding the effect of fire on sharp-tailed grouse. However, the data suggest that prescribed burning in the upper grasslands had no long-term detrimental effect on the breeding behavior of sharp-tailed grouse, but care should be taken not to burn during the lekking period.

Bats

As very little was known regarding bats in these grassland ecosystems, and even less was known regarding the effect of prescribed fire on bats, the goal of bat research was to determine species presence in the Junction and compare habitat use by bats in burned and unburned areas. We used a combination of mist-netting to confirm species identity and reproductive status with remote ultra-sonic bat detection to determine indices of bat habitat use. It was suspected that some species of bats may prefer to fly and feed in habitats with structural elements such as big sagebrush, aspen groves, or forest openings, rather than the open expanses of grassland created by the prescribed burns.

To compare indices of habitat use between burned and unburned locations, tunable *QMC Mini-BAT* detectors, combined with tape recorders and "talking" clocks, were set out. One bat detector was set out at 40 kHz range to detect the *Myotis* complex and the other detector was set at 20 kHz range to detect silver-haired bats (*Lasionycteris noctivagans*), big brown bats (*Eptesicus fuscus*) and possibly hoary bats (*Lasiurus cinereus*) (Holroyd et al. 1994). Burned and unburned upper grassland, sage benches, aspen groves and open Douglas-fir forest habitats were sampled over a total of 10 nights in July and August.

As still-water ponds were rather limited in the Junction, and many species of bats come to these types of areas to feed and drink, we concentrated our netting to areas in the vicinity of ponds and over the water. We conducted a total of 46 "net-hours" of mist-netting on five nights from July 12 to July 17, 1995.

Seven species of bats were captured: big brown bat, small-footed myotis (*Myotis ciliolabrum*), yuma myotis (*Myotis yumanensis*), long-eared myotis (*Myotis evotis*), little brown myotis (*Myotis lucifugus*), silver-haired bat and Townsend's big-eared bat (*Corynorhinus townsendii*). The spotted bat (*Euderma maculatum*) also was confirmed by acoustic detection in the Junction. Of the eight species of bats recorded, the small-footed myotis, Townsend's big-eared bat and spotted bat are "blue-listed" (considered for legal designation as vulnerable) in British Columbia. These listed bat species occur at the northern limit of their distribution in the Junction, and it is therefore important to conserve bat habitat to ensure their sustenance.

Although data were limited, there was greater than 40 kHz bat activity recorded in unburned sites (3.9 bat passes per night) than burned sites (2.3 bat passes per night). Unburned sites with big sagebrush had 20 kHz activity (probably big brown bat or silver-haired bat), while burned sites did not. These data suggest the long-term effects of burning may affect some bat activity by removal of structural habitat elements.

Conclusions

The results of our one-year retrospective study on 10- to 20-year-old prescribed burns in the Junction Wildlife Management Area suggest that songbird communities respond differentially depending on habitat type. Burn treatment appeared to have little long-term effect on the density or diversity of bird communities in steep grassland/shrub slopes or upper grassland habitat types. Prescribed burns which reduced vegetative structure in the lower shrub/grassland bench habitats appeared to have lower songbird density and diversity. Although these results may indicate trends, definitive long-term effects of prescribed burning on songbird communities in the Junction go beyond the scope of this study.

Our results for burn-treatment selection by sharp-tailed grouse, long-billed curlews and bats also were tentative, but may indicate the importance of burned and unburned areas in creating key habitat for these species. Sharp-tailed grouse leks occurred in the burned upper grasslands, but the observed nest occurred in unburned, thick grass in a snow accumulation hollow. Long-billed curlews seemed to hold territories in areas with good visibility in upper grassland, regardless of burn treatment. Some bat species utilized sites with big sagebrush but not similar burned sites without big sagebrush, presumably as the greater habitat structure provided by the big sagebrush attracted more or different insects.

We believe that prescribed burning in some habitat types of the Junction may be appropriate in maintaining the historical fire pattern. However, upper grasslands should be burned at a time when bird courtship, incubation, fledging or migratory behaviors were not occurring. Mature aspen groves, wildlife tree patches, sage patches and some snow accumulation hollows should be avoided. Further investigation regarding the short-term effects of prescribed burning on long-billed curlew and sharp-tailed grouse nesting success, and the insect prey base would enhance our ability to manage grasslands and sustain the diversity of species in this important ecosystem.

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Restoring Cross Timbers Ecosystems with Fire

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The Cross Timbers resource area occupies nearly 12 million acres (5 million ha) of Oklahoma, Texas and Kansas (Soil Conservation Service 1981) and is biogeographically the western extension of the oak/hickory ecosystem of the Ozark Plateau (Garrison et al. 1977). Trees in the Cross Timbers occur on course-textured soils in a climate that is marginal for tree survival, with only 64 to 102 centimeters of annual precipitation (Bailey 1995, Harlan 1958). Post oak (*Quercus stellata*) and blackjack oak (*Q. marilandica*) dominate the overstory of uplands, whereas the understory contains a rich mixture of other woody plants and vines (Rice and Penfound 1959, Ewing et al. 1984). Although the majority of the vegetation is forest, livestock grazing is the primary economic land use (Byington et al. 1983), which together with lease hunting, is an economically favorable use of resources (Bernardo et al. 1992). Timber and wood products are not economically viable enterprises in the region (Byrd et al. 1984).

The original character of the cross timbers likely was a mosaic of grassland, savannahlike grassland and oak mottes, oak thickets, and dense woodlands (Johnson and Risser 1975, Penfound 1962, Rice and Penfound 1959, Smeins 1994). Periodic fire in these xeric forests resulted in prolific sprouting (Gregg 1844, Irving 1835), which increased the density of oak stems (Dyksterhuis 1948, Harlan 1958), but also promoted understory vegetation similar to tallgrass prairie of the region (Axelrod 1985, Abrams 1992).

Most stands today are closed forests because of fire suppression (Abrams 1992), whereas some stands are regrowth thickets resulting from herbicide applications, infrequent spring burning or mechanical disturbance. Dormant-season fires in closed stands where leaf litter serves as the primary fuel usually are low intensity (Engle and Stritzke 1995). Growing-season fires, which were quite common on the presettlement landscape in the region (Bragg 1982, Foti and Glenn 1991, Masters et al. 1995), may be sufficiently intense to restore habitat conditions to that of the presettlement period (Anderson 1972, Boyer 1990, Glitzenstein et al. 1995).

The objective of our study is to compare the behavior of fires in three structurally different cross timbers habitats and relate the fire environment to restorative effects of fire in two seasons. This paper discusses the influence of season of burn and existing vegetation structure on fire behavior, and the influence of reintroducing fire in this habitat type on short-term changes in vegetation structure and composition.

Methods and Materials

We chose three study locations in Oklahoma with contrasting structure and composition because of different management histories. Each study location is positioned on upland, sandy loam soils that historically produced upland cross timbers. We applied two burning-season treatments (dormant season and growing season) and an unburned check at each location.

One study area is located on the Tallgrass Prairie Preserve (TGP) in Osage County, Oklahoma. Because of disturbance about 10 years before the study began, the TGP location was characterized by sprouting hardwoods about 3 meters in height. The understory was dominated by grasses. The study location is divided into three stands of about 50 acres (20 ha) each by vehicle trails. One part was burned September 1992 and again in September 1993, one burned March 1993 and March 1994, and a third part had not been burned recently.

A second study location is on the south side of Lake Carl Blackwell (LCB) in Payne County, Oklahoma. Fire suppression and no recent anthropogenic disturbance resulted in a closed canopy old-growth stand of post oak and blackjack oak with a diverse, but sparse understory of woody vines and shrubs. Few herbaceous plants were in the understory. Vehicle trails divide the location into three stands of about 24.7 to 39.5 acres (10-16 ha).

The third study location, about 27 kilometers east of Tulsa, is on the south side of Keystone Lake (KEY). The area had been subjected to periodic fires, with the last fire occurring four growing seasons before the study began. The vegetation was an open stand of post oak and blackjack ranging from resprouts to mature trees. Understory herbage production was intermediate between the TGP and LCB locations. Drainages separate the location into three stands of about 6.2 to 9.9 acres (2.5-4 ha) each.

Burn treatment (unburned check, growing-season fire or dormant-season fire) was assigned randomly to the stands at KEY and LCB. The recent stand treatments imposed at TGP were continued. Growing-season fires were planned for mid- to late growing season (between July and October) as weather, fuel load and fuel moisture would allow. Dormant-season fires were planned for mid- to late dormant season (between February and April). We prescribed both growing-season and dormant-season fires for hot, dry, windy weather with prolonged drying conditions preceding the burns. As compared with present-day fire prescriptions, these "hot" prescriptions, which we believe more nearly mimic presettlement fire conditions, were largely achieved in each of the six burns.

Immediately before each stand was burned, air temperature and relative humidity were measured with a standard sling psychrometer. Average wind speed of 2 meters was measured with a totalizing anemometer. Fuel load was measured by harvesting fuel components within 0.5 by 0.5-meter quadrats placed at random. Material within each quadrat was separated into live and dead 1-hour time-lag fuels (primarily grasses, downed deciduous leaf litter and downed woody debris ≤0.25 inch [0.64 cm] in diameter) and live and dead 10-hour time-lag fuels (downed, woody debris between 0.25 to 1 inch [0.65-2.54 cm] in diameter) (Nelson 1969). Fuel load components were weighed in the field, oven dried at 158 degrees Fahrenheit (70°C), and reweighed to obtain fuel moisture on a dry-weight basis. Weather and fuelbed conditions of the burns are listed in Table 1.

Table 1. Weather and fuelboard conditions associated with fires in six cross timbers stands.

	Lake Carl Blackwell		Keystone Lake		Tallgrass Prairie Preserve	
Bum date	Jul 7, 1994	Feb 18, 1995	Sep 9, 1994	Feb 21, 1995	Sep 5, 1995	Mar 24, 1995
Percentage relative humidity	52	27	48	20	49	44
Air temperature[a]	24	18	28	22	32	22
Wind speed[b]	0	3	6	10	6	15
Fuel loading[c]						
One-hour live	0	410	1,240	410	2,080	250
Ten-hour live	0	300	60	800	0	290
One-hour dead	15,280	7,500	8,200	6,800	3,350	3,780
Ten-hour dead	3,560	2,190	1,320	410	320	3,560
Fuel consumed	9,800	6,240	6,720	5,760	5,750	4,480
Percentage dead fuel moisture						
One-hour	8	20	11	10	12	17
Ten-hour	9	55	46	10	35	139
Total	8	20	29	14	33	25

[a]In degrees Celcius.
[b]In kilmoeters per hour.
[c]In kilograms per hectare.

Fireline intensity (I_F), defined as the rate of energy or heat release per unit time per unit length of fire front, was calculated from fire behavior observations using the equation I = Hwr (Byram 1959, Alexander 1982). The fuel load heat content (low heat of combustion, H) was obtained by adjusting high heat of combustion for fuel moisture and heat of vaporization. High heat of combustion (17,300 kJ/kg), was calculated from data taken from similar fuels in southeastern Oklahoma (Masters and Engle 1994). Fuel load was adjusted to fuel consumption (w) by subtracting unburned residue, which was sampled after burning, from fuel load. Forward rate of spread (r) was estimated by timing passage of the fire front between two points marked with metal rods within the fuelbed. Flame depth and flame length were visually estimated as the flaming front passed by each metal rod ruled in metric units (0.25 m). Heat per unit area (HA), the total energy or heat released per unit area, was calculated by dividing I by r (Rothermel and Deeming 1980). Reaction intensity (I_R), the rate of energy release per square meter of flaming zone, was calculated by dividing I_F by flame depth (Albini 1976, Alexander 1982). We sampled fuels and fire behavior in a single location within each stand, but on most fires, we sampled multiple fire runs. Hence, fire behavior measurements are reported as a single observation per stand.

We sampled vegetation in year one (1994) of the study by measuring mid-summer standing crop of major understory herbage components and canopy cover of woody plants and vines by species within two vertical strata (<1.5m and >1.5m) along five randomly placed 15-meter line transects in each treatment unit (Bonham 1989). These same parameters were measured again in year two (1995). Hence, the stands at TGP were sampled in 1994 after two successive burns were applied to the growing-season burned stand and the dormant-season burned stand. The dormant-season burned stand at TGP was burned again in 1995, so sampling in year two (1995) was after three burns had been applied to that stand. Sampling at the other two locations was before (1994) and after (1995) the growing-season and dormant-season burns were applied.

Means and standard errors for summarized vegetation data (total understory herbage standing crop, total overstory canopy cover and total understory canopy cover) were calculated for each stand. To relate environmental factors to plant community composition based on overstory and understory canopy cover of individual species, we used canonical correspondence analysis (CCA), a direct gradient analysis technique, in the program CANOCO (ter Braak 1988). We examined the uniplot of the first ordination to reduce environmental variables (i.e., HA, I_F, I_R, FL, number of burns from 1992 to 1994, estimated time (years) since the location was burned before the study began in 1992, and location). In this first ordination, centroids for study location separated distinctly, indicating study location was an important and perhaps overriding environmental variable related to community composition. The centroids for burning season were clustered near the origin of the first two axes, indicating season of burning was not an important environmental factor related to community composition in the initial years of the study. Moreover, the centroids of I_F, I_R and FL all were in close proximity to each other, indicating gradients of these elements of fire behavior are associated somewhat similarly with plant community composition. Hence, we ordinated using location, season of burning, I_R and FL as covariables to investigate more thoroughly the influence of I_F, number of burns from 1992 to 1994 and time (years) since the location was burned before the study began in 1992. These results are presented as a uniplot of centroids of this simplified set of environmental factors.

Results

Fire behavior, especially I_F and I_R, differed considerably among locations, with the fires at LCB being much less intense than those at the other two locations (Figure 1). Only the fires at KEY differed substantially between seasons with respect to I_F, with the dormant-season fire at KEY

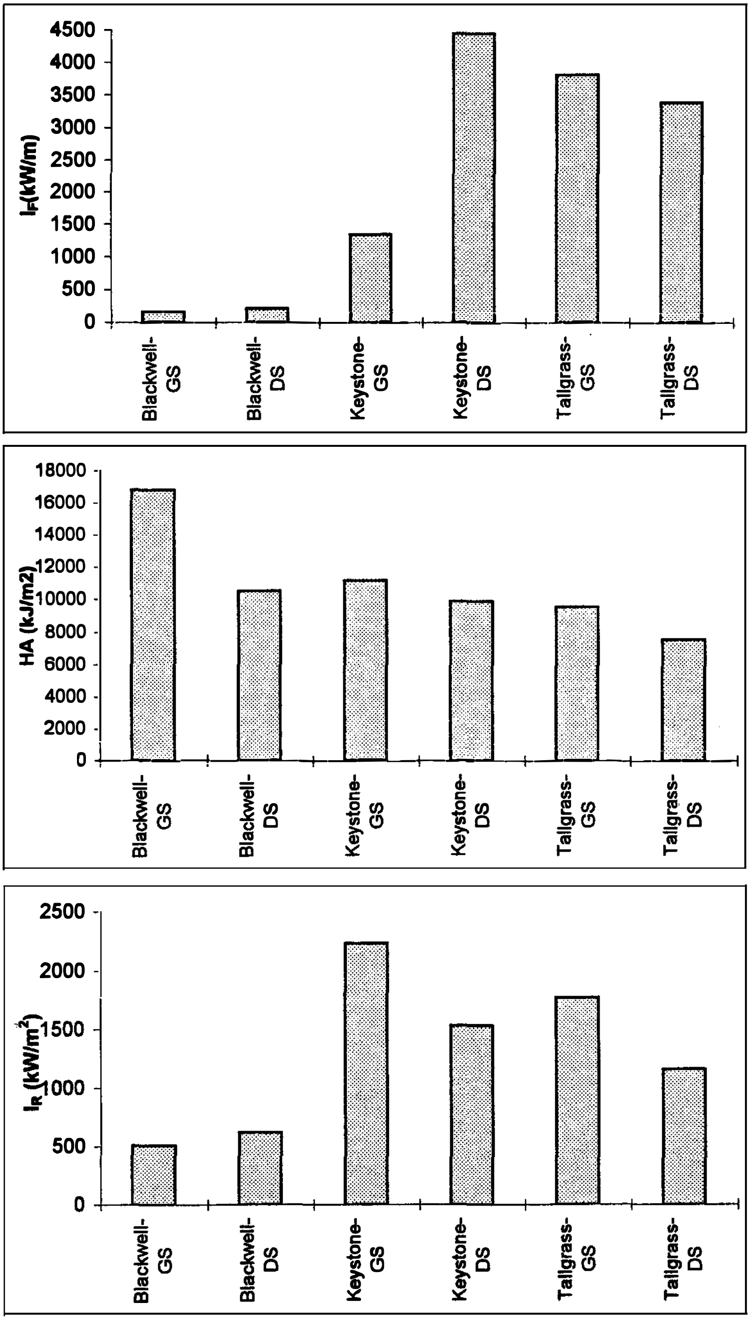

Figure 1. Behavior of fires in six cross timbers stands burned in this study. I_F = fire intensity, HA = heat per unit area and I_R = reaction intensity.

and the two TGP fires considerably more intense than the other three fires. The two fires at LCB were very low intensity. Because I_F is a good indicator of the degree to which tree crowns are exposed to direct flames and hot convective gases above the flame (Rothermel and Deeming 1980), the fires at TGP and the dormant-season fire at KEY should have been most effective in reducing overstory woody plants. Reflecting the high-intensity fires in the burned stands at TGP, cover of overstory woody plants was least in burned stands at TGP (Figure 2a). However, the stand burned in the growing season at TGP had more understory woody plant cover than the stand burned in the dormant season (Figure 2b).

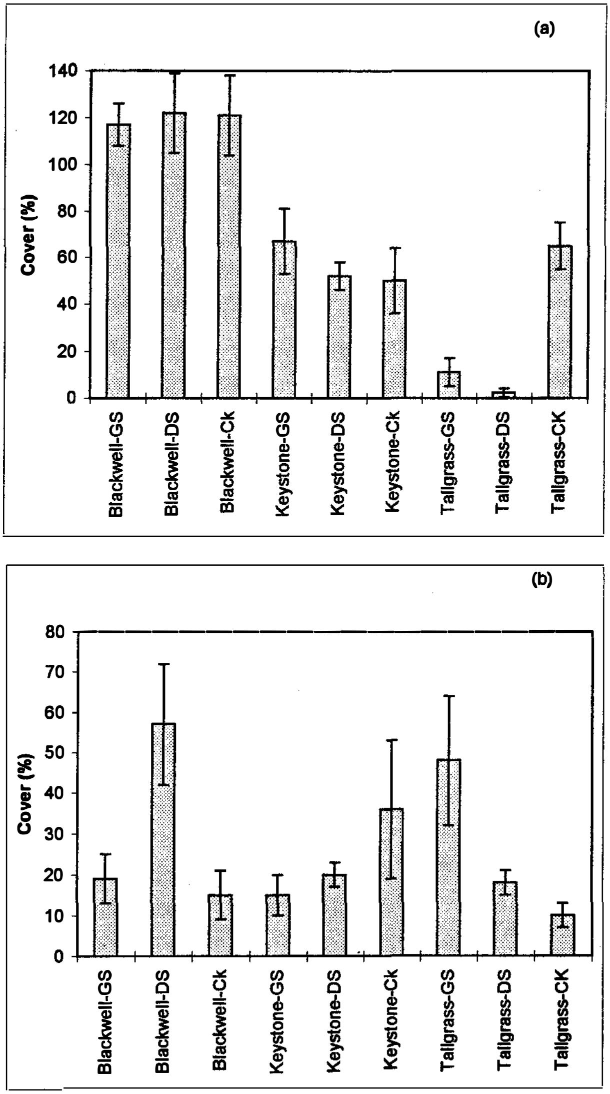

Figure 2. Total canopy cover (means and standard error bars) of woody plants and vines above 1.5 meters (a) and below 1.5 meters (b) in nine cross timbers stands in this study.

HA and I_R, indicators of the amount and rate, respectively, of heat provided to the site in the active combustion zone also differed among burns (Figure 1). We were not surprised at the high HA at LCB in the growing-season fire, given the slow rates of spread. Had fuels been drier and more fuel consumed in the dormant-season fire at LCB (Table 1), HA likely would have been as high as in the growing-season burn. Rate of energy release per unit area in the active combustion zone (I_R) was quite high in each of the burns except those at LCB (Figure 1), again because of a slow rate of spread in these two fires.

HA and I_R provide an indicator of the influence of fire on plants with meristems near the soil surface or within the zone of active combustion (Sapsis and Kauffman 1991). Production of herbaceous plants is influenced by these two fire behavior measures in grasslands (Bidwell and Engle 1992), and girdling of small-diameter woody plants with thin bark also might be expected in fires with high HA and I_R. However, the influence of these two variables is confounded by the effects of overstory cover. Indeed, understory herbage production (woody plus herbaceous) in 1995 was greatest on the TGP burned stands, even though HA and I_R in the TGP burns were equivalent to HA and I_R in the KEY burns (Figure 1). The dense overstory cover at LCB suppressed the understory in all three stands, but the high HA fire on the LCB growing-season burn, however, may have killed or injured some herbs, vines, shrubs and hardwood sprouts, and further reduced the understory (Figure 2b) that already was suppressed by a closed overstory (Figure 2a).

The woody plant community is associated most strongly with the number of burns within a four-year period (Figure 3), although HA also contributed substantially to the association of the fire environment to community composition. The stand burned in the dormant-season at TGP was the only stand to be burned three times in this three-year period, which indicates fire frequency is an important influence on community response to fire (Figure 3). Surprisingly, HA was associated more with plant community responses than I_F, according to this CCA. We think variation in history of fire and management among sites and its reflection in pre-study vegetation structure is responsible for this response. That is, fires at LCB, where overstory woody cover was dense, were propagated in hardwood leaf litter and were slow spreading, so I_F was low and little overstory change was realized. Fires at TGP and KEY, although intense (i.e., high I_F), were conducted in vegetation in which the woody overstory already had been significantly reduced by fire or other methods before the present study began.

Discussion

Oak dominance in eastern North American oak forests is believed to be fire maintained, so that many oak forests now are much different structurally and compositionally than presettlement (Abrams 1992). Although oaks continue to dominate the cross timbers, large expanses of these forests have changed markedly with respect to canopy cover and age class since settlement. Fire exclusion, coupled with livestock grazing, is the primary factor cited in conversion of presettlement oak savannas into closed canopy post oak/blackjack forests (Rice and Penfound 1959, Abrams 1992). Fuel accumulations on productive cross timbers sites in presettlement periods may have supported intense fires resulting in high tree mortality that converted forest to savannah (Rice and Penfound 1959, Anderson and Brown 1986). Livestock grazing after settlement reduced accumulation of fine fuel, so recurrent intense fire ceased. A closed canopy of trees developed and further reduced the likelihood of fuel accumulations to support intense fire (Box 1967, Ehrenreich and Crosby 1960, Anderson and Brown 1986). Thus, the current cross timbers is, at least in part, a result of a sequence of events that are difficult to reverse (Johnson and Risser 1975).

Fire season is considered an important variable related to hardwood responses to fire in the pine forests of the southeastern U.S. (Robbins and Myers 1992). Dormant-season burns will

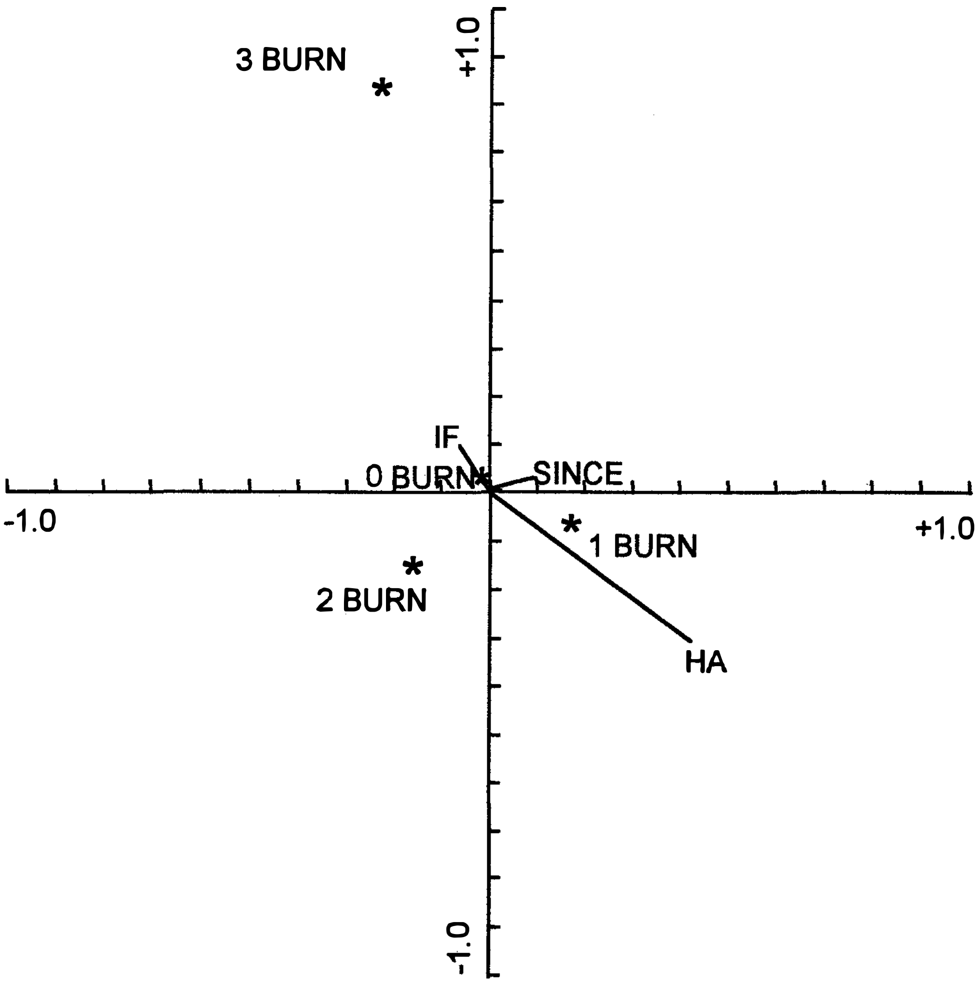

Figure 3. Uniplot of centroids of environmental variables resulting from canonical correspondence analysis of woody plant cover and fire environment. Covariables were burn treatment, study location, FL and I_R. IF = fireline intensity, HA = heat per unit area, 1BURN = one burn since 1993, 2BURN = two burns since 1993, 3BURN = three burns since 1993, 0BURN = no burns since 1993 and SINCE = number of years in 1993 since the previous burn.

maintain tallgrass prairie in the central U.S. (Bragg and Hulbert 1976), but 15 years of dormant-season burns were incapable of restoring savannahlike conditions in a Minnesota oak forest (White 1986). Evidence from other eastern forests suggests that recurring growing-season fires can revert forests to a savannahlike structure more effectively than dormant-season fires (Komarek 1974, Masters 1991, Van Lear 1991, Waldrop et al. 1992). This disturbance regime would more clearly mimic the fire regime created by Native Americans, who frequently used fire, including growing-season fire, which produced a mosaic of vegetation types and stand ages (Buckner 1989, De Vivo 1991). Komarek (1965, 1974) believed that annual growing-season burning would maintain open grassland in the eastern deciduous forest, whereas dormant-season fires would merely control size, but not numbers of hardwoods.

Given our experience in the shortleaf pine/oak forests of southeastern Oklahoma (Masters et al. 1993) and others' experience in the southeastern forests (Waldrop et al. 1987, Waldrop et al. 1992), we did not expect to convert a closed-canopy oak forest at LCB into an oak savannah with a single burn, regardless of the season. Rather, our interest in this study was to determine the reciprocal influence of fire on vegetation composition and structure in the cross timbers. At this stage of fire reintroduction in the cross timbers, fire behavior appears more important than fire season for manipulating these habitats. This view is supported by research in Florida longleaf pine savannas (Glitzenstein et al. 1995), where plant population dynamics were influenced more by fire behavior than by either fire season or fire frequency. Both tree crown scorch and mortality are highly correlated with FL and I_F (Van Wagner 1973, Trollope 1984), and tallgrass prairie communities also are influenced by various fire behavior parameters (Bidwell and Engle 1992).

The fire environment is multifaceted, so that no single factor alone, but rather interactions of factors shape plant communities (Wright and Bailey 1982). Fire season and fire behavior, while certainly major factors, interact with fire frequency, fire weather, fuels and other factors to shape the response of vegetation to fire. Our data underscore the importance of the current vegetation state in not only shaping the fire environment, but also in the response of vegetation to a given fire. This strongly suggests that generalizations on proper fire management and fire prescriptions may not provide sufficient guidance to managers in the cross timbers who may be managing lands with a variety of histories of fire and other disturbances.

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Influence on Birds of Dormant Versus Lightning-season Prescribed Fire in Longleaf Pine Forests: Experimental Design and Preliminary Results

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Fire has been an integral part of the ecology of the southeastern coastal plain for thousands of years (Watts and Hansen 1988, Robbins and Myers 1992). During historical times, prescribed fires in the Southeast commonly were set during the winter to provide fresh forage for cattle and to control brush and groundcover in turpentine operations (Robbins and Myers 1992). Most naturally occurring fires, however, resulted from lightning-caused ignitions during late spring and early summer (Komarek 1964, Robbins and Myers 1992). Evidence for the importance of lightning-season fire to the longleaf pine ecosystem comes from flowering phenology of some important herbaceous species (Platt et al. 1988), particularly wiregrass (*Aristida berenchium*), in response to warm-season fire. The shift from natural lightning-season fire to prescribed dormant-season fire was made to control fire and create habitats or resources to meet human needs. As ecosystem management gains recognition, more lightning-season prescribed fire is being used because such fires mimic natural fires that shaped the landscape.

Prior to European settlement, longleaf pine (*Pinus palustris*) forests dominated the southeastern coastal plain upland comprising 40 percent of the entire region. In 1986, this ecosystem had declined by more than 98 percent and currently comprises less than 1 percent of the region. This precipitous decline makes longleaf pine forest the most imperiled natural community in the region (Noss et al. 1995).

The deterioration of the longleaf pine ecosystem of the southeastern United States deserves special attention from the natural resource conservation community (Kelly and Bechtold 1990). This ecosystem supports a variety of vertebrate species that are either endangered or declining, such as northern bobwhite (*Colinus virginianus*), red-cockaded woodpecker (*Picoides borealis*), Bachman's sparrow (*Aimophila aestivalis*), Henslow's sparrow (*Ammodramus henslowii*), gopher tortoise (*Gopherus polyphemus*), indigo snake (*Drymarchon corais couperi*) and fox squirrel (*Sciurus niger*). These declines are related, at least in part, to the overall decline in the amount of longleaf pine in the South; however, such declines also are related to changes in vegetation structure and composition associated with forest management and lack of prescribed fire. Effective conservation and stewardship of such lands requires that the effects of management actions that mimic ecosystem processes be understood fully. Alteration of natural fire cycles in longleaf pine forest by shifting fire regimes from historical, lightning-season burns to those dominated by dormant-season fire also can result in management problems ranging from unnatural hardwood encroachment to limited natural regeneration of longleaf stands (Abrahamson and Hartnett 1990).

Although longleaf pine forests throughout the region have been managed during the past half century using a prescribed fire regime dominated by dormant-season burning, there is surprisingly little scientific information that can be used to predict the effects of lightning-season fire on terrestrial vertebrates. Therefore, we designed and initiated a set of replicated field experiments to test the effects of dormant- versus lightning-season prescribed fire on bird populations and communities in longleaf pine forests on a regional scale.

Our objectives are to assess how bird communities, ground-nesting birds in particular, and populations of individual species respond to two different fire regimes: biennial dormant-season (January) and lightning-season (May through June) burns. It is designed as a four-year study in mature longleaf pine forests in Florida and North Carolina. We report on data collected in 1995 in the first treatment year in Florida and pretreatment data collected in North Carolina.

Methods

Avian species richness in mature longleaf pine forests varies considerably among sites. Groundcover is an important structural component of the habitat for the avian community (Engstrom 1993). Approximately 40 percent of the breeding bird community in an old-growth longleaf pine forest nest or forage on or near the ground (R.T. Engstrom personal observation: 1996). A significant percentage of the winter bird community also is associated with the groundcover in longleaf pine forests (e.g., sedge wren [*Cistothorus platensis*], house wren [*Troglodytes aedon*] and Henslow's sparrow). Winter and breeding bird species associated with the groundcover are potentially most affected by the season of prescribed fire. Fire eliminates escape cover and foraging substrate and can burn up nests during the breeding season. Additional species frequently forage on the ground, although they roost or nest in the canopy (e.g., northern flicker [Colaptes auratus]). These species would be affected, at least temporarily, by the condition of the groundcover after fire. Midstory and understory hardwood composition and structure affect these species insofar as they alter distribution and extent of native groundcover.

Season of prescribed fire can have long- and short-term effects on the structure and function of the plant community, and these changes can influence productivity of individual bird species and overall bird community species richness. Long-term changes in plant community structure, such as hardwood mid-story development, may influence avian community composition. Short-term effects include temporary exposure of bare ground, elimination of nests and/or young, and temporary alteration of food supply and cover. Alteration of invertebrate abundance associated with groundcover in response to fire could be long- and/or short-term.

Study Sites and Design

Our objective is to assess how bird communities in the longleaf pine forest respond to biennial prescribed fires in lightning and dormant seasons. We chose biennial fires because this frequency is close to the estimated natural fire frequency of three to five years for the longleaf pine/ wiregrass system. Prescribed fire every year would be impractical, because the fuel base would not be fully recovered. Dormant-season burn plots will be considered reference plots, and lightning-season burn plots will be considered experimental treatments. It is not possible in this type of study to have strict controls that are not subjected to treatment. The experimental plan is to use a design that will encompass pre-treatment surveys and post-treatment assessments of birds on both reference and treatment sites.

The Florida study involves four replicate pairs of 12-hectare plots (one dormant-season and one lightning-season plot in each pair) in the Apalachicola National Forest to the southwest of Tallahassee, Florida. Longleaf pine forests on the Apalachicola National Forest (ANF) have been managed during the past half century using a prescribed fire regime dominated by dormant-season burning, although lightning-season fire now is being used more commonly. All plots were selected to be as similar as possible, with a mature longleaf pine dominated overstory and relatively undisturbed understory dominated by wiregrass. Each pair of plots is located in the same USDA Forest Service administrative compartment and all plots had similar fire histories (burned three to seven times between 1977 and 1994, twice as many winter as summer fires). Pretreatment data were collected in 1994 (breeding season only), and data were collected before and after dormant season (January through February) and lightning season (June through July) prescribed fires in 1995. Spot-mapping data, behavioral observations of breeding status and data on nests were collected on all plots.

The North Carolina study sites consist of two replicate 12-hectare plots on Fort Bragg Military Reservation and two replicates on the Sandhills Wildlife Management Area (WMA). Both study areas are located less than 64 kilometers apart in the longleaf sandhills physiographic region of southcentral North Carolina. Sites were selected using the following criteria: mature (>55 years), xeric stands dominated by an overstory of longleaf pine with a primarily dormant-season fire history. Each pair of replicate sites were selected to have similar overstory longleaf pine and understory turkey oak stem density and an herbaceous wiregrass component. Study sites have a similar total tree stem density to those in the Apalachicola study sites (160/ha to 351/ha). The Fort Bragg study sites, because of past forest management goals, prevalence of wildfires due to military troop activity and endangered species management objectives, have a lower basal area of turkey oak and a higher density of wiregrass than the study sites in the Sandhills WMA. The Sandhills WMA study sites have a slightly lower overstory basal area of longleaf compared with the Fort Bragg study sites, due to different forest management goals. This variation, however, is between blocks of replicate study sites, not within replicate pairs. One 12-hectare plot within each pair has been randomly assigned a dormant season or growing season fire. The treatments will begin with growing season prescribed burns scheduled for June 1996.

Avian Sampling

Effects on birds of season of fire were measured with the following variables: (1) abundance and species richness will be measured according to standard spot-mapping procedures. The number of territories will be estimated in the breeding season (Robbins 1970) and the average number of individuals counted during the winter (Kolb 1965). Species richness can be compared directly between treatments because sampling effort and plot size will be standardized. Breeding bird communities were assessed in both North Carolina and Florida; winter bird communities were measured only in Florida; and (2) estimates of productivity were made by nest searches (Martin and Geupel 1993, Anonymous 1994) and an index of productivity provided by behavioral scoring (Vickery et al. 1992a).

Vegetation Sampling

Vegetation will be monitored according to National Park Service procedures (National Park Service 1992). This involves establishment in each plot of ten 20 by 50 m (0.1 ha) subplots in which all trees and snags at least 2 centimeters in diameter at breast height are tagged and mapped. Trees will be monitored annually to estimate mortality rates of pines and hardwoods. Snags also will be measured annually to estimate abundance, mean persistence time and duration of usefulness for cavity-nesting birds. Groundcover structural characteristics (height profile and stem density) were measured at 33 grid points within each plot by a dowel-intercept method. Plant species composition will be monitored within one randomly selected 1-square meter quadrat within each subplot. Groundcover structural characteristics will be measured quarterly throughout the year.

Vegetation structure and composition around each above-ground nest located will be described according to the BBIRD protocol (Anonymous 1994). BBIRD variables (number of trees in each species by size class, percentage canopy cover and canopy height) are similar to those of the 0.1-acre circular sample method of James and Shugart (1970). Nest height and location characteristics also will be collected. These data will be used to examine questions related to which species are affected by fire and how, and if nest site characteristics or vegetation structure changes in response to season of fire.

Hypotheses to be Tested

Questions of interest are: (1) Is breeding bird species richness (BBSR) different between the dormant- (D) and lightning-season (L) fire plots (H_o: $BBSR_D = BBSR_L$)? BBSR is calculated as the total number of species that have at least 0.25 territory (0.5 in North Carolina) located on the plot. This test is made for the Florida treatment year data only. (2) Are abundances of Bachman's sparrows (the most abundant species that nests and forages on the ground) significantly lower in the lightning-season fire plots than in the dormant-season fire plots (H_o: $BS_D > BS_L$) (Florida only)?

Eventually, we will address whether nesting success (NS) or an index of nesting success (Vickery score) differ between the dormant- and lightning-season fire plots for selected species (H_o: $NS_D = NS_L$). We present the Vickery score data for North Carolina pre-treatment comparisons.

Results

Avian censuses in Florida were highly similar among dormant- and lightning-season plots (Table 1). Pearson correlation coefficients of all possible combinations of the spotmapping data for the eight study plots ranged from 0.717 to 0.967. In the year of the first application of prescribed fire in this study, overall species richness of the growing season plots was not significantly less than species richness of the dormant season plots (two-sample, one-sided t-test; H_o: $BBSR_D > BBSR_L$; p=0.28; 5 df).

The hypothesis that the abundance of Bachman's sparrows, as determined by spot-mapping territories, is negatively affected by growing-season fire can be rejected (H_o: $BS_D > BS_L$; t=-0.63; P=0.72; df=4).

Preliminary results from Florida include: (1) no evidence of mortality of adults; (2) relatively mild behavioral response to fire; (3) opportunistic feeding in response to fire, especially in winter; and (4) alteration of winter territories of some species after dormant-season fires. Relatively few nesting birds were affected by the application of June/July growing-season fires, because of the long breeding season (March-July) in Florida.

On North Carolina sites, the 1995 season was used as a pilot study to locate sites, identify avian communities, and field test census and productivity measures. One pair of 12-hectare plots was sampled on each Fort Bragg and Sandhill Gamelands. Total species richness was relatively similar between Fort Bragg (12-16) and Sandhills Gamelands (17-19) (Table 2). Total number of territories was higher in Sandhill Gamelands. Evaluation and comparison of Vickery scores will be made on a species-by-species basis. Fire treatments will be applied beginning with the 1996 growing season.

Discussion

A case can be made that fire in the longleaf pine ecosystem is not a disturbance (*sensu* White and Pickett 1985), because it does not disrupt the ecosystem. If anything, elimination of fire is more of a disruption of community structure and composition (Engstrom et al. 1984). From an ecological perspective, the issue of whether or not to burn in southeastern upland pine forests clearly is in favor of the use of frequent prescribed fire. Managers are faced with how best to use fire to maintain the ecosystem. This means that fire frequency, season and intensity will be manipulated to meet management objectives.

Table 1. Breeding bird communities of longleaf pine forests in Apalachicola National Forest in Florida in 1995.

	Dormant-season plots				Growing-season plots			
	100D	95D	71D	11D	100L	95L	71L	11L
Northern bobwhite	0.25	0.25	0.25	0.25	0	0	0	0
Mourning dove (*Zenaida macroura*)	0.75	0.75	0.75	0.5	0	0.25	0.75	0
Common nighthawk[a] (*Chordeiles minor*)	+	0	0	+	+	0	0	0
Red-headed woodpecker (*Melanerpes erythrocephalus*)	0.75	0	0.75	0.5	1.0	1.25	0.25	1.0
Red-bellied woodpecker (*Melanerpes carolinus*)	0	1.0	0.75	0.75	0.5	1.0	0.25	0.75
Red-cockaded woodpecker	0.5	0.5	1.0	0.5	0.75	0.5	0.5	0.25
Northern flicker	0	0.5	0.75	0.5	0	0	0	0
Pileated woodpecker (*Dryocopus pileatus*)	0	0	0	0	0	0	0	0.25
Great crested flycatcher (*Myiarchus crinitus*)	1.25	0.5	1.0	0.5	0.5	1.0	0.5	0.75
Eastern kingbird (*Tyrannus tyrannus*)	0.25	0	0.5	0	0	0	0.5	0
Carolina chickadee (*Parus carolinensis*)	0	0	0	0	0	0.25	0	0
Brown-headed nuthatch (*Sitta pusilla*)	1.0	1.25	1.5	1.75	1.75	1.5	1.0	1.75
Blue-gray gnatcatcher (*Polioptila caerulea*)	0	0.75	0.75	0.5	0	1.0	0.5	1.0
Eastern bluebird (*Sialia sialis*)	1.0	0	0.5	0.5	0.75	0	0	0
Pine warbler (*Dendroica pinus*)	3.25	5.0	4.25	4.75	4.25	4.5	4.0	3.0
Common yellowthroat (*Geothlypis trichas*)	0	0.5	0	0.5	0	1.0	0	0
Summer tanager (*Piranga rubra*)	0	0.25	0.75	0	0.5	1.0	1.0	0.75
Rufous-sided towhee (*Pipilo erythrophthalmus*)	0	0	0	0	0	0.75	0	0
Bachman's sparrow	1.25	3.25	2.0	3.5	3.5	3.0	2.25	2.75
Eastern meadowlark (*Sturnella magna*)	1.0	0	0	0	0	0	0.25	0
Brown-headed cowbird (*Molothrus ater*)	0	0	0	0	0	0	0.5	0
Total individuals	11.25	14.5	15.5	15.0	14.0	14.25	12.5	12.25
Total species	11	12	14	13	10	13	14	10

[a]Number of individuals was not estimated for common nighthawk.

Table 2. Pre-treatement breeding bird census and Vickery score summary for the North Carolina study lots.

	Fort Bragg plots				Sandhill Gamelands plots			
	A		B		A		B	
	No. of territories	Vickery[a]	No. of territories	Vickery[a]	No. of territories	Vickery[a]	No. of territories	Vickery[a]
American kestrel (*Falco sparvarius*)	1.0	2						
Mourning dove	0.5	2	1.0	1	2.0	1,1	1.0	1,1
Red-headed woodpecker					0.5	3(U)	0.5	1
Red-bellied woodpecker	0.5	1						
Downy woodpecker (*Picoides pubescens*)							1.0	1
Red-cockaded woodpecker	0.5	2			0.5	2	0.5	2
Northern flicker	1.0	5			0.5		0.5	3(U)
Pileated woodpecker	0.5						0.5	1
Eastern wood pewee (*Contopus virens*)					0.5	1	1.0	1
Great-crested flycatcher	2.0	4(H)	1.0	1	2.0	1,7(F)	1.5	1,1
Blue jay (*Cyanocitta cristata*)	1.0	5			1.5	1,5	0.5	1
Carolina chickadeee	2.0	5,5	2.0	5,5	3.0	1,2,5	2.0	5,5
Tufted titmouse	1.5	5	1.0	5			2.0	5,5
Brown-headed nuthatch					1.0			1
Carolina wren (*Thryothorus ludovicianus*)	1.0	1	1.0	5	1.0	1	0.5	5
Blue-gray gnatcatcher			1.5	5,2	2.5	1,2,5	1.5	1,5(F)
Wood thrush (*Hylocichla mustelina*)			2.5	1,1,5(P)				
Brown thrasher (*Toxostoma rufum*)							1.5	1,2
Red-eyed vireo (*Vireo olivaceus*)	1.0	1	1.0	1				
Pine warbler	2.5	5(F) 4(D)	2.0	5,5	4.5	2,4,5,5 6(D),7(F)	5.0	1,4,5,5,5
Prairie warbler (*Dendroica discolor*)					1.0	5		
Ovenbird (*Seiurus aurocapillus*)			1.0	5				
Common yellowthroat					0.5			1
Summer tanager	1.0	1	1.0	6(F),?(F)	1.5	2,2	2.0	3,5(F)
Northern cardinal (*Cardinalis cardinalis*)							0.5	1
Rufous-sided towhee	1.5	1,2			1.0	1	1.0	1,1
Bachman's sparrow					1.0	1		
Chipping sparrow (*Spizella passerina*)			0.5	5(F)			1.5	5 5(U)
Total score	17.5	56	15.5	63	24.5	82	24.5	90
Average score		3.11		3.7		2.93		2.65

[a]Letter in parentheses indicates nest outcome: F = fledged; U = unknown; P = predated; D = destroyed; and H = hatched.

Use of lightning-season fire for management has several advantages: hardwood control, enhanced reproduction of some plant species and a broader window of opportunity to use fire Robbins and Myers 1992). Although lightning-season fires were the most common in nature, concerns have been expressed about their effects on bird populations, particularly ground-nesting species, such as the northern bobwhite.

At least on the community level, our preliminary results for Florida show little sign that growing-season fire has a negative effect on bird populations (Table 1). Also, the species (Bachman's sparrow) that we would expect to be most negatively affected by fire in the growing season shows no indication of a detrimental effect. The lack of northern bobwhites in the growing-season fire plots in Florida, however, deserves further scrutiny.

Optimally, we would like to obtain an index of site fidelity based on mist net captures for both breeding and wintering birds. Site fidelity in the breeding season also is correlated with number of young fledged (Gavin and Bollinger 1988). Productivity and site fidelity estimates would be powerful variables for determining effects of fire on the avian community because density estimates based on male singing may not be a good indicator of habitat quality (Van Horne 1983; Vickery et al. 1992b). These data, however, can only be obtained with a large amount of field effort.

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Using Fire and Bison to Restore a Functional Tallgrass Prairie Landscape

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Ecological disturbances are recognized as important components of natural systems, creating patchy environments that are essential to the maintenance of biological diversity (Levin and Paine 1974, Platt 1975). They operate at different scales and at all levels of ecological organization.

Naturally functioning grasslands are no longer viewed as stable communities of climax species, but as a dynamic mosaic of different age and size patches composed of both pioneer and climax species (Loucks et al. 1985). Bison (*Bos bison*) grazing and fire were the principal ecological processes that constantly reshaped the large-scale patch mosaic of Great Plains grasslands. Small-scale disturbances, such as small mammal burrowing, also are important in enhancing species diversity and community heterogeneity in prairies (Collins and Barber 1985, Huntly and Inouye 1988, Collins and Glenn 1988). Interactions also occur among these agents of disturbance (Collins 1987, Steuter et al. 1995).

Ideally, preserves are large enough to allow the natural disturbance regime to operate and support a mosaic of patches in different stages of disturbance, successional recovery and community maturation (Pickett and Thompson 1978). This can be especially challenging in landscapes such as Great Plains grasslands where presettlement ecosystem processes have been significantly altered. This paper will describe The Nature Conservancy's efforts to restore a functioning tallgrass prairie landscape through the use of fire and bison. The underlying ecological model and management plan will be addressed.

Literature Review

Fire Effects

After climate, fire was the most important determinant in the spread and maintenance of North American grasslands (Axelrod 1985). Estimates of presettlement tallgrass prairie fire frequencies range from every 5 to 10 years (Wright and Bailey 1982) to two to five times every 10 years (Hulbert 1973).

Review of Great Plains historical accounts generally is consistent regarding presettlement fire seasonality. For the southern plains region, Moore (1972) reports October and then July through August as the peak fire seasons, with a distinctly smaller season in April through May. For the southern tallgrass region, Shaw and Lee (1995) found nearly all fires were in the September through November period, with a peak in October. A much smaller proportion occurred in July through August. No winter through early spring fires were reported, but this is due to the fact that explorer expeditions were only in the field from May through November. For the northern plains region, Higgins (1986) reports seasonal peaks in March through May and September through October, with a smaller peak in July through August.

All of the above historical reviews indicate the July through August period, to varying degrees, as a seasonal fire peak. This is the primary lightning strike season, a pattern that holds for most of the continental U.S. Orville (1991) reported 13.4 million lightning ground flashes in 1989 in the contiguous U.S., of which 50 percent occurred in the July through August period. The Flint Hills region of Kansas and Oklahoma (western edge of the tallgrass prairie) appears to be especially lightning prone. In 1989, the Flint Hills had the highest density of lightning strikes (6-8/ km2) in the United States west of the Mississippi River.

Clearly, lightning was an important source of fire in the central grasslands. However, July through August fires likely were of small size. Grassland fire behavior is controlled primarily by fine fuel load (Sneewjagt and Frandsen 1976), fine fuel moisture and wind speed (Rothermel 1983). Central grasslands, especially tallgrass prairies, are lush and green at this time (high fuel moisture), thereby greatly reducing fire spread and intensity.

In contrast, autumn (and early spring) fires likely had a much larger spatial influence on the presettlement landscape. Fuel moisture levels are low during these dormant periods. Rates of fire spread and intensity of 15 to 20 times greater than those of the July through August period have been measured (Steuter 1986).

Since Native Americans were the source of these influential dormant-season fires (essentially no lightning strikes during those seasons), authors such as Axelrod (1985) and Steuter (1991) have suggested that much of the grassland biome was anthropogenic in origin. Native Americans have inhabited North America since soon after the Wisconsinan glaciation, at which time the center of the continent still supported a boreal forest (Delcourt and Delcourt 1987). Climatic changes in concert with aboriginal use of fire likely shaped the vegetative composition and extent of the grassland biome. This is especially likely in the more mesic tallgrass region, where a successional tension exists between grassland and forest. Efforts to simulate the original fire regime must consider dormant-season aboriginal fires and summer lightning-set fires both to be "natural." This is the evolutionary history of our central grasslands.

Season of burn is an important variable in determining plant community response and patch structure. In tallgrass prairie, dormant-season burns tend to maintain the dominant matrix of warm season grasses, reduce forbs and create homogeneous burn patches (Collins 1987). Growing-season burns reduce matrix graminoid dominance, increase forb abundance and often create uneven or "spotty" burns (Adams et al. 1982, Ewing and Engle 1988).

Bison

Bison are behaviorally and physiologically well adapted to the grassland biome. They feed primarily on the matrix graminoid vegetation (Peden et al. 1974, Plumb and Dodd 1993), can efficiently utilize coarse forage (Towne et al. 1989) and are less restricted by distance from water or topography than cattle (Van Vuren 1982). This is not surprising given the species' evolutionary history, which coincides with the rise of the central grasslands (McDonald 1981).

Bison apparently occupied southern tallgrass prairies in relatively low densities, at least when compared with numbers in mixed- and shortgrass prairie (Shaw and Lee 1995). Most authors now agree that bison were nomadic and not migratory, responding to landscape forage patterns (Hanson 1984, Roe 1970, Shaw and Lee 1995).

Bison/Fire Interaction

During the growing season, bison are strongly attracted to patches of high-quality forage. Bison have demonstrated selective use for prairie dog (*Cynomys ludovicianus*) colonies (Coppock et al. 1983) and burn patches (Shaw and Carter 1990, Vinton et al. 1993, Coppedge and Shaw 1995). Burned patches are very attractive to bison due to their higher quality (and sometimes quantity) of forage (Coppock and Detling 1986).

In essence, there is a close spatial and temporal interaction between bison and fire. Concentration of bison grazing on burned patches defers grazing of other areas. Fuels then build up on ungrazed patches, thus increasing the probability of burning in the future (Steuter 1986). Bison also determine where and when fires occur by altering fuel levels. This dynamic fire/bison interaction results in a process-driven patch mosaic. Such a landscape gets increasingly complex and diverse through time, as patches move across the landscape, eventually overlapping.

Site Description

The Tallgrass Prairie Preserve is a 15,200-hectare natural area owned and managed by The Nature Conservancy. The cornerstone property, the historic 11,800-hectare Barnard Ranch, was purchased by the Conservancy in November 1989. The preserve is located in Osage County in northeast Oklahoma (36°49'N, 96°23'W) near the southern end of the Flint Hills—the largest extant block of tallgrass prairie in North America. Approximately 80 percent of the preserve is tallgrass prairie vegetation, dominated by *Andropogon gerardii*, *Sorghastrum nutans*, *Schizachyrium scoparium* and *Panicum virgatum*. The remaining 20 percent of the preserve is wooded: *Quercus stellata/Q. marylandica* on the uplands, and gallery forests along stream courses.

Ecological Goal

The Tallgrass Prairie Preserve ecological goal is as follows: Develop and maintain an appropriately scaled preserve that will protect the natural communities, full array of species, and other biodiversity features indigenous to the preserve locale, in an evolutionary viable setting that utilizes those ecological processes that are essential to maintaining a naturally functioning tallgrass prairie landscape. Action: Restore the original fire/herbivore interaction that will simulate a process-driven tallgrass prairie landscape, resulting in a dynamic mosaic of landscape patches, representing the full range of variability considered natural to the indigenous natural communities.

Ecological Management Plan

Bison

The bison starter herd of 300 head was introduced in October 1993. The initial bison pasture of 1,960 hectares consisted of several consolidated pastures (internal fences removed), and recently has been enlarged to 2,870 hectares to keep pace with the growing herd. Over the next six to seven years, the herd will expand through internal recruitment to a maximum of 1,400 animal units (1 AU = one 454-kg animal). The initial stocking rate of approximately 1.3 AUM per hectare per year (1 AUM = 1 AU forage requirement for one month) is a very light stocking rate, consistent with historical information indicating southern tallgrass prairies did not have high bison densities (Shaw and Lee 1995).

Average herbage production for the site is approximately 4,000 kilograms per hectare per year. The proposed stocking rate allocates 12.5 percent of this herbage to bison intake at a rate of 13 kilograms air-dried herbage per AU per day (3 percent of body weight/day). This stocking rate is about half that of a typical area year-round cow/calf cattle program (usually about 25 percent intake).

As the herd expands over the next six to seven years, additional area is added to their pasture on an annual basis to approximate the 12.5-percent forage intake target. Knowing herd sex and age structure allows calculations of total animal unit number through time and associated herbage needs. USDA soil survey maps have been digitized and linked to herbage production estimates for each soil type (Bourlier et al. 1979). Linking bison herbage requirements and land production estimates determines when and how much land needs to be added to the bison unit. Additions are made to the bison unit by temporarily upgrading existing internal cattle fences, and then removing that fence after the temporary pasture boundary shifts again. Eventually, the 1,400 AU resident herd will occupy about 13,200 hectares of the preserve.

The bison herd can range freely year-round over its entire unit with unrestricted access to all burned and unburned areas. There will be no internal fences except around several bison excluded areas (experimental control unit, headquarters, etc.). It is a drive-through, "open range" situation, where the public can drive the gravel county road that passes through the center of the preserve and the bison unit.

Management of the bison herd is similar to that used with the Conservancy's three other Great Plains bison herds. The entire herd is rounded up each year in autumn and processed through a specially designed corral system. The effects of extirpated large predators are simulated by culling older adult bison (males >6 years, females >10 years) and a majority of the calves. Culled animals are separated from the herd and sold live to private bison ranchers by sealed bid. A strict disease control program is followed, with all animals tested before entering or leaving the preserve for brucellosis and tuberculosis. All heifer calves are vaccinated for brucellosis. The herd does not receive supplemental feed or protein at any time. Salt with trace minerals is provided free-choice, since this element may be lacking within the bounded landscape. Water is provided by natural stream flow and small stock ponds.

Fire

The preserve prescribed burning program was fully implemented in spring of 1993. During the bison build-up phase, two separate programs will be in effect.

First, fire outside the bison unit will be used for forage improvement for cattle grazing, control of encroaching woody species, restoration of a more appropriate structure to wooded communities, restoring vigor and later seral plant species to grassland communities, and fuel reduction to control wildfires. These restoration/management burns will be primarily spring burns (March/April), and will be conducted as deemed necessary during the bison herd build-up phase.

In order to ensure adequate refugia for fire-sensitive species (insects, prairie nesting birds, small mammals, etc.), at least half of the entire preserve will be left unburned in any given year.

The second portion of the preserve prescribed burn program consists of simulating the presettlement fire frequency and seasonality in the fire/bison unit. The preliminary fire return interval will be five years (20 percent of fire/bison unit area burned each year). Seasonality of the acreage that is burned each year will be divided as follows: 40 percent dormant spring (March/April); 20 percent late growing season (August/September); and 40 percent dormant autumn (October through December). At least two burns will be conducted each burn season, with probably three to four burns conducted in the late growing season to reflect the fuel and ignition conditions at that time (low rates of spread, but peak lightning strike season).

Burn units will not be fixed on the landscape. Rather, the entire bison unit landscape will be surveyed just prior to each burn season, and burn units will be selected randomly from those areas with a minimum of 900 kilograms per hectare of fine fuels. USDA Forest Service fire behavior models (Burgan and Rothermel 1984, Andrews 1986) were used to determine this minimum fuel load threshold. All wildfires will be suppressed on the preserve and The Nature Conservancy will assist neighbors with suppression of wildfires on adjacent lands. When wildfires do occur in the fire/bison unit, the area burned will be counted toward the annual burning target.

Cattle

As mentioned above, it will take six to seven years for the bison herd to build up to its desired size. During this build-up period, grazing pressure is desired in areas not yet occupied by bison. Cattle are the most effective way to approximate bison grazing.

After resting the prairie for the 1991 and 1992 growing seasons, cattle were first grazed on the preserve in 1993. As the size of the bison unit expands, the acreage devoted to cattle grazing will decrease.

The principal cattle grazing program objectives are the maintenance of the dominant warm-season native grasses with a diverse assemblage of native forbs, and the maintenance of a variety of grassland vegetative cover and structural types. Grazing treatments to be utilized will include intensive-early stocking (IES), season-long stocking (both with and without rotation among several pastures) and unburned/ungrazed areas. The Nature Conservancy will set season of use, stocking rates, rotation schedules, and type of cattle for all leases.

Dormant-season/winter grazing with protein supplements also will be permitted to allow the lessee to build his cattle herd prior to summer stocking. Winter removal of forage by cattle may reduce the amount of acreage that needs to be burned each spring, which is the usual practice for IES grazing systems. In addition, winter grazing will result in less homogenous burns, leaving scattered refugia for fire-sensitive species. If only a portion of a pasture that will be summer cattle grazed is burned, then that pasture will be stocked based on the burned acreage only.

Research

Our working hypothesis is that the full array of native species will benefit from the resulting landscape patch mosaic. However, the fire/bison management regime is untested and surely will need to be adjusted through time.

Research at the site is focused on the relationships between landscape patterns, ecological processes and biological diversity. The abundance and distribution of birds, invertebrates and plants within the fire/bison unit are being compared with conventional cattle grazing systems, as well as investigations regarding small-scale disturbance agents and detection of landscape-level patchiness using remote sensing tools. Similar investigations are being conducted at Konza Prairie Research Natural Area, Kansas (tallgrass prairie), operated by Kansas State University, and at the Conservancy's Niobrara Valley Preserve, Nebraska (sandhills prairie) and Cross Ranch Preserve, North Dakota (mesic mixed-grass prairie).

Conclusions

In essence, we are attempting to preserve biological diversity by reconnecting the historical linkages of fire and herbivory, with the desired result being a spatially and temporally dynamic landscape. This effort is critical to realizing our goals at the Tallgrass Prairie Preserve, and also should be valuable for management planning at other grassland preserves.

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Enhancing Oak Regeneration with Fire in Shelterwood Stands: Preliminary Trials

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Oak-dominated (*Quercus* spp.) hardwood forests cover large portions of eastern North America, providing important wildlife habitat and valuable forest products. Successful regeneration of these forests on better sites has been difficult in recent decades owing to already established shade-tolerant and invasive fast-growing species outcompeting the slow-growing oak reproduction (Lorimer 1992).

Shelterwood harvests often are used to create conditions more favorable for oak reproduction (Sander et al. 1983). However, this technique frequently fails on better-quality sites as less-desirable hardwoods, i.e., red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*) and yellow-poplar (*Liriodendron tulipifera*), rapidly occupy the site (Schuler and Miller 1995). These other hardwoods lack the timber and wildlife values of oak, making successful oak regeneration on better-quality sites a major challenge for resource managers throughout the eastern hardwood forest.

Some resource professionals believe that oak regeneration needs occasional fire disturbance to remain competitive on better-quality sites (Van Lear 1990, Lorimer 1992). Long-term fire studies in loblolly pine (*Pinus taeda*) conducted in the coastal plain of South Carolina seem to confirm this theory. Van Lear and Waldrop (1988) reported that oaks resprouted more frequently than most other hardwood species following burning. Langdon (1981) reported between 58 and 70 percent non-oak mortality compared with only 40 percent for oak species following 26 years of biennial summer burning in pine stands.

The study objective was to determine if growing-season prescribed fires conducted in shelterwood stands would improve the competitive position of oak in the advance regeneration pool.

Study Site

The study was conducted in two mature hardwood stands, portions of which were partially harvested three years earlier using the shelterwood system, at the Powhatan Wildlife Management Area in the Piedmont of central Virginia. This area consists of broad, gently rolling hills at an elevation of approximately 300 ft (91 m) above sea level. Both stands were 75 to 95 years old and had not been disturbed for at least 30 years. Site index for oak50 was measured at 75 feet (23 m) and basal area was 110 to 120 square feet per acre (25-28 m2/ha). Prior to initial harvest, white oak (*Quercus alba*) and scarlet oak (*Q. coccinea*) dominated the canopy. Other overstory species included yellow poplar, sweetgum and hickories (*Carya* spp.), red maple, beech (*Fagus grandifolia*), southern red oak (*Q. falcata*) and black oak (*Q. velutina*). Midstory and advance regeneration species included red maple, beech, flowering dogwood (*Cornus florida*), ironwood (*Carpinus caroliniana*), blackgum (*Nyssa sylvatica*) and black haw (*Viburnum prunifolium*). Oak reproduction was sparse in the advance regeneration pool.

Portions of both stands were treated with the first stage of a two-step shelterwood harvest in summer 1990. Both stands were marked to remove poorer-quality oaks and lower-value species with a target of 50-percent canopy opening after harvesting. Actual postharvest basal area was 34 square feet per acre (7.8 m2/ha). Advance regeneration became abundant with yellow-poplar dominating the advance regeneration pool. The shelterwood harvest enhanced oak regeneration, but it was overwhelmed by the density and height of hardwood competitors.

Methods

Following harvest, ten 0.01-acre (0.004 ha) plots were systematically located in the shelterwood portion of each stand to monitor development of the advance regeneration pool. Three years after initial harvest, it was evident that these stands were not regenerating to oak. Therefore, prescribed fire was chosen as a follow-up treatment and each shelterwood area was divided into burn and no-burn treatments. This division of the shelterwood stands separated the advance regeneration monitoring plots into three burn and seven no-burn plots in each stand.

Prescribed fires were conducted in both burn treatments during the afternoon of August 24, 1993 using strip head fires. Weather conditions were: air temperature 87 to 90 degrees Fahrenheit (31-32 C), relative humidity 40 to 50 percent, and south/southwest winds at 5 to 10 miles per hour (8-16 km/hr). Both areas burned readily and flame lengths generally were 2 to 4 feet (0.6-1.2 m).

After burning, five additional plots (two in burn unit and three in uncut area) were systematically located in each stand to increase sample size. Although statistical design tenets obviously were compromised, this arrangement was analyzed as a randomized complete block design with two blocks (stands) and three treatments (uncut, shelterwood/no burn and shelterwood/burn) per block. Our purpose was to detect trends in the advance regeneration pool to provide the rationale for a replicated study to be installed at a later date (Brose and Van Lear 1995).

One year after prescribed burning, all plots were inventoried for density and height of advance regeneration. All seedlings and sprouts between 12 inches (0.30 m) tall and 5 inches (0.13 m) diameter at breast height (dbh) in each plot were identified as oak, hickory, red maple, sweetgum, yellow-poplar or miscellaneous. Multiple stump sprouts were tallied as a single stem. Heights were measured to the nearest 0.5 feet (0.15 m).

In this study, we examined effects of no harvest, shelterwood harvest with no burning and shelterwood harvest with burning on advance regeneration of three species (red maple, sweetgum and yellow-poplar) and three species groups (oak, hickory and miscellaneous midstory). Differences in species density and height were detected among and within treatments using analysis of variance with Duncan's multiple range test (= 0.05). When needed, data was rank transformed to correct for unequal variances and nonnormality.

Results

No block effect was noted, so data were pooled to decrease variance and ease of reporting (Table 1). Advance regeneration densities in the uncut control ranged from 20 to 1,380 stems per acre (49-3,409 stems/ha). Density of midstory species was 1,380 stems per acre (3,409 stems/ha) and was greater than yellow-poplar's density of 20 stems per acre (49 stems/ha). Densities of other groups and species ranged from 100 to 300 stems per acre (247-741 stems/ha). Total advance regeneration was sparse, only 2,290 stems per acre (5,656 stems/ha). Heights were not measured in the control plots.

The unburned shelterwood areas had abundant advance regeneration totaling 11,990 stems per acre (29,615 stems/ha), with all species except hickory having higher densities than the uncut control (Table 1). Yellow-poplar density was 5,930 stems per acre (14,647 stems/ha) and miscellaneous midstory density was 2,510 stems per acre (6,200 stems/ha). These did not differ but were more common than all other groups and species within the shelterwoods. Oak density was 1,630 stems per acre (4,026 stems/ha), while sweetgum density was 1,070 stems per acre (2,643 stems/ha) and red maple density was 940 stems per acre (2,322 stems/ha). They did not differ from each other but outnumbered hickory density of 260 stems per acre (642 stems/ha).

Table 1. Density in stems per acre (hectare) of advance regeneration for the three treatment areas.

Species	Uncut[a, b]	Unburned shelterwood	Burned shelterwood
Oak	220 (543)aAB	1,630 (4,026)bB	1,450 (3,582)bA
Hickory	300 (741)aAB	260 (642)aC	260 (642)aB
Red maple	100 (247)aAB	940 (2322)bB	170 (420)aB
Sweetgum	270 (667)aAB	1,070 (395)bB	30 (74)aB
Yellow poplar	20 (49)aB	5,930 (14,647)bA	180 (445)aB
Midstory	1,380 (3,409)aA	2,510 (6,200)bA	2,590 (6,397)bA

[a]Means followed by different lowercase letters are different (α = 0.05) among treatments (columns) for that species (row).
[b]Means followed by different uppercase letters are different (α = 0.05) among species (rows) for that treatment (column).

The burned shelterwood treatment differed dramatically from unburned shelterwood treatment in stem density (Table 1). Top-kill among advance regeneration was nearly 100 percent, and one to two overstory trees per acre (2-5 trees/ha) were killed. Yellow-poplar density was 180 stems per acre (445 stems/ha), red maple density was 170 stems per acre (420 stems/ha) and sweetgum density was 30 stems per acre (74 stems/ha). These densities were markedly reduced from their unburned densities. Oak, hickory and miscellaneous midstory species' densities did not differ between burned and unburned treatments. Although density did not change for the miscellaneous group, a composition change occurred as blackgum replaced beech, dogwood and hornbeam.

Oak regeneration was shorter than the regeneration of its competitors in the unburned shelterwoods but not in the burned shelterwoods (Table 2). In the unburned shelterwoods, oak height was 2.8 feet (0.85 m), while heights were 9.1 feet (2.77 m), 8.5 feet (2.59 m) and 8.1 feet

Table 2. height in feet (m) of advance regeneration for two of the three treatment areas.[a]

Species	Unburned shelterwood[b, c]	Burned shelterwood
Oak	2.8 (0.85)aB	2.1 (0.64)aA
Hickory		
Red maple	9.1 (2.77)aA	3.1 (0.94)bA
Sweetgum	8.5 (2.60)aA	2.9 (0.88)bA
Yellow poplar	8.1 (2.47)aA	2.5 (0.76)bA

[a]No data were collected for these species in the the Uncut treatment area.
[b]Means followed by different lowercase letters are different (α = 0.05) among treatments (columns) for that species (row).
[c]Means followed by different uppercase letters are different (α = 0.05) among species (rows) for that treatment (column).

(2.47 m) for red maple, sweetgum and yellow-poplar, respectively. There were no differences in height among species in the burned treatment. Red maple, sweetgum and yellow-poplar were shorter in the burned treatment than in the unburned treatment, but there were no height differences for oak between treatments.

Discussion

Although these results must be viewed as preliminary, they indicate that the competitive position of upland oaks in the advance regeneration pool can be enhanced by prescribed burning in shelterwood stands. Density and height of oak advance regeneration are not adversely affected by fire, while density and height of its principal competitors are markedly reduced.

This shelterwood-burn approach for regenerating oak stands has important ramifications for wildlife management. It creates quality early successional habitat for popular upland game species, i.e., white-tailed deer (*Odocoileus virginianus*), wild turkey (*Meleagris gallopavo*) and bobwhite quail (*Colinus virginianus*), as well as many non-game species. The residual overstory oaks and hickories provide habitat for songbirds and squirrels, vertical cover, and hard mast crops. Burning stimulates production of berries, grasses and legumes on the forest floor. Resprouting hardwood regeneration has nutrient-rich foliage and serves as horizontal cover. The occasional death of overstory trees results in snags for raptors and beetle-foraging sites for woodpeckers while standing and cover for small mammals once fallen.

Frequent repeat burning (annual or biennial) in the shelterwood would create a savannahlike understory; a habitat type once common but now rare in the eastern U.S. (Lindestrom 1656, Buckner 1982). Such habitat would be valuable for a wide variety of wildlife species, such as those neotropical migrant songbirds dependent on grasslands. Occasional repeat burning, once or twice a decade, would create a two-layered stand with an open hardwood overstory and a well-developed understory, a potentially important habitat in mixed hardwood ecosystems.

Besides creating wildlife habitat, another positive aspect of this approach is that it can maintain high-quality oak reproduction in the regeneration phase for release as management needs dictate. This regeneration technique allows for fairly precise control of managing land by area regulation. It also would allow for more economically attractive cutting unit size without sacrificing area regulation or age structure. Additionally, managers could exploit strong markets by overcutting initially and, later, gradually releasing appropriate acreage from burning. Such an approach may be useful as a contingency for liquidating large acreage of mature oaks in the face of imminent gypsy moth defoliation without sacrificing a desirable age class structure. In short, this technique seems to be quite flexible.

Given the rapid appreciation of oak sawtimber and the current age of many of our oak forests, it seems apparent that a great deal of cutting will occur in the next 10 to 20 years. If a substantial proportion of this acreage is to remain in oak-dominated forests, successful regeneration strategies must be identified and made available to landowners and managers. Toward this end, a long-term study has been initiated in the central Piedmont of Virginia to fully document effects of this regeneration method on advance reproduction and how it may favor oak regeneration.

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Effects of Prescribed Burning on Black-capped Vireo Habitat and Territory Establishment

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The black-capped vireo (*Vireo atricapillus*) was listed as an endangered species in November 1987 by the U.S. Fish and Wildlife Service (Ratzlaff 1987). The former breeding range of the species included scrub-oak habitats in southcentral Kansas, central Oklahoma, central Texas and northern Coahuila, Mexico (Graber 1961, Grzybowski et al. 1986,Grzybowski 1991b). Reports of the species' demise in Kansas, endangered status in Oklahoma, and a desultory pattern of disappearance throughout much of the northern, eastern and central parts of the distribution in Texas illustrate the dire situation of the species (Grzybowski 1991a). Habitat loss from natural community succession, encroachment and dominance of juniper trees due to fire suppression, and poor range management practices are contributing factors to the species' decline (Ratzlaff 1987, Shaw et al. 1989,Grzybowski 1991b).

The absence of periodic fires in the Edwards Plateau region of Texas has altered the community successional trends and enhanced the rapid invasion of Ashe juniper (*Juniperus ashei*) onto open woodlands (Smeins et al. 1988). Gehlbach (1988) noted that fire may be the primary reason oaks dominate over juniper and fire suppression allows Ashe juniper to proliferate. Heavy grazing pressure in tandem with fire suppression can transform a mixed-oak savanna into a dense juniper stand (Fonteyn et al. 1988). The invasion of juniper and decrease in low, dense deciduous woody vegetation are incongruous with the habitat requirements of the black-capped vireo.

In areas subject to rapid succession, fire may be important in the production and maintenance of black-capped vireo habitat (Graber 1961, Shaw et al. 1989,Grzybowski 1991b). However, few studies have addressed the effects of fire on avian communities residing in a scrub habitat (Breininger et al. 1992). Observations on distribution and population density of black-capped vireos in burned areas provide an unclear picture of the effect of fire disturbance. The time from burn disturbance to occupancy or re-occupancy by black-capped vireos has not been well-documented and probably is site specific (Grzybowski 1991b). Breininger and Smith (1992) showed that birds in a scrub-type habitat generally are not influenced by changes resulting from periodic fires; however, burning too frequently could have an adverse effect on shrub-dwelling birds. Graber (1957) found vireos were common on burn sites. Areas occupied in the Wichita Mountains of Oklahoma buffeted by a substantial burn were fully recolonized by black-capped vireos the second year following the burn (Grzybowski 1989, 1990). However, recolonization by banded black-capped vireos in burned pastures at the Kerr Wildlife Management Area (KWMA) showed mixed results. The largest populations of vireos in the Wichita Mountains, Fort Hood Military Reservation, KWMA and Austin, Texas vicinity occur on landscapes recovering from burning (Graber 1957, Grzybowski et al. 1994).

Fire has been used on the KWMA since 1979 as a tool for juniper control and range management in a white-tailed deer (*Odocoileus virginianus*) management program. Research conducted on KWMA has demonstrated that prescribed burning is an effective and economical tool for controlling regrowth Ashe juniper (Texas Parks and Wildlife Department 1994, 1995). In addition, prescribed burning and reduced grazing pressure by domestic and wild animals has enhanced the resurgence of brushy vegetation mottes, especially live oak (*Quercus virginiana*), white shin oak (*Q. durandii*), flameleaf sumac (*Rhus copallina*) and Texas redbud (*Cercis canadensis*). These mottes, surrounded by open grassland, have provided nesting habitat for an expanding population of black-capped vireos on KWMA (Figure 1).

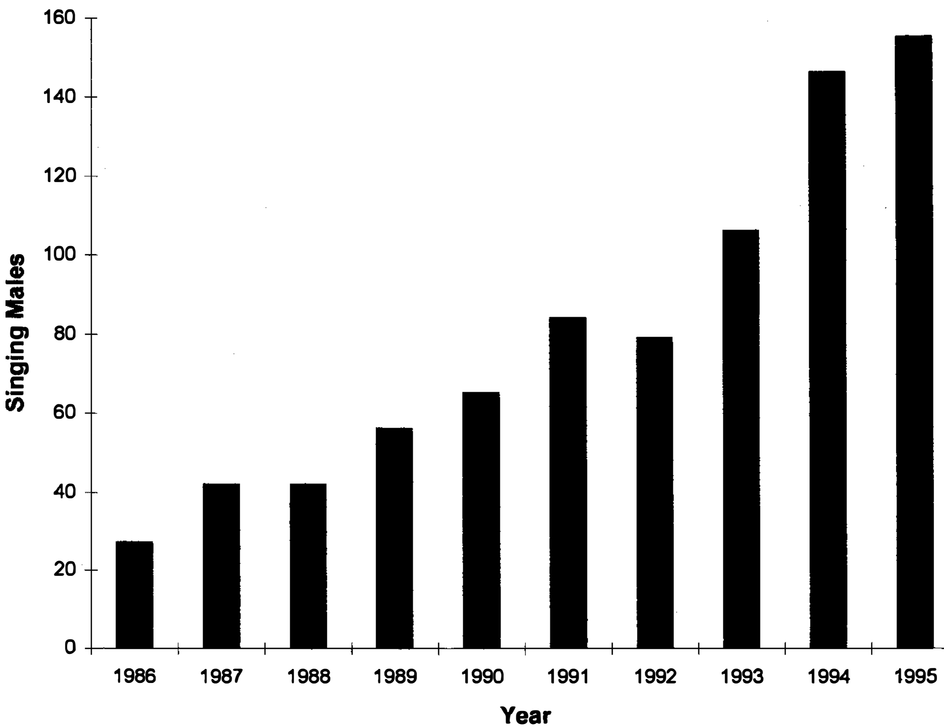

Figure 1. Black-capped vireo population trend based on combined surveys of singing males at the Kerr Wildlife Management Area. Brown-headed cowbirds were trapped 1986 to 1995. A partial survey was conducted in 1992.

Habitat disturbance, notably fire, appears to be a necessary factor in the maintenance and continuance of the plant community that provides black-capped vireo nesting habitat. However, the effects of prescribed burning on known populations of black-capped vireos have not been formally studied. The objectives of our study were to determine the effects of prescribed burning on black-capped vireo habitat and territory establishment at the KWMA. We believe this vital information will assist wildlife biologists in making sound recommendations about the use of prescribed burning as a management tool for improvement and maintenance of black-capped vireo habitat and recovery of populations.

Study Area

This study was conducted on the Kerr Wildlife Management Area, a 6,493-acre (2,629 ha) facility owned and operated by the Texas Parks and Wildlife Department. It is located in northwest Kerr County, 12 miles (19.4 km) west of Hunt, Texas. The area is bordered on the south by the head waters of the North Fork of the Guadalupe River (Texas Parks and Wildlife Department 1986). Elevation is about 2,000 feet (610 m). The slightly rolling to hilly topography remains relatively dry throughout the year except during heavy rainfall. No natural, permanent sources of water occur on KWMA. Mean annual rainfall is 30 inches (76 cm). Five major range sites occur on KWMA with low, stony hills predominating. Range conditions are at a slightly higher successional level than most of the Edwards Plateau region (Cross 1984). Live oak, white shin oak, Texas oak (*Quercus buckleyi*) and Ashe juniper are the dominant woody plants, with Texas redbud and flameleaf sumac dominant in localized areas. Dense, decadent Ashe juniper stands occur on uncleared areas. Dominant grasses are little bluestem (*Schizachyrium scoparium*), big bluestem (*Adropogon gerardii*) and Texas wintergrass (*Stipa leucotricha*). Forbs generally are abundant, but are dependent on rainfall (Texas Parks and Wildlife Department 1991). Cattle grazing on KWMA is managed by a rotational grazing system. Cowbirds are trapped during the time black-capped vireos are on the area.

Materials and Methods

Five pastures at KWMA were selected as study sites. North Rock (154 acres [62.3 ha]), South Rock (196 acres [79.4 ha]) and North Doe (124 acres [50.2 ha]) pastures were designated as experimental units and scheduled for prescribed burns in early 1994. Middle Rock (214 acres [86.6 ha]) and South Doe (186 acres [75.3 ha]) pastures were untreated controls.

Prior to each prescribed burn in the treatment pastures, the fine fuel load was estimated by W.E. Armstrong, an experienced fire control officer. An ocular perception of the amount of ground debris, bare ground, and the height, density and distribution of dead vegetation was done at 10 or more sites within a pasture to render the fine fuel load estimate.

Table 1. Atmospheric conditions during prescribed burns of treatment pastures at the Kerr Wildlife Management Area (Texas Parks and Wildlife Department 1994, 1995).

Pasture	Date and times	Percentage relative humidity	Wind direction/speed	Air temperature
South Rock	Feb 16, 1994			
Backfires ignited	1:20 p.m.	35	SW/3-7 mph	68°F (20.0°C)
Headfires ignited	2:30 p.m.	30	SW/3-7 mph	74°F (23.3°C)
End of burn	4:30 p.m.	43	SW/3-7 mph	68°F (20.0°C)
North Doe	Mar 10, 1994			
Backfires ignited	12:25 p.m.	41	NW/5 mph	60°F (15.5°C)
Headfires ignited	1:20 p.m.	41	NW/5 mph	61°F (16.1°C)
End of burn	3:30 p.m.	41	NW/5 mph	62°F (16.7°C)
North Rock	Jan 31, 1995			
Backfires ignited	10:55 a.m.	29	SW/10 mph	62°F (16.7°C)
Headfires ignited	1:35 p.m.	26	SW/10 mph	66°F (18.9°C)
End of burn	4:57 p.m.	20	SW/10 mph	67°F (19.4°C)

A total count of black-capped vireo territories was conducted from June 14, 1993 to July 25, 1993 in all treatment and control pastures. A foot-survey route was established in each pasture. The course of the route, based on topographic features and locations of previously known black-capped vireo territories, extended over the entire pasture. Surveys were conducted under acceptable weather conditions as defined by Robbins (1981). The initial survey for territories within each study pasture was conducted for a minimum of five days. Once the initial survey of each pasture was complete, areas within each pasture were surveyed again a maximum of four times to verify the presence or absence of a black-capped vireo territory. At least two surveys of one-hour duration were conducted in areas of pastures with no documented black-capped vireo territories. A maximum of 15 minutes per territory was spent searching for nest sites. To reduce the possibility of double counts, each male bird was followed to determine the cap-color class, approximate boundary of the territory, and the presence or absence of leg bands used in a study by Grzybowski (1991a). If uncertainties about the location of a territory or the presence of a territory existed, the area or territory was resurveyed until the problem was resolved. Each territory was assigned a field number and recorded on a topographic map.

After territories were identified, 40 were randomly selected (10 each in North, Middle and South Rock pastures and 5 each in North and South Doe pastures) for further study. Within each selected territory, a viable vegetation motte was selected for assessment of nest site damage during a prescribed burn. Mottes were selected based on the presence of a nest or the potential of the motte to serve as a nest site. After the vireos migrated in late summer, the length and width of each motte was measured along north-south and east-west axes. The height of each motte was recorded at five locations within the motte and average height was calculated. Length, width and average height were used to estimate the volume of each motte.

South Rock Pasture was burned on February 16, 1994. Estimates of the fine fuel load in the pasture ranged from 1,000 to 2,500 pounds per acre (1,120-2,802 kg/ha). The estimated mean fine fuel load for South Rock Pasture was 1,800 pounds per acre (2,017 kg/ha).

North Doe Pasture was burned on March 10, 1994. Estimates of the fine fuel load in the pasture ranged from 1,000 to 2,000 pounds per acre (1,120-2,241 kg/ha). The estimated mean fine fuel load for the pasture was 1,400 pounds per acre (1,569 kg/ha).

North Rock Pasture was scheduled for burning in early 1994, but because the estimated mean fine fuel load was less than 500 pounds per acre (560 kg/acre), this pasture was not burned.

After prescribed burns, the length, width and height of marked mottes were remeasured to assess the extent of damage. All pastures were surveyed for black-capped vireo territories beginning May 16, 1994 by methods used in 1993 with the following additions. A maximum of one hour was spent in known territories searching for nests. If a nest was not located, the territory was revisited within three weeks. A maximum of four attempts were made to locate nests. Territories were monitored until August 4, 1994.

Mottes used as nesting sites in 1994 in North Rock and Middle Rock pastures were marked, the dimensions measured and volumes estimated by methods used in 1993. Six mottes with nests in 1994 were included in the 1995 North Rock sample.

North Rock Pasture was burned on January 31, 1995. Estimates of the fine fuel load in the pasture ranged from 1,500 to 2,500 pounds per acre (1,681-2,801 kg/ha). The estimated mean fine fuel load for the pasture was 2,000 pounds per acre (2,241 kg/ha). Marked mottes in North Rock Pasture were measured after the burn and all pastures were surveyed for black-capped vireo territories starting on May 12, 1995 and monitored until August 10, 1995 by methods used in 1994.

Preburn and postburn measurements of marked mottes were used to calculate the mean percentage change in motte volume. Differences in preburn and postburn mean motte volumes were tested with a one-tailed Student's *t* test (Zar 1984).

The general locations and numbers of territories plotted on topographic maps for each year were compared to assess any major changes that may have been in response to habitat alterations by the prescribed burn. A two-tailed Student's *t* test was used to test for differences in the mean net annual increase of black-capped vireo territories in treatment and control pastures.

Results

The mean volume of mottes in South Rock Pasture was reduced 34.9 percent ($P[t_{\alpha(1),9} = 3.245] = 0.005$) from 20,164 cubic feet (571 m^3) to 13,137 cubic feet (372 m^3) by the prescribed burn. The mean volume of mottes in North Doe Pasture was reduced 7.3 percent ($P[t_{\alpha(1),4} = 1.676] = 0.09$) from 27,757 cubic feet (786 m^3) to 25,744 cubic feet (729 m^3). The mottes in North Rock Pasture had the largest reduction in the mean volume of mottes from 20,306 cubic feet (575 m^3) to 9,394 cubic feet (266 m^3), a reduction of 51.5 percent ($P[t_{\alpha(1),15} = 3.583] = 0.001$).

Treatment and control pastures had net gains in the number of black-capped vireo territories (Figure 2). Considering the number of territories in pastures in 1993 (baseline data), there was a net gain of 11 territories in burned pastures compared with a net gain of nine territories in control pastures during our study. There was no significant difference ($P[t_{\alpha(2),7} = 0.033] = 0.97$) in the mean net annual increase in number of territories for burned pastures (mean = 2.20, n = 5) and control pastures (mean = 2.25, n = 4). An increase from 17 to 23 territories following a prescribed burn in South Rock Pasture was the greatest annual increase for all pastures. The number of territories declined in two pastures. In North Rock Pasture, the number of territories declined by four the

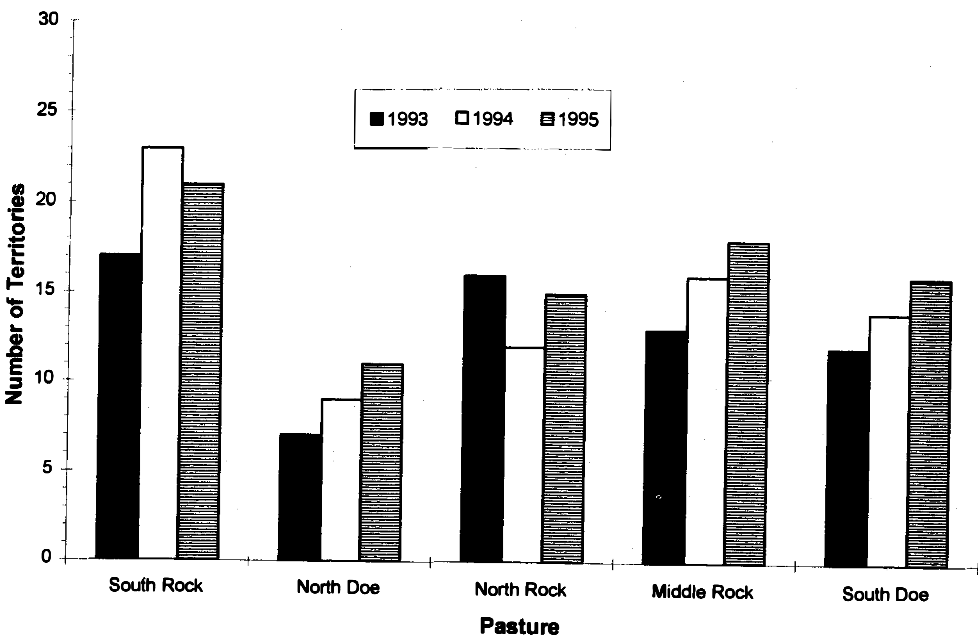

Figure 2. Comparison of the number of black-capped vireo territories in treatment (South Rock, North Doe, North Rock) and control (Middle Rock and South Doe) pastures at the Kerr Wildlife Management Area from 1993 to 1995. Prescribed burn dates: South Rock—February 16, 1994; North Doe—March 10, 1994; and North Rock—January 31, 1995.

year before a prescribed burn. The number of territories in South Rock Pasture the second year postburn decreased by two. However, the overall trend for all pastures during our study was an increase in the number of territories.

Discussion

The black-capped vireo recovery plan calls for developing techniques for managing vireo habitat by converting and maintaining an area as vireo habitat (Grzybowski 1991b). The KWMA has accomplished the conversion of areas into vireo habitat by using prescribed burning and reducing grazing pressure. Juniper encroachment over time, however, will diminish the value of areas as vireo habitat. The recovery plan identifies the need to determine the best methods for managing habitat for vireos. Prescribed burning is the primary method identified by personnel of the KWMA to accomplish this task, however, prior to our study, the effect of burning on a population of black-capped vireos was unknown.

The influence of prescribed burning on the plant community at KWMA has been addressed in several studies (Baccus 1981, 1982, 1983, 1984, Fonteyn et al. 1988). One aspect of these studies concentrated on the effect of prescribed burning on the morphology of small mottes composed of woody vegetation, especially live oak. On the KWMA, these mottes serve as primary nesting sites in black-capped vireo territories. These studies showed that under conditions of high moisture content in litter, desiccation of the litter suppressed the energy of the fire, causing the fire to bypass mottes, leaving them intact. Extensive damage to large mottes only occurred when prescribed burns were conducted under conditions of high temperature, low humidity, low litter moisture and wind speeds above 5 miles per hour (8.1 km/hr). The data acquired in our study are concordant with these results.

The prescribed burns during this study encompassed a full range of intensity. The burn in North Doe Pasture was conducted when a substantial amount of green vegetation and a discontinuous fine fuel load were present. These factors in concert with the relative humidity, air temperature and wind speed resulted in a very cool fire and sporadic burning of vegetation in the pasture. Mottes with a nest or potential as a nest site sustained little or no damage. There was little or no impact on the successional stage of vegetation.

South Rock Pasture was last burned in 1984, and growth of oak mottes since the burn had caused them to coalesce, reducing the amount of openness. Cover provided by low, deciduous, woody vegetation is the key element of vireo habitat, but the vegetation must have a heterogeneous pattern with 45 to 65 percent of the area open (Grzybowski 1991b). Amos and Gehlbach (1988) concluded that fire may be the most important non-edaphic factor controlling vegetation patterns. The prescribed burn of medium to high intensity in South Rock Pasture penetrated many mottes and caused an increase in the amount of space between mottes. Three mottes were completely destroyed and three were reduced by about 50 percent. Four mottes were unaffected by the fire. This diversiform effect of fire created a mosaic pattern of vegetation. The reduction in woody cover by damage or destruction of mottes and regrowth juniper did not diminish the pasture's suitability as black-capped vireo habitat. This pasture had the greatest postburn increase in number of territories. However, this was the only treatment pasture with a second-year postburn decrease in number of territories. The reason territories were not re-established in the second-year postburn is unknown.

The reduction of black-capped vireo territories in North Rock Pasture from 16 in 1993 to 12 in 1994 is difficult to explain. The plant community may have reached a stage of succession that no longer was optimum habitat for the black-capped vireo, or some vireos may have abandoned this pasture to inhabit nearby burned pastures.

The high intensity of the prescribed burn in North Rock Pasture in 1995 set back succession, eliminated regrowth juniper and created a spatial pattern associated with black-capped vireo habitat. Even though this pasture sustained a substantial burn perturbation, the number of established territories increased from 12 in 1994 to 15 in 1995. In five territories, mottes used for nesting prior to the burn were completely destroyed. All of these territories were re-established the following spring. Vireos built nests in nearby suitable mottes that sustained little or no damage.

Occupancy of the KWMA by black-capped vireos indicates that prescribed burning, in conjunction with sound grazing practices, can be an effective range management tool in developing and maintaining black-capped vireo habitat. The data acquired during our study suggest that winter prescribed burning in known nesting habitat, regardless of intensity, does not sufficiently degrade the habitat to cause a postburn decline in black-capped vireos. Patches of suitable habitat remain for birds to occupy and nest in while damaged areas recover. The cyclic burning of pastures, reduced grazing pressure and cowbird control on the KWMA seem to be the keys for an expanding population of vireos.

Succession of the plant community and invasion of Ashe junipers following prescribed burns necessitate monitoring of the black-capped vireo population to determine habitat changes that result in unsuitable habitat for nesting. This information is critical for wildlife managers to properly manage black-capped vireo habitat.

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Effects of Prescribed Burning on Wild Turkeys

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Benefits to wild turkeys (*Meleagris gallopavo*) from prescribed burning of pine forests have been appreciated for decades (Stoddard 1963, Hurst 1978). Stoddard (1931, 1963) was first to recommend a two- to three-year burning frequency to produce groundstory vegetation beneficial to bobwhite quail (*Colinus virginianus*) and turkeys. Since then, research has demonstrated forest groundstory vegetation responds to prescribed burning by changes in structure and composition that increase the quantity and quality of forage and fruit available to turkeys (Hurst 1981a).

In Mississippi, the USDA Forest Service (USFS) manages more than 1.4 million acres (600,000 ha) of potential wild turkey habitat, and prescribed burning of pine forests occurs on a large scale. While the USFS uses prescribed burning to control hardwoods, reduce fuel and improve wildlife habitat, frequency of burning rarely has approached Stoddard's recommendations, except in pine stands managed for red-cockaded woodpecker (W. Burger personal communication: 1996). Information is needed on how prescribed burning programs of the USFS affect turkey habitat selection and reproductive success (Hurst 1981b).

In this paper, we demonstrate how low-frequency prescribed burning generated temporary benefits to wild turkeys. Further, we establish how low-frequency prescribed burning limited habitat quality on a large scale by decreasing the amount of area suitable to turkeys. Also, we hypothesized how low-frequency prescribed burning may reduce reproductive potential of turkey populations on remnant areas of suitable habitat. Finally, we show how gobblers and hens respond differently to prescribed burning.

Methods

The study area consisted of 35,600 acres (14,410 ha) of the Tallahala Wildlife Management Area (TWMA), Strong River District, Bienville National Forest and associated private lands. The area was 95-percent forested and was composed of bottomland hardwood (30 percent), pine (37 percent), mixed pine/hardwood forests (17 percent), and pine and hardwood regeneration areas (11 percent). Age of most pine and hardwood stands exceeded 50 and 70 years, respectively. Nonforested areas occurred on private lands and were composed of old field (4 percent), agriculture (1 percent) and residential areas (< 1 percent). Hardwood forests were located in four broad alluvial creek drainages. Pine and hardwood regeneration areas averaged 31.4 acres (12.7 ha) and 12.8 acres (5.2 ha), respectively.

During February and March, pine forests in USFS planning compartments were prescribe burned. Of 26 compartments on TWMA, 1 to 3 were prescribe burned each year. Compartments averaged 1,027 acres (416 ha, SD = 79), with an average of 59 percent in pine or mixed pine/ hardwood forests. Burning frequency of pine forests depended on the compartment in which they resided, but ranged from 3 to 10 years. Variation in burning frequency among compartments resulted from differences in management objectives and liability risks from prescribed burning. Therefore, different aged burns (i.e., pine forests prescribe burned 0-10 years prior) existed across TWMA from one year to the next as a shifting distribution of large blocks of similarly aged burns.

Turkeys were captured by cannon-netting during January and February and July and August, 1984 through 1989, following Bailey (1976). Turkeys were equipped with a 107 g battery-powered, "backpack-style" transmitter with a mortality or motion switch (Wildlife Materials Inc., Carbondale, Illinois), leg bands and black (hens) or colored (gobblers) patagial wing tags.

We determined turkey location by triangulation (Cochran and Lord 1963, Heezen and Tester 1967) from two telemetry stations ($\underline{n}$ = 275) using a hand-held, three-element yagi antenna and a Telonics (Mesa, Arizona) TR-2 receiver. Error of test azimuths for transmitters at known locations averaged 7.2 degrees (SD = 6.3).

We used photo interpretation and USFS stand data to delineate habitats into six types: pine forests were composed of greater than 70-percent pine, bottomland hardwood forests were greater than 70-percent hardwood, mixed forest had 30 to 70 percent pine, regeneration areas (after logging, four years post-planting), sapling (5-15 years post-planting), field, pasture and agricultural. Habitat types were transferred from color, infrared aerial photos to 7.5 minute quadrangles using a vertical sketchmaster and digitized into a personal computer. All stand map analyses were conducted using PC Arc/Info (ERSI, Inc. 1989).

Monitoring of Habitat Use

Radio-equipped gobblers were located twice daily every other day, January through September, 1986-1990. Locations were separated into two seasons: spring (February 1-May 31) and summer (June 1-September 30). Radio-equipped hens were located daily from March 1 through June 30, 1985 through 1989. This period encompassed flock break-up, searching for nesting range, incubation of nests and some brood rearing. In this paper, we concentrate on habitat use of hens from break-up of winter flocks to incubation of nests, or the pre-incubation period.

Habitat-use Statistical Analyses

Proportion of habitat use was compared with proportion of habitat availability for each season/period using chi-square analysis and simultaneous confidence intervals (Neu et al. 1974, Byers et al. 1984). If the chi-square was significant, a set of simultaneous confidence intervals was constructed for the proportion of use for each habitat type. If proportion availability was greater (less) than the upper (lower) bound of the usage confidence interval, the habitat was considered to be used less (greater) than expected. Statistical tests were protected at $\alpha = 0.10$.

Use of Different-aged Burns

Use of different-aged burns by gobblers was compared with their availability for spring and summer 1989 when sample size of gobblers was greatest. For gobblers, different-aged burns were classified into four groups; pine forests prescribe burned 0, 1 to 2, 3 to 4, and 5 or more years prior. We compared use with availability of different age prescribed burn classes for hens in 1986, 1988 and 1989. For hens, prescribed burns were classified into three groups; pine forests prescribe burned 0, 1 to 2, and 3 or more years prior. Percentage use and availability of each burn class were compared using simultaneous confidence intervals (Neu et al. 1974).

Many pine stands that had not been prescribe burned for more than three years were used by hens on TWMA. Use of these pine forests by hens may have been related to their juxtaposition with bottomland hardwood forests, a habitat selected by hens year-round on TWMA (Palmer 1990).

We investigated if hen use of pine forests was affected by their juxtaposition to bottomland hardwood forests. This was accomplished by comparing the proportion of pine stands adjacent to bottomland hardwood forests that were used by hens and prescribe burned zero to three years prior with those prescribe burned more than three years prior to use by hens. A period of three years was used to delineate between prescribe burned and "unburned" stands based on habitat use results and relevant literature (Exum et al. 1987, Sisson et al. 1990).

Research on TWMA indicated that hen movements were associated closely with habitats that border creeks, such as bottomland hardwood forests and forested corridors along upland creeks (Palmer and Hurst in press). In 1989, we investigated the interaction of hen movements and creeks in areas with and without pine forests prescribe burned within three years. We plotted random locations in individual hen-use polygons and calculated distances of hen locations and random points to the nearest creek. Differences in distances to creeks from random and actual locations were examined using t-tests. We calculated an index of an individual hen's "attraction" to habitats near creeks as:

$$\frac{(RD_i - OD_i)}{RD_i}$$

where RD_i was the mean distance from random locations, plotted within a hen's use polygon, to the nearest creek and OD_i was the mean observed distance from telemetry locations for hen I to the nearest creek. Positive values of the index indicated that a hen was "attracted" to habitats near creeks and negative values indicated an "avoidance" of habitats near creeks. Relation of the index to pre-incubation home range characteristics was determined using correlation analyses.

Burning of pine forests modifies groundstory vegetation making pine forests suitable habitat for hens. If prescribed burning pine forests permits some hens to locate pre-incubation home ranges in predominantly upland areas, rather than in association with creeks, does this shift in habitat use affect their reproductive success? We investigated if successful nesters were more likely to have pre-incubation home ranges composed primarily of pine forests, mixed forests or bottomland hardwood forests by comparing percentages of forest types within pre-incubation home ranges of successful and unsuccessful nesting hens using a Mann-Whitney test (Steel and Torrie 1980). Based on the relationship between number of telemetry locations and incremental increases in hen home range size, pre-incubation ranges were judged adequately sampled if more than 30 locations were obtained.

Vegetational Response of Hens

To better assess habitat use and movement patterns during the pre-incubation period for the purpose of conducting vegetation analyses, a subsample of 20 "focal" hens was randomly selected in 1989 for intensive monitoring. These hens were located three times per day, with hourly observations obtained one day per week per hen during the pre-incubation period. Vegetation measurements were completed on hens which incubated nests. All vegetation measurements were completed within three weeks of the onset of continuous incubation of nests.

Within each focal hen's home range, vegetation characteristics were determined for regions used and not used by hens based on telemetry data. Vegetation sampling points ($\underline{n} = 40$) were established equidistantly along randomly chosen azimuths in used and not used regions. Overstory measurements included basal area by species, height of nearest dominant tree using a clinometer and canopy closure using a densiometer (Lemmon 1957). We measured groundcover using six groundcover boards (GCB) placed systematically about the sampling point and directly above groundstory. Each GCB was composed of 50, 2- by 4-inch (5 x 10 cm) rectangles. Number of rectangles occupied by vegetation (> 50 percent obstructed) were counted and assigned to grass/sedge, forb, woody or vine vegetation classes. Difference in groundcover classes between used and not used regions were analyzed by G-factor contingency table analyses (Sokal and Rohlf 1981). Groundstory structure, defined as degree of obstruction to horizontal vision through vegetation (Gysel and Lyon 1980) was measured indirectly using a sighting board (an 8- by 36-inch [20 x 90 cm] board with each 12-inch (30 cm) section alternately painted orange or white) placed at the sampling point. At each of the cardinal directions, an observer moved directly away from the sighting board and recorded the distance when each 8- by 12-inch (20 x 30 cm) section became 100-percent occluded by vegetation.

We used Kolmogorov-Smirnov (K-S) one-sample tests to test for normality of vegetation variables (Steel and Torrie 1980). Variables that followed the normal distribution were tested for equality of variances using Bartlett's test (Neter et al. 1985). When assumptions of ANOVA were met (with raw or log-transformed data), we used ANOVA with equal subsampling to determine differences in variables between used and not used regions (Peterson 1985). Otherwise, an overall mean was determined for each hen and treatment, and was compared using either paired t-tests or t-tests for unequal variances (Steel and Torrie 1980). All statistical tests for micro-habitat differences were conducted using SPSS/PC (SPSS, Inc. 1988) at $\alpha = 0.05$.

Results

Prescribed Burning and Turkey Use of Pine Forests

Influence of prescribed burning on gobbler habitat use was investigated in 1989 when sample size was greatest. A total of 30 gobblers (25 adult, 5 juvenile) was located 354 times during spring, and 18 gobblers (13 adult, 5 juvenile) were located 552 times during summer. Gobblers avoided pine forests during spring, but selected pine forests during summer (Table 1). Burning influenced use of pine forests. Gobblers used 0- to 4-year-old burns in proportion to their availability during spring. During summer, gobblers selected pine forests burned one to two years prior and avoided pine forests burned the previous spring or winter. In all seasons, gobblers avoided pine forests not burned for five or more years.

Table 1. Selection of mature pine forests, by years since last prescribed burned, by radio-equipped gobblers on Tallahala Wildlife Management Area, Mississippi, 1989.

		Years since burned[a]				
Season	Age	All	0	1 to 2	3 to 4	5 or more
Spring	Adult	<	=	=	=	<
Spring	Juvenile	=	=	=	=	<
Summer	Adult	>	<	>	=	<
Summer	Juvenile	=	<	>	=	<

[a]Habitat use <, > or = indicate availability (*P* < 0.10).

We examined use of different-aged burns (i.e, prescribed burning pine forests) by hens during pre-incubation in 1986, 1988 and 1989. Number of locations per year averaged 256 (range: 164-344) and was obtained on an average of 27 (range: 20-42) hens per year. Pine forests prescribe burned the previous winter/spring were selected in two of three years, and used in proportion to availability in one year (Table 2). Pine forests prescribe burned one to two years prior were selected in one year and avoided in two, and pine forests prescribe burned three or more years were avoided in two of three years. The ratio of use of different-aged burns to their availability averaged 1.7 for pine forests prescribe burned the previous winter, 1.0 for pine forests prescribe burned one year prior and remained below 1 for pine forests prescribe burned three or more years prior.

Table 2. Selection of mature pine forests, by years since last prescribed burned, by radio-equipped hens on Tallahala Wildlife Management Area, Mississippi, 1984 - 1989.

Year	Years since burned[a]			
	All	0	1 to 2	3 to 9
1986	<	=	>	<
1988	<	>	<	=
1989	<	>	<	<

[a]Habitat use <, > or = indicate availability (P < 0.10).

Use of pine forests by hens during pre-incubation was dependent on juxtaposition of pine forests with bottomland hardwood forests. Pine stands not prescribe burned for more than three years and used by hens were more likely adjacent (48 percent) to bottomland hardwoods than recently prescribe burned pine forest stands used by hens (25 percent) (P = 0.06).

Hen Movements, Creeks and Prescribed Burning

In 1989, 13 focal hens were monitored (n = 875 locations) during pre-incubation to investigate influence of creek drainages on their movements and habitat use. Within all home ranges, locations were closer to creeks than random points (P < 0.001). Within pine forests only, distance to creeks from hen locations (n = 259) was similar to random locations (P = 0.28). However, hens with more than a quarter of their pre-incubation home range in pine forests prescribe burned within three years were located on average farther from creeks than hens with less than a quarter in pine forests prescribe burned within three years (P = 0.014). Similarly, the creek index was negatively correlated (r = -0.65; P = 0.017) to availability of pine forests prescribe burned within three years, but not to availability of pine forest (r = -0.21), bottomland hardwood forest (r = 0.24) or mixed forest (r = -0.27) within pre-incubation home ranges (P > 0.05).

Home Range Characteristics and Nesting Success

We used 35 nesting hens which were located more than 30 times ($\bar{X}$ = 50.4; range: 31-75) during pre-incubation, 1984 through 1989, to determine if proportion of different forest types within pre-incubation home ranges was related to nesting success. Pre-incubation home ranges of successful hens (n = 14) averaged 34 percent (SE = 0.06) bottomland hardwood forest versus 52 percent (SE = 0.04) for unsuccessful hens (n = 21) (P = 0.011). All five hens with ranges composed of less than 18-percent bottomland hardwood forest were successful, and all five hens with ranges composed of more than 65-percent bottomland hardwood forests were unsuccessful. Successful hens had a greater proportion of their pre-incubation home range in mixed forest ($\bar{X}$ = 20 percent; SE = 0.03) than unsuccessful hens ($\bar{X}$ = 11 percent; SE = 0.02) (P = 0.008). Proportion of home range in pine forest was not significantly different (P = 0.17) for successful ($\bar{X}$ = 33 percent; SE = 0.05) and unsuccessful ($\bar{X}$ = 25 percent; SE = 0.03) hens. Both percentage mixed forest (r = -0.73) and pine forest (r = -0.87) were negatively correlated with percentage bottomland hardwood forests within pre-incubation home ranges (P < 0.001).

Overstory and Groundstory Vegetation Analyses

Vegetation measurements were completed for 11 focal hens nesting in 1989. Hens were monitored ($\bar{X}$ = 101 locations/hen) an average of 44 days (range 38-53) from March 1 to onset of continuous incubation.

Height of canopy trees (P = 0.34), canopy closure (P = 0.45) and basal area (P = 0.33) did not differ significantly between used and not used regions. Overall, basal area from used regions had more hardwood than not used regions (P = 0.001), however, three hens had similar or greater pine basal area on used regions.

Percentage groundcover was similar (P = 0.32) on used ($\bar{X}$ = 36; SE = 0.75) and not used ($\bar{X}$ = 0.40; SE = 0.91) regions. However, groundstory vegetation in used areas was more likely grass and forbs, and less likely woody and vine ($\underline{P} < 0.001$). Groundstory vegetation was significantly lower on used ($\bar{x}$ = 28 cm; SE = 0.31) than not used areas ($\bar{x}$ = 58 cm; SE = 0.55) ($\underline{P} < 0.001$). Sighting board distances were significantly higher on used areas ($\bar{x}$ = 42 m; SE = 0.94) than not used areas ($\bar{x}$ = 24 m; SE = 0.62).

Conclusions

Use of pine forests by turkeys was dependent on burning history, season and sex. During spring and summer, gobblers consistently used older prescribe burns than did hens. While gobblers used one- to two-year-old prescribed burns more than expected during summer and consistently used three- to four-year-old burns in proportion to their availability, these prescribe burned forests generally were avoided by hens. Disparate selection of different-aged prescribed burns by gobblers and hens probably stemmed from their different nutritional needs and life histories. Hens require a high protein diet during egg laying and meet their nutritional needs from insects and green vegetation (Hurst 1992). Gobblers also use green vegetation and insects during spring and summer, but soft mast also is important (Hurst 1992). Gobblers avoided pine forests prescribe burned the previous winter where fruit production likely was limited (Hurst 1981a). Forest groundstory plants tend to produce more fruit several years following a prescribed burn. Johnson and Landers (1978) reported that areas prescribe burned within two to three years yielded more soft mast. Biologists in Alabama and Mississippi, realizing the need to maintain fruit production, recommended a burning rotation of four years (Speake et al. 1975, Godwin et al. 1992).

Overall avoidance of pine forest by hens during pre-incubation was an outcome of long burning rotations. Hens also avoided unburned pine forests on TWMA during brood rearing, autumn and winter (Palmer 1990). Burning of pine forests affected hen habitat use during pre-incubation. Hens selected pine forests prescribe burned the previous winter and used one-year-old burns according to availability. Sisson et al. (1990) reported similar habitat use patterns by hens during spring in Georgia. Prescribed burning reduces woody groundcover and promotes forbs and grasses (Stoddard 1963, Hurst 1981a, Exum 1985, Exum et al. 1987), thus improving suitability of pine forests for hens. During spring, groundcover in unburned pine forests generally was shrubs and vines interspersed with dead grass and forbs; nearly a complete canopy closure and a six-year prescribed burning rotation fostered these conditions. Many of the pine stands used by hens that had not been burned for three or more years were located next to bottomland hardwood forests.

Vegetation analyses indicated habitat selection by hens during pre-incubation was dependent on the condition of groundstory vegetation more than overstory vegetation. Hens selected areas with low groundstories composed of mainly grasses and forbs, and avoided areas with high woody and vine groundcover; although this type of groundstory was used to escape disturbance (Wunz 1971, Palmer 1990) and for nest site selection (Seiss 1989, Palmer 1990). During spring, hens meet nutritional needs from mast, green vegetation and insects (Korschgen 1973, Healy 1985, Hurst 1992). Groundcover dominated by woody and vine plant species provides fewer insect and plant foods than herbaceous groundcover and may interfere physically with hen feeding behavior (Hurst 1981a, Healy 1985). During autumn and winter, hens on our study area also avoided woody/vine groundstories even where soft and hard mast foods were available (Palmer 1990). Suitable groundstory conditions were found in bottomland hardwood forests, mixed forest corridors along creeks and in recently prescribe burned pine forests.

Frequency of prescribed burning was too long to maximize habitat benefits for turkeys. Groundstory vegetation reverted to a vine and woody plant assemblage within a few years following burning. Each year, less than 17 percent of pine forests had been prescribe burned within two years, and their availability to the hen population was limited due to the clumped distribution.

Therefore, a significant proportion of TWMA was not suitable as hen turkey habitat during spring and summer. Similarly, each year nearly half of all pine forest had not been burned for five or more years, limiting its suitability for gobblers.

The hen population on Tallahala was highly connected to creeks and drainage systems (Palmer and Hurst in press), probably due to suitable groundstory conditions present in bottomland hardwood forests and in forested corridors along creeks. After leaving winter flocks in early spring, hens moved from bottomland hardwood forests into upland forests following relatively open, forested corridors along creeks. Burk et al. (1990) reported similar use of streamside management zones in pine plantations in Mississippi. On TWMA, this movement pattern resulted in hens remaining year-round within one creek drainage (Palmer and Hurst in press). Rarely did adult hens move between adjacent drainage systems. Therefore, since prescribed burning occurred only in one or two planning compartments each spring, the distribution of 0- to 1-year-old burns was clumped. This prescribed burning pattern limited benefits to that segment of the hen population within the drainage system where the prescribed burn occurred.

We assume habitat selection by hens during the pre-incubation period is critical to success of subsequent nesting attempts for at least three reasons: (1) hens require high-quality nutrition during reproduction which must be provided by their habitat; (2) hens should select areas in which they are safe from predation; and (3) hens should select areas with a low density of nest predators and/or habitat conditions favorable to minimizing nest predation. Patterns of hen dispersal, home range selection and habitat use observed during pre-incubation resulted in hen home ranges associated with creek drainages, rather than upland forests. This habitat-use pattern appeared to be a result of low frequency of prescribed burning of pine forests adjacent to open corridors along creeks. Our data suggests that pre-incubation home ranges, in which hens nest, in association with bottomland hardwood forests and corridors along creeks may increase the probability of a nest being destroyed by predators. Many studies have documented higher densities of common nest predators (e.g., raccoon [*Procyon lotor*], opossum [*Didelphis virginiana*]) in bottomland hardwood forests than in upland pine forests (Verts 1963, Leberg et al. 1983, Leberg and Kennedy 1987, Sanderson 1987). Telemetry studies of the major nest predator on TWMA, the racoon, have found they selected bottomland hardwood forests during winter and summer, but increased use of mixed pine/hardwood corridors along creeks during the turkey nesting period (Priest et al. 1995). Hens nesting in pine forests had higher rates of success than hens in pine regeneration areas (Seiss et al. 1990); relative to pine forests, regeneration areas also are predator-dense habitats (Miller and Leopold 1992). Therefore, we hypothesize that long (greater than three years) prescribed burning rotations and closed overstory canopies maintain upland forests as unsuitable hen habitat during pre-incubation, which may negatively impact turkey populations in two main ways. First, by confining hen movements and habitat use to a smaller area, and second, by reducing nesting success of hens selecting pre-incubation home ranges in association with predator-dense habitats along creeks. Many studies of ground-nesting birds have documented a positive correlation between useable area and nesting success (Rodenhouse et al. 1983, Puckett et al. 1995). Puckett et al. (1995) found that bobwhite quail nesting success increased dramatically following crop growth and subsequent nesting in crop fields rather than along edges of fields; presumably, increases in useable nesting area reduced the probability of predators locating nests.

In summary, benefits derived from vegetation changes after prescribed burning are short-lived when burning rotations exceed four years. Low-frequency prescribed burning of pine forests limits useable area for turkey hens and gobblers and may indirectly reduce reproductive success of hens by limiting habitat use during pre-incubation and nesting to predator-dense habitats. Hens and gobblers respond differently to prescribed burning and their different needs should be considered when planning prescribed burning. Both frequency and distribution of prescribed burning should be considered when designing burn programs for the purpose of benefiting wildlife populations.

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Responses of Avian Populations and Vegetation to Prescribed Burning in Pine Forests of the Arkansas Ozarks

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Prescribed burning, or fire set under planned conditions to alter habitat for specific management objectives, has been a major part of wildlife management since the early 1930s (e.g., Stoddard 1931, Lay 1967, Wood 1981, Pyne 1984). It currently is used by the USDA Forest Service as a management tool to discourage hardwood invasion in pine stands and to increase suitability of those forests for certain wildlife (Grano 1970). In pine forests of the southeastern United States where canopy fires are rare, the main effect of burning is to remove most of the understory tree and shrub layer (Wade and Johansen 1986).

The recent decline in birds that migrate from the New World Tropics to nest in North America has generated considerable interest (e.g., Askins et al. 1989, Robbins et al. 1989, Finch and Stangel 1992, Hagan and Johnston 1992). Among all birds nesting in southeastern forests, these neotropical migrants appear to be the most vulnerable to disruptions of breeding efforts because, compared with local residents and short-distance migrants, neotropical migrants tend to arrive on breeding grounds late and depart early. Thus, their breeding seasons are compressed resulting in decreased nesting opportunities each year. Any habitat changes that reduce avian nesting success could impact neotropical migrants more than other nesting birds.

Since the mid-1920s, fire suppression has changed the structure of forests throughout North America (Rotenberry et al. 1995). In the Arkansas Ozarks, this has allowed development of a primarily deciduous understory that often reaches into the mid-canopy. This effect is most pronounced in pine stands where fire once was relatively common (Smith and Petit 1988, Smith and Neal 1991). The present study examines the immediate effects of prescribed burning in mature pine stands on nesting neotropical migrant and resident birds.

Study Area and Methods

This study was conducted in the Ozark National Forest within the Bayou Ranger District at Griffin Mountain, 8 miles (13 km) northeast of Jerusalem, Conway Company, Arkansas (35°27′N; 92°47′W). The vegetation in the study areas was mature secondary forest composed primarily of 60- to 80-year-old shortleaf pine (*Pinus echinata*) with occasional large oaks (*Quercus* spp.). Mean basal area of pine:hardwood saw timber (stems >9.8 inches [25 cm] diameter breast height or dbh) was 130:60 square feet per acre. A total of 365 acres (148 ha), designated the treatment stand (burn unit 92-6), was burned in late February, 1993, by the USDA Forest Service. A control stand of equal size that was not burned was established adjacent to the treatment stand. The fire was of low intensity, averaging 1-foot (0.3 m) high flame lengths that blackened 85 percent of the treatment stand, but no crown scorch or soil exposure resulted. A 1992 (preburn) and 1993 (postburn) analysis of both stands were conducted May through July.

Birds were censused using a fixed-radius point count method (Hutto et al. 1986). There were two transects, a long one with 12 permanent points plus a short one with 6 points, centered through each stand studied (18 points per stand). Census points were spaced approximately 136.7 yards (125 m) apart in the transects. In both preburn and postburn years, bird censusing lasted from early May through mid-June. Every point was visited four times (144 counts) each year. Censusing was conducted during the period from sunrise to about three hours thereafter. Starting points and path directions were varied to reduce time biases. The observer walked the transect stopping at each point for 10 minutes to count all bird species seen and heard within a 54.7-yard (50 m) fixed-radius circle centered at the point. This fixed radius was used to maximize the probability that bird counts coincided with the habitat characteristics measured at the point. In addition, all birds detected outside the fixed radius were recorded to ensure total detection of species.

To compare treatment and control stands over burn and preburn years, 27 habitat characteristics were measured in four subplots at each bird census point. The first subplot was located at the center of the point count circle. The other three were separated from each other by 120 degrees in a circle around the central one and 38.3 yards (35 m) from it (one being due north of the center). In the preburn year, habitat characteristics were measured at each of the 36 census points (144 subplots), and in the postburn year the 18 census points that were subjected to prescribed fire were sampled again to detect any changes in habitat characteristics (72 subplots).

Within a 5-meter radius circle at each subplot, all small stems of vegetation were counted, classified as deciduous or coniferous (pine), and categorized as seedlings (2.5 cm in diameter at 10 cm above ground) or saplings greater than 2.5 to 8 centimeters dbh. All tree species were counted and classified as deciduous or coniferous (pine) and grouped by dbh classes (>8-23, >23-38, and >38 cm dbh) within 11.3-meter radius circles centered on the subplots. Canopy cover was measured at the center of each subplot using a spherical densiometer. Percentage slope and canopy height were measured using a clinometer.

Percentage ground cover at each subplot was determined using a sighting tube (James and Shugart 1970), readings taken every 2 meters along each of two perpendicular string lines bisecting the 5-meter radius circle (5 readings per string, 10 total). Three other measurements were made at each of these 2-meter intervals. Litter depth was measured (mm) using a long sharp object inserted through the leaf litter until striking mineral soil. Average shrub height was determined by measuring a random shrub (woody plant between 0.5-1.4 m tall) at every 2 meters. To obtain a cross-sectional profile of ground to shrub vegetation, a 150-centimeter rod divided into 10-centimeter increments (0-10, 10-20, 20-30, etc.) was randomly placed perpendicular to the ground at each 2-meter interval along the string and the number of vegetational contacts in each division were counted. (Values from the four subplots at a census point were compiled to obtain a single value for each of the 27 habitat characteristics for that point count circle.)

Avian data from the fixed-radius point counts were analyzed using Fisher's Exact Test to determine differences between and within years for treatment and control stands. The 27 habitat characteristics measured were analyzed using univariate (ANOVA) and multivariate (MANOVA) analyses of variance to compare treatment and control stands and identify important broad-scale habitat differences between and within years. All tests were performed at $\alpha = 0.05$ using SAS routines (SAS 1985) available on the IBM 4381 mainframe computer at the University of Arkansas.

Results

Habitat Characteristics

The complete ANOVA results appear in Salveter (1994). Comparison of preburn treatment and control stands showed significant differences for 6 of 27 characteristics measured. Means for characteristics that were significantly greater in the treatment stand than in the control stand were deciduous trees in the size classes greater than 2.5 to 8 and greater than 8 to 23 centimeters dbh, deciduous and coniferous trees in the size class greater than 23 to 38 centimeters dbh. Means for characteristics that were significantly greater in the control stand than in the treatment stand were percentage ground cover and percentage slope.

Results of ANOVA between the control stand and postburn treatment stand showed significant differences for 11 of 27 characteristics measured, of which four differences carried over from the preburn comparison described above. Means for characteristics that had significantly lower values in the postburn treatment stand than in the control stand were litter depth, average shrub height, small deciduous and coniferous trees in the size classes of 2.5 centimeters or less in diameter (at 10 cm above ground), low vegetational profile increments 0 to 10, 10 to 20 and 30 to 40 centimeters above ground.

Preburn and postburn ANOVA of the treatment stand showed that means for 10 habitat characteristics in the treatment stand decreased significantly after the burn. The characteristics that had significantly lower values in the treatment stand after the burn, and could be directly associated with an effect of burning were litter depth, average shrub height, number of small deciduous and coniferous trees in size classes of 2.5 centimeters or less in diameter (at 10 cm above ground) and greater than 2.5 to 8 centimeters dbh, and low vegetational profile increments of 0 to 10, 30 to 40, 90 to 100 and greater than 100 centimeters above ground.

Differences in stands described above are displayed in Figure 1 based on results of MANOVA. Habitat analysis points in the burned stand are strongly separated from preburn and control sites along the first canonical variable (Figure 1, abscissa). This axis was highly correlated with changes in litter depth, average shrub height and deciduous tree seedlings. As would be expected, the burned stand had less litter, lower average shrub height and fewer deciduous tree seedlings than the unburned sites (Figure 1). The first canonical variable accounted for 92 percent of the total variance, or most of the differences in the system measured, but an additional 6 percent of the variance was associated with the second canonical variable (Figure 1, ordinate) that partially separated points from the control and preburn treatment stands based on initial habitat differences. These were overall steeper slope for the control stand and greater numbers of large pines (>23-38 cm dbh) in the treatment stand.

Neotropical Migrants

Out of 22 recorded, only 12 neotropical migrant species qualified for analysis (Salveter 1994). These birds were categorized with respect to nesting site: ground, shrub, subcanopy or forest canopy (Table 1). There were no significant differences in density or number of species of neotropical migrants within census plots between treatment and control stands in 1992, prior to burning (Table 1). There also was no significant change in number of species of neotropical migrant birds associated with treatment and control stands between 1992 (preburn) and 1993 (postburn), nor any significant population changes in any one species (Table 1). When the four nesting categories were combined to test for an overall relationship between densities of neotropical migrants and prescribed burning, results showed that prescribed burning generally was associated with a decrease in overall density of neotropical migrants ($\underline{P}$ = 0.05). However, when totals for nesting categories were analyzed separately, the relationship was significant only for ground-nesting neotropical migrants ($\underline{P}$ = 0.05). Density of ground nesters, particularly ovenbirds, decreased in the treatment stand after burning (Table 1). Shrub nesters ($\underline{P}$ = 0.45), subcanopy nesters ($\underline{P}$ = 0.21) and canopy nesters ($\underline{P}$ = 0.15) showed nonsignificant changes for numbers in both treatment and control stands between years. One species, the eastern wood pewee, was found in both stands in 1992 but was totally absent in 1993. Inspection of results in Table 1 show that some species exhibited slight increases between years in the two stands, some decreased in both areas and others lacked consistency.

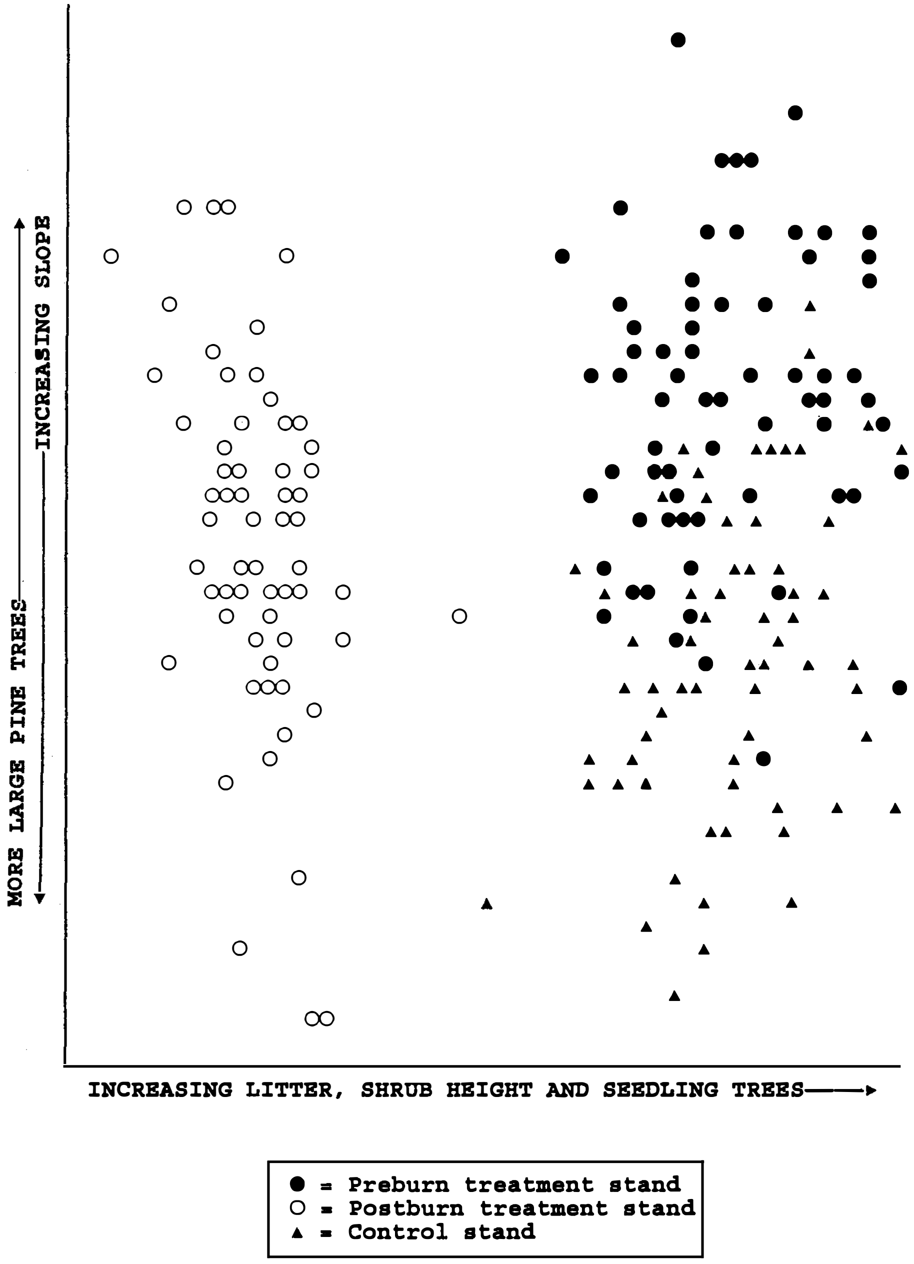

Figure 1. Ordination of habitat samples along the first (abscissa) and second (ordinate) canonical variables produced by multivariate analysis of variance, thus providing maximum separation among stands between and within years.

Table 1. Neotropical migrant densities from point counts conducted during preburn and postburn years.[a]

Species	Number of birds per 40 hectares: Treatment[b] 1992	Treatment[b] 1993	Control[a] 1992	Control[a] 1993
Ground nesters[c]				
Ovenbird (*Seiurus aurocapillus*)	8.8	4.1	5.5	4.8
Black-and-white warbler (*Mniotilta varia*)	4.5	2.8	4.6	3.7
Worm-eating warbler (*Helmitheros vermivorus*)	1.2	1.6	1.6	3.2
Shrub nesters[d]				
Indigo bunting (*Passerina cyanea*)	3.0	4.4	3.9	5.5
Subcanopy nesters[d]				
Eastern wood-pewee (*Contopus virens*)	0.4	0.0	0.9	0.0
Red-eyed vireo (*Vireo olivaceous*)	8.5	6.9	5.3	6.0
Summer tanager (*Piranga rubra*)	4.6	3.2	4.4	3.9
Wood thrush (*Hylocichla mustelina*)	0.4	0.5	0.3	1.1
Yellow-billed cuckoo (*Coccyzus americanus*)	1.9	1.8	2.3	1.4
Canopy and cavity nesters[d]				
Pine warbler (*Dendroica pinus*)	26.8	29.9	22.7	30.6
Great crested flycatcher (*Myiarchus crinitus*)	2.4	1.1	1.4	1.8
Scarlet tanager (*Piranga olivacea*)	0.9	1.2	2.5	1.2
Total individuals (all species)[e]	63.4	57.5	55.4	63.2

[a]There were 72 point counts in each study stand each year.
[b]Site subjected to prescribed burn in February 1993.
[c]$0.10>P>0.05$.
[d]$P>0.10$.
[e]$P<0.05$.

Residents

As with neotropical migrants, there were only 12 of 22 resident species recorded (Salveter 1994) that qualified for analysis (Table 2). These were divided into categories of ground, foliage and cavity nesters (Table 2). There were no significant differences in density or number of species of resident birds within census plots between treatment and control stands in 1992, prior to burning. There also was no significant change in number of species of resident birds associated with treatment and control stands between 1992 (preburn) and 1993 (postburn), nor any significant population change for any one species (Table 2). When the three nesting categories were combined to test for an overall relationship among densities of resident birds and prescribed burning, results showed that prescribed burning was associated with an increase in density of resident birds ($\underline{P}$ = 0.02). When totals for nesting categories were analyzed separately, the relationship was close to statistical significance only for cavity-nesting resident birds ($\underline{P}$ = 0.076). Densities of cavity-nesting birds increased slightly from preburn and postburn years for most species in the treatment stand (Table 2). Northern flickers were absent from postburn point counts in both treatment and control stands. Densities of foliage-nesting resident birds remained relatively unchanged in both treatment and control stands between years ($\underline{P}$ = 0.94). The most dramatic increase in this group between years for both treatment and control stands was the density of brown-headed cowbirds.

Ground-nesting residents, northern bobwhite and wild turkey showed relatively low densities and little change (P = 0.92) between stands and years (Table 2).

Table 2. Resident bird densities from point counts conducted during preburn and postburn years.[a]

	Number of birds per 40 hectares			
	Treatment[b]		Control	
Species	1992	1993	1992	1993
Ground nesters[c]				
Northern bobwhite (*Colinus virginianus*)	0.7	0.9	0.9	1.1
Wild turkey (*Meleagris gallopavo*)	0.2	0.7	0.2	0.3
Foliage nesters[c]				
Blue jay (*Cyanocitta cristata*)	3.4	3.7	4.9	3.2
Northern cardinal (*Cardinalis cardinalis*)	0.7	1.1	0.7	2.3
Brown-headed cowbird (*Molothrus ater*)	0.2	4.9	3.0	6.4
Cavity nesters[d]				
Carolina chickadee (*Parus carolinensis*)	0.9	1.9	1.4	2.1
Carolina wren (*Thryothorus ludovicianus*)	1.1	2.5	0.7	2.5
Northern flicker (*Colaptes auratus*)	0.5	0.0	0.3	0.0
Pileated woodpecker (*Dryocopus pileatus*)	1.6	1.9	2.8	2.6
Red-bellied woodpecker (*Melanerpes carolinus*)	0.5	0.2	0.2	0.0
Red-headed woodpecker (*Melanerpes erythrocephalus*)	0.0	0.2	0.5	0.2
Tufted titmouse (*Parus bicolor*)	0.7	2.8	2.1	1.6
Total individuals (all species)[e]	10.5	20.8	17.7	22.3

[a]There were 72 point counts in each study stand each year.

[b]Site subjected to prescribed burn in February 1993.

[c]$P>0.10$.

[d]$0.10>P>0.05$.

[e]$P<0.05$.

Discussion and Summary

Prescribed burning in Ozark pine forests affected vegetational characteristics primarily associated with vegetational strata on or near the forest floor. Specifically, prescribed burning significantly reduced litter depth, average shrub height, seedling and sapling deciduous and coniferous trees, and portions of the vegetational profile close to the forest floor. Initial differences in habitat characteristics between treatment and control stands before the burn were not great enough to confound interpreting effects of prescribed burning on the habitat (Figure 1).

Despite changes in habitat characteristics, prescribed burning in a mature Ozark pine forest had no immediate affect on number of bird species present (tables 1 and 2). These results agree with similar fire-related studies (Emlen 1970, Michael and Thornburgh 1971, Johnson and Landers 1982, Lyon and Marzluff 1984). The partitioning of bird species into nesting height categories in the present study was a unique analytical approach compared with other fire-related studies that grouped bird species into foraging guilds as a means of examining effects of forest burning (Bock and Lynch 1970, Emlen 1970, Johnson and Landers 1982, Lyon and Marzluff 1984). In the present study, prescribed burning was associated with a decrease in density of neotropical migrants (P = 0.05, Fisher's Exact Test), especially ground-nesting species (Table 1). An effect of prescribed burning on numbers of ground-nesting neotropical migrants, particularly ovenbirds (Table 1), is not surprising. Fire removed a significant portion of the leaf litter and low vegetation, both essential elements of ground-nesting habitat. In addition to nesting on the ground, ovenbirds also forage on the ground while scanning leaf litter and low vegetation for invertebrate prey (Stenger 1958, Zach and Falls 1979). Dickson (1981) found that litter-dwelling forms of invertebrates eaten by birds are reduced by ground fires in the short term, a change in food supply that could adversely affect reproductive success of birds that forage and nest on the ground.

The other nesting categories of neotropical migrant birds (Table 1) did not contribute strongly to the significant effect found for prescribed burning on the overall densities of neotropical migrants. Absence of the eastern wood pewee from both treatment and control stands after the burn ruled out any possible result of prescribed burning. No study to date has shown that prescribed ground fire affects canopy-dwelling species. In mature pine stands, the bird community is characterized by canopy dwellers that increase in numbers as stands age (Johnson and Landers 1982). In the present study, pine warblers in the canopy were the commonest avian species in the forest in both stands and followed the expected trend of increasing between years (Table 1).

Prescribed burning was associated with an increase in density of resident birds ($\underline{P} = 0.02$, Fisher's Exact Test), particularly cavity-nesting species (Table 2). The effect of burning on resident birds in the present study is similar to that found by Emlen (1970) in other pine stands. The little overall effect on resident breeding birds in these stands was explained by the apparent tendency toward site faithfulness by birds immediately after the burn. In addition, Dickson (1981) showed that certain species of flies and beetles are drawn to the smoke and heat of ground fires, or later to damaged trees. Although speculative, such increases in abundance of insects for food may have contributed to overall increases in densities of resident birds and sudden appearance of the red-headed woodpecker, a forager on damaged trees, in the treatment stand after the burn (Table 2). Absence of the northern flicker from both treatment and control stands after the burn ruled out the possibility of its disappearance due to prescribed burning. Because the control stand was not subjected to burning or other habitat manipulations, absence of the red-bellied woodpecker (Table 2) in 1993 could not be explained. The remaining nesting categories of resident birds did not appear to contribute much to the overall significant effect prescribed burning had on densities of resident birds (Table 2).

In summary, prescribed burning removed forest vegetation on and near the forest floor in mature pine forests of the Arkansas Ozarks. However, this result had a different effect on nesting neotropical migrants than on resident birds. Prescribed burning was associated with a decrease in density of neotropical migrants, especially ground nesters, and an increase in density of resident species, especially cavity nesters. This suggests that in the short term, prescribed burning as a management tool in Ozark pine lands may adversely affect some neotropical migrants but benefit resident birds. The situation has immediate implications in view of the recent declines in populations of some neotropical migrant birds. However, it is not known from this short study whether the results will persist in the long term. Other studies have suggested that long-term use of fire may be beneficial to other neotropical migrants (Wilson et al. 1995). More years of investigation are needed to determine if and when the populations will return to original levels and on the cumulative effects of fire.

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Fire Seasonality Effects on Vegetation in Mixed-, Tall- and Southeastern Pine-Grassland Communities: A Review

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Fire is an ecological force and a natural disturbance in many habitats throughout the world (Kozlowski and Ahlgren 1974, Ohmann and Grigal 1981, Wright and Bailey 1982, Pyne 1982, Waldrop et al. 1992, Howe 1995). Fire, along with other environmental factors, such as topography and climate, created and maintained a mosaic of presettlement communities, including grasslands, savannahs and forests (Pyne 1982, Anderson and Brown 1986, Anderson 1990, Waldrop et al. 1992). In the United States, lightning and aboriginal set fires prevented the invasion of eastern forests into the central grassland region (Adams et al. 1982, Axelrod 1985, Ewing and Engle 1988). These fires played an important role in shaping mixed- and tallgrass prairie ecosystems (Bragg 1982, Towne and Owensby 1984) and formerly abundant pine-grassland communities of the southeastern U.S. (Buckner 1989, Platt et al. 1988, Waldrop et al. 1992).

Aboriginal-set fires occurred in all seasons of the year in the northern Great Plains, with the majority in late summer and autumn (Bragg 1982, Ewing and Engle 1988, Higgins 1986). However, historical accounts of aboriginal set fires in Oklahoma and Arkansas indicate that late summer/early autumn was the primary fire season (Foti and Glen 1991, Masters et al. 1995). Evidence of seasonality from Florida is less clear (Robbins and Myers 1992). In forests of Oklahoma and Arkansas, lightning fires occur with a bimodal distribution in late winter/early spring and summer, with most fires occurring during late summer (Foti and Glenn 1991, Masters et al. 1995). While in Florida, lightning fires occur mostly from late spring to late summer (Komarek 1964).

Contemporary fire regimes in these communities differ from presettlement fire regimes. Fires often have been eliminated or restricted to specific seasons. Exclusion of fire in these systems decreases ground-level forage for wildlife and livestock (Lewis and Harshbarger 1976, Ewing and Engle 1988, Masters 1991a), leads to forest densification (Kreiter 1995) and allows structural changes that affect a host of wildlife species (Masters et al. 1995, Wilson et al. 1995). Management in mixed-grass and tallgrass communities emphasizes late dormant-season burns for livestock management (Bragg 1982), while prescribed fire in pine-grassland communities primarily is conducted during mid-dormant season to meet timber, livestock and wildlife objectives (Chandler et al. 1983).

Robbins and Myers (1992) reviewed the effects of fire season on both herbaceous and woody species in primarily coastal plain pine-grassland ecosystems. Long-term effects of fire season have been explored in South Carolina on the Santee Experimental Forest (Lewis and Harshbarger 1976, Waldrop et al. 1992). In mixed- and tallgrass systems, there are no long-term studies on the effects of fire season. However, several short-term studies linked plant phenology with season of fire (Hover and Bragg 1981, Steuter 1987, Howe 1994a). Studies in grassland communities often have focused on the use of dormant-season fires to increase herbage quality and production (Howe 1994a).

Many studies have explored the effects of fire season on specific plant communities, but few have compared seasonal effects in different ecosystems. Our primary objective for this paper is to present evidence that season of fire has similar effects on ground-level vegetation in pine-grassland, mixed-grass and tallgrass ecotypes. An additional objective is to show managers how knowledge of seasonal effects of fire can be used for planning fire prescriptions for wildlife, livestock or natural area restoration.

Season of Fire in Mixed- and Tallgrass Communities

Grassland communities, such as the tallgrass prairie and northern mixed prairie, are "fire-derived" and "fire-maintained" (Towne and Owensby 1984, Anderson 1990, Howe 1995). Occasional fires are needed in these systems to suppress woody species and encourage grasses, forbs and legumes (Hover and Bragg 1981, Adams et al. 1982, Howe 1994a, 1995).

Herbaceous Species Response

Species actively growing at the time of a fire are more susceptible to heat injury than are dormant species or species in early stages of development (Towne and Owensby 1984). Late-spring fires reduce cool-season species while favoring warm-season species that are dormant or have exerted little energy for development (Owensby and Anderson 1967, Hover and Bragg 1981, Towne and Owensby 1984, Hulbert 1988, Howe 1994a). Summer fires reduce warm-season species that are actively growing and, therefore, favor cool-season species (Hover and Bragg 1981, Ewing and Engle 1988, Biondini et al. 1989, Howe 1994a). Summer fires, compared with winter fires and unburned areas, increase community species diversity and richness by increasing the number of annuals and promoting cool-season grasses and forbs (Towne and Owensby 1984, Biondini et al. 1989, Howe 1994b).

Wildlife managers prescribe winter fires because these fires tend to increase forbs (Bidwell et al. 1990). Autumn burns reduce the number of forbs, while winter burns produce an abundance of forbs; however, grass production remains unchanged after autumn and winter fires (Box and White 1969). In general, dormant-season fires benefit warm-season grasses and forbs, while suppressing species that develop early in the spring (Howe 1994a).

Woody Species Response

There are a variety of conclusions on which season is best for controlling woody species in mixed- and tallgrassland biomes. Adams et al. (1982) showed that a late winter burn was more efficient than a summer burn at suppressing woody species. Box and White (1969) determined that autumn burns were more effective at controlling woody vegetation than winter burns. Anderson (1981) noted that growing-season or summer burns were more efficient than dormant-season burns at suppressing woody species.

Season of Fire in Pine-Grassland Communities

Pine-grassland communities, once common in the southeastern U.S., consisted of open "parklike" pine stands with a distinct grass-dominated herbaceous layer (Waldrop et al. 1992) and woody resprouts, depending on fire frequency (Masters 1991a, Masters et al. 1995). Evidence suggests these communities developed under frequent fire regimes of aboriginal and lightning origin (Buckner 1989, Foti and Glenn 1991, Waldrop et al. 1992, Masters et al. 1995). Fire or lack of fire are principal considerations in land management because of potential effects on ecosystem integrity (Masters et al. 1995, Wilson et al. 1995) and on timber and livestock production (Lemon 1949). Fire is an essential management tool for control of woody species (Lewis and Harshbarger 1976, Boyer 1990) and maintenance of forage production on forested range (Lewis and Hart 1972, Grelen 1983).

Herbaceous Species Response

In southeastern forests, as with mixed- and tallgrass prairie ecosystems, growing-season burns favor cool-season grasses and forbs, while decreasing warm-season species (Robbins and

Myers 1992). Growing-season fires produce more flowering stems than stands burned in other seasons and increase synchronization in forb flowering habits among species (Platt et al. 1988). Grasses, such as wiregrass (*Aristida stricta*), little bluestem (*Schizachrium scoparium*) and other bluestems (*Andropogon* spp.), flower more profusely in response to growing-season burns than to fire in other seasons (Lewis 1964, Robbins and Myers 1992). Hodgkins (1958) noted that composites and legumes increased with growing-season burns compared with dormant-season burns. However, White et al. (1991) found that annual winter burns increased legumes more than periodic summer and winter burns or annual summer burns.

Woody Species Response

Understory species. Several studies suggest growing-season burns are more effective than dormant-season fires at controlling hardwoods (Grano 1970, Grelen 1975, Waldrop et al. 1987, Boyer 1990). Summer fires, when compared with other burn seasons, tend to reduce cover of understory woody plants (Lewis and Harshbarger 1976). This reduction was confirmed during a 40-year study in South Carolina where all burn plots, except summer burns, had a higher density of small woody stems than unburned plots (Waldrop and Lloyd 1991). Ferguson (1961) reported that winter burns topkilled fewer woody species than spring and summer fires. Dormant-season fires may result in higher stem density because of multiple sprouting, but use of frequent fire may prevent sprouts from reaching larger size classes (Waldrop et al. 1987, 1992). The majority of literature concludes that growing-season fires topkill a higher percentage of stems, topkill larger stems, increase the number of individuals completely killed and reduce the vigor of resprouting when compared with dormant-season fires (Robbins and Myers 1992). However, Sparks et al. (1996) found woody stem kill was directly related to fire behavior rather than season of burn. Glitzenstein et al. (1995) found that longleaf pine (*Pinus palustris*) dynamics were related more to fire behavior than season of burn.

Canopy species. Dominant canopy species in southeastern pine-grassland forests consist of pines with occasional hardwoods. These trees are directly affected by fire only when their plant tissue is heated to lethal temperatures, generally 60 degrees Celsius for one minute or more, because of thick insulative bark and height of terminal buds above the fire (Wade 1986, Waldrop et al. 1992). Lethal temperatures that injure canopy species are more readily obtained with growing-season burns because of higher ambient temperatures and lower lethal temperatures (Robbins and Myers 1992). It appears that mortality of dominant canopy species is greater following late growing-season fires than early growing-season fires (Ferguson 1961, Robbins and Myers 1992).

Discussion

Season of fire often is confounded by environmental variables such as weather conditions, fuel type, topography, soils, grazing pressure and fire frequency (Ohmann and Grigal 1981, Sousa 1984, Wade 1986, Masters et al. 1993, Masters and Engle 1994). These factors affect fire behavior which directly influences above-ground portions of woody plants (Van Wagner 1973, Rothermel and Deeming 1980, Alexander 1982, Wright and Bailey 1982, Wade 1986). For example, fireline intensity affects survival of small diameter shrubs and trees (Wade and Johansen 1986) and herbaceous composition (Bidwell et al. 1990). The amount of live or green fuel also affects fire behavior and may reduce fireline intensity (Bragg 1982). Fireline intensity may have an overriding effect on seasonality, depending on burning conditions (Glitzenstein et al. 1995, Sparks et al. 1996). These factors vary among specific locations within a region and managers should consider variations for each community type (Sousa 1984).

The response of herbaceous species to season of fire is related to seasonal plant phenology, or growth stage at time of burning (Towne and Owensby 1984, Robbins and Myers 1992).

Plants actively growing at the time of a burn are most susceptible to damage or negative effects of the fire (Towne and Owensby 1984, Howe 1994a). This is the primary reason warm-season species are reduced by summer fires and cool-season species are suppressed by winter and early spring fires (Hover and Bragg 1981, Towne and Owensby 1984, Biondini et al. 1989, Howe 1994a). Mixed-, tall- and pine-grassland communities contain herbaceous species with similar phenologies and growth habits, including cool- and warm-season grasses, forbs, and legumes (Masters 1991a, Waldrop et al. 1992, Masters et al. 1993, Howe 1994a). The similarity in plant composition is a probable cause for similar vegetation response to season of fire.

Results from southeastern forests indicate that growing-season fires, in contrast to dormant-season fires, are more efficient at suppressing woody species (Lewis and Harshbarger 1976, Boyer 1990). Fire reduces many woody species in size by topkilling them, but actually can increase stem abundance because of sprouting (Boyer 1990, Waldrop et al. 1992). Annual or biennial burning can reduce sprouting and decrease woody species densities (Grano 1970, Boyer 1990, Masters 1991a, Masters et al. 1993). Inconsistency concerning fire season effects on woody species in grassland communities may be a result of different fire behavior. Mixed- and tallgrass communities contain a number of the same woody species as pine-grassland communities; therefore, summer fires may be more efficient at suppressing woody species. If woody species control is a manager's primary objective, desired fire intensity, as well as seasonality, are important when planning fire prescriptions.

Applications

Vegetation manipulation is necessary in both grassland and forested communities to benefit wildlife, livestock and natural area management (Lewis and Harshbarger 1976). The following sections present tentative guidelines for use of different fire seasons as management tools.

Wildlife

The effects of fire on wildlife generally are indirect by changing habitat structure and food availability, quantity and quality (Komarek 1963, Wright and Bailey 1982). Most species of wildlife require specific habitats and without some form of successional redirection or method of disturbance (such as fire), these habitats will change progressively (Komarek 1963). Many wild animals benefit from diverse mixtures of grasses, forbs and browse (Leopold 1933, Shaw 1985). Plant species diversity, richness and abundance can be manipulated by the fire season implemented in an area (Lewis and Harshbarger 1976, Bidwell et al. 1990, Robbins and Myers 1992).

The season in which a fire occurs can have profound effects on the type, quantity and quality of herbaceous material available for wildlife. Cool-season forbs and grasses, such as panicums, are favored after growing-season fires and benefit species of wildlife dependent on these plants (Grelen and Lewis 1981). Frequent summer and winter burns may lead to dominance by fire-tolerant grasses which could be detrimental to some forms of wildlife such as white-tailed deer (*Odocoileus virginianus*) (Stransky and Harlow 1981), but beneficial to other wildlife such as the greater prairie chicken (*Tympanuchus cupido*) (Manske and Barker 1987). Frequent summer burns reduce legumes which would be detrimental to bobwhite quail (*Colinus virginianus*), but periodic winter burns tend to promote legumes which benefit bobwhite quail and other gallinaceous birds (Grelen and Lewis 1981, Landers 1987). Late spring backfires have advantages over autumn or winter burning because of reduced loss of food and cover for wildlife; these backfires tend to leave patches of standing herbaceous material which are beneficial to nesting birds (Bidwell 1988). Burning small areas in autumn or winter in a patchwork fashion can benefit quail because of increased legume production over patches burned in other seasons (Landers 1981). Dormant-season fires would be beneficial to wildlife managers attempting to increase availability of young woody browse, such as sumac (*Rhus* spp.), elm (*Ulmus* spp.) and greenbriar (*Smilax* spp.).

Many breeding birds require specific habitat structures for foraging and nesting, these might include a dense shrub layer or an open understory, depending on the species. Several of these specific habitats require periodic fire to create or maintain them (Wilson et al. 1995). Periodic dormant-season burns can be used to suppress woody species and induce sprouting, therefore creating a recurrent shrub understory to benefit species such as the prairie warbler (*Dendroica discolor*) (Wilson et al. 1995). In comparison, frequent growing-season burns can be used to reduce woody species and create an open herbaceous understory. For example, growing-season fires may be more efficient at preventing midstory development in red-cockaded woodpecker (*Picoides borealis*) clusters where old-growth or near old-growth pines without a midstory are required for survival.

The intricacy of the fire/wildlife habitat complex in prairies may be further illustrated by expanding Steuter's (1986) fire/bison (*Bison bison*) grazing interaction hypothesis to include the greater prairie chicken (*Tympanuchus cupido*) (Masters 1991b). A fire/bison interaction may explain how breeding habitat for the prairie chicken was provided historically in tallgrass and mixed-grass habitats. Prairie chickens require sites with relatively sparse, low-stature grass or grass/forb cover for booming grounds and breeding (Manske and Barker 1987), and taller adjacent vegetation for brood-rearing cover (Newell et al. 1987).

Bison grazing tends to concentrate on burned areas and produces discontinuous fuels that may modify fire return intervals (Steuter 1986, Pfeiffer and Hartnett 1995). The resultant vegetation mosaic would include early seral stages, particularly near watering sources or wallows; mid-successional stages with shorter sparse vegetation because of trampling and grazing effects of large herds; and later stages with dense vegetation on ungrazed sites (Steuter 1986, Pfeiffer and Hartnett 1995). Periodic plant community shifts toward lower successional stages would occur based on fire return intervals and grazing patterns (Steuter 1986). Adjacent sites in the vegetation mosaic with different fire return intervals would provide taller vegetation required for brood-rearing cover (Newell et al. 1987). Prairie chickens seasonally require a diversity of habitats with different heights and different stages of growth (Christisen 1985). Historically, this vegetation mosaic could be produced in tallgrass prairie only by the type of fire/bison interaction proposed by Steuter (1986).

Livestock

Seasonality of fire also is important to domestic livestock ranchers. Season of fire affects total herbage production, species composition and woody species abundance (Anderson 1965, Lewis and Harshbarger 1976). If burns are conducted immediately before warm-season tallgrass regrowth (late spring), forb production will decrease at the expense of dominant warm-season grasses (Launchbaugh and Owensby 1978). Time or season of burning is a crucial factor ultimately affecting total herbage production (Anderson 1965, Towne and Owensby 1984). Herbage quality and overall yield can be affected by the season of fire (Grelen and Epps 1967, Lewis and Hart 1972). Increased weight gains of livestock on spring burns is likely, although grass production may not be altered by burning (Anderson 1964, Svejcar 1989). If a manager is attempting to increase herbage quality and minimize yield reduction, late spring burns are most preferred.

Natural Areas

Often, natural areas must be maintained by fire or another management tool to maintain them in a natural state (Lewis and Harshbarger 1976). Literature indicates that season of fire directly influences vegetation composition and structure, therefore, contemporary fire regimes may be reshaping communities that evolved under the influence of fire in a different season (Howe 1994b). Reestablishment of natural areas or ecosystem restoration requires managers to obtain knowledge of an area's fire history and presettlement vegetation composition (e.g., Wilson et al.

1995, Masters et al. 1995). If management objectives are to restore or establish an area similar to precolumbian times, contemporary fire regimes should mimic presettlement fire regimes in fire season, intensity and frequency (e.g., Masters et al. 1995). When using fire to control invading plant species, the season of fire should be when the plant is phenologically intolerant of fire, but before seed production.

Conclusions

Seasonal effects of fire have some similarities between mixed-grass, tallgrass and pine-grassland communities, even with major differences in growing season length. Effects of fire on herbaceous vegetation depend on the plant's phenology at the time of burn. Dominant, warm-season species are reduced by summer fires and replaced with a variety of cool-season species, while cool-season species are reduced by late spring burns and replaced with warm-season species. Late summer fires reduce abundance of dominant, warm-season grasses and increase species diversity of the community by increasing cool-season grasses and forbs.

Fire season effects on woody species may vary regionally, but most studies suggest that growing-season burns suppress woody species more effectively than dormant-season burns. However, fire behavior and specifically fireline intensity many have an overriding influence. Large dominant trees generally are affected only when conditions are severe (e.g., extended drought, high ambient air temperatures). Many woody species tend to resprout after fire in any season, but may be controlled by frequent fires. Other factors, such as fuel type, grazing pressure, weather conditions, topography, soils, and intensity and frequency of fire play a major role in the effects of fire on vegetation. Knowledge of the effects of fire seasonality can be used by managers to manipulate vegetation for the benefit of wildlife, timber, livestock and natural areas. Future research on fire effects on different plant communities should quantify fire behavior, plant phenology and specific dates to facilitate comparisons and increase our understanding of the variable nature of fire.

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Closing Remarks

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Someone once remarked that inside every fat book is a thin book trying to get out. My closing remarks will be extremely thin relative to the information presented this morning, as I suspect a highly significant inverse relationship between my ability to say anything profound and for you to listen to it, and the level of hunger for lunch that we probably all are experiencing. I will comment on a few points, though, that were particularly salient: (1) the value of looking at life groups of species when we seek to determine potential effects of prescribed fire; (2) the caution we need to exercise in interpreting unreplicated studies; (3) caution in interpreting presence/absence data with its attending and nagging shortcoming of not revealing anything about source-sink habitats and reproductive success; and (4) the obvious danger of extrapolating short-term studies to the long term.

If you were present this morning when I spoke of Arlo Guthrie's song and his lyric "Friends, they may think it's a movement," and you're enthusiastic about the role of prescribed burning in wildlife management, whistle or hum a few bars of *Alice's Restaurant* as you mill around the conference during the remainder of your stay.

Special Session 4. *Social and Economic Benefits of Investments in Fish and Wildlife Management*

Chair
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Cochair
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Implications of Economic Information for Natural Resource Managers: An Alaskan Case Study

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Perspective and Context

Economics and economic information are terms that are bandied about as if everyone knows what they mean. The uses and misuses of economic information in actual practice indicate otherwise. Economics is the science dealing with allocating scarce resources. Scarce means people cannot have all they want of a particular resource for free. Allocating scarce resources implies there are competing uses for the resources, and the uses to which resources are put need to be determined based on some evaluation of what constitutes best use. The problem is: "How does one compare alternative uses of resources and what criteria should be used to choose between alternatives?" Our objective is to review the principle of economic value, following which we discuss differences in the kind and amount of economic information used by public and private sector resource managers, and how various factors complicate public resource management decision making. Finally, we present an example using Alaskan information.

Economic value is an expression of the relative worth, utility or importance of a good, service or resource to a person or group in a particular context. In theory, it captures everything that provides benefit—anything from which a person derives utility.[1] Problems arise in a couple of ways. A technical problem is that the state-of-the-art is just not capable of measuring all the ways people derive utility from complex goods and services. For example, we cannot currently measure how much utility a person derives from the spiritual uplifting that might come from a particularly moving experience in a natural setting. It is uncertain, at present, to what extent we can measure the utility a person derives from knowing that a particular resource or wildlife species continues to exist. Such things are technical problems that might be solved over time, although capturing some public resource values might be very difficult (Aylward 1992). A philosophical problem arises in knowing exactly what to measure. People might not know exactly what benefits arise from particular goods and services, or from particular interactions in nature. They might not recognize some subtlety that, if fully realized, would bring them utility. The question is: "Can people derive utility from something they never know about?" The point is: "While economics captures all relevant values in theory, in empirical practice some things get left out."

Economic information is one piece in a mosaic of information relevant to natural resource management, along with biological, ecological, geological, hydrological, sociological, theological, psychological and other information. All the pieces look at certain aspects of the whole picture from a particular perspective. Economics attempts to bring those diverse perspectives together by summarizing effects of alternative resource uses (as they affect people) in a common unit—typically dollars, but dollars are nothing more than one unit of measure. Economic information should be regarded as a complement to other information, not a substitute.

Economic values can be expressed in different ways. One way is through markets. Goods and services are produced and consumed, resulting in market transactions. Different activities produce different kinds and magnitudes of market activity; and people express values by the products they consume. In a competitive market system, price is the expression of value—one values a good or service at least as highly as one is willing to pay to acquire it. Values expressed in the market change over time. Fur prices rise and fall in response to fads and fashions. One occasionally sees "coonskin caps" today, but not nearly as many as were seen during the Davy Crockett fad in the late 1950s.

Economic values also can be expressed through the political system. Values for some things people think are important are not adequately represented in the market.[2] In such cases, values can be imposed or mandated via a legislative or political process. One example, again, can be seen in the fur industry. Some European countries are giving expression to their citizens' values

[1]Some may balk at the qualifier that value relates to worth or importance to a person, arguing that animals and other facets of nature have intrinsic value, independent of any human perception or interaction. In his discussion of the concept of value, Brown (1984) distinguishes economic value as an "assigned value"—the expressed worth of an object to a person—as opposed to a "held value," which is a broader concept that Brown defines as "an enduring conception of the preferable which influences choice and action." Held values include such things as frugality, generosity, fairness, wisdom and freedom. In the present context, intrinsic values of nature can be included in economic value, but only to the extent that they are perceived and provide utility to a person or group.

[2]For several reasons, there are some goods and services that, if left to the market, would be provided in quantities that are not economically efficient from a societal perspective. This notion of "market failure" has a substantial literature of its own. Classic cases of such "public goods" include national defense, public education and roads. Other public goods are goods and services, such as air and water quality, and a variety of regulatory functions of government.

for animal rights by phasing in import bans on furs caught in traps considered to be "inhumane." Those import bans are having effects in fur markets. Another example is the Endangered Species Act. In the late 1960s/early 70s, many people thought the value of species preservation was not adequately expressed in the market. That led to a legislative expression of value. Society, through Congress and the President, said: "We place so much value on species preservation that we will prohibit activities that might adversely affect their viability." Species preservation was taken out of the market arena by legislatively setting the value of species preservation so high that it outweighs virtually any market value.[3] Similar to what happens in the market, politically expressed values can change over time. Society currently is rethinking the value placed on species preservation. Congress is considering modifying the Endangered Species Act, effectively removing the legislatively set high value for species preservation and putting it back into the market arena for determination of value.

Political values can be expressed through incentives—society pays landowners to manage their land in ways that might otherwise be unprofitable. Landowners can reduce the taxable value of their property by deeding certain development rights (thus protecting riparian or other natural areas) to qualified groups under the Conservation Easement Program. Some agricultural programs (land banking, etc.) provide incentives to manage land in certain ways.

Constituency and Priorities

Different types and levels of decision making serve different constituencies and have different priorities. One dichotomy is between public and private sector decisions. The private sector manager only needs to consider the interests of himself or his employer, subject to relevant legal constraints. On a basic level, the private manager is out to maximize the return to his or her employer or investors. He or she seeks to externalize (pass on to someone else, e.g., society) as many costs as possible in order to maximize the difference between revenue and cost. Society has imposed certain "ground rules," in the sense that there are some political values so strongly expressed that they are in the form of laws everyone has to abide by—pollution laws, toxic waste disposal restrictions, etc. Some people argue that such laws came about because private decision makers went too far in externalizing their costs, causing society to step in and force internalization of those costs.

Public resource managers must consider a broader range of interests. The public manager's employer/investors (or constituency) is the society at whatever level he or she is at (i.e., federal, state, local), including future generations. No costs can be externalized because, at the societal level, all costs are, by definition, internalized—someone in society pays the cost. Additionally, public resource managers need to consider political values expressed in a less formal, somewhat less stringent manner than laws and regulations. Those can come in the form of requirements for "multiple-use management," or scheduled timber harvests, etc.

Society has decided that recreation access is a desirable thing, as is wildlife habitat, as are some levels of timber harvest and mineral extraction, etc. Further, society has decided that access to those products of resource management is so desirable that users will not be charged the full cost of provision in order to ensure their availability to all segments of society. The result is further constraints (or priorities) imposed on public natural resource managers that are not faced by private-sector resource managers. Those constraints/priorities are neither good nor bad, just different between public- and private-sector resource managers.

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[3]Under the existing system, species preservation does not absolutely outweigh all other values. There is an option for an Endangered Species Committee, consisting of the Secretary of the Interior and others, to rule against listing a particular species as endangered.

Within the public sector, different forces and pressures affect federal, state and local decision makers and resource managers differently. For one thing, the different levels represent different constituencies. In theory, at least, federal resource managers are to represent the interests of the nation as a whole. State-level resource managers are supposed to act in the best interests of the state—a different mandate than that of federal managers. Local-level (city, county, etc.) resource managers have a still more narrow population in whose interests they are supposed to act.

Different legislative mandates are placed on the different levels of resource managers. Such mandates impose guidelines and/or specific priorities. The USDA Forest Service has a mandate to manage lands under their stewardship for "multiple use" (Multiple Use, Sustained Yield Act of 1960) such that any one resource use is not to dominate others. The Alaska Department of Fish and Game is bound by the State constitution, which contains a "common-use clause" specifying that fish and wildlife resources are to be managed for the common use. Except for specific exemptions granted for trap lines and salmon fishing, that common-use clause implies no preferential treatment can be given in the use of fish and wildlife resources. More recent federal legislation has granted "subsistence users" preferential rights with regard to fish and wildlife on federal land. A manager can follow one but not both of those directives.

That different aspects of land resources are valued differently by different constituencies can be seen in an example (D. Mylius personal communication: 1996). In 1959, under the Alaska Statehood Act, the State acquired but did not receive patent on a 24,000-acre parcel of federal land within what became Kachemak Bay State Park on Alaska's Kenai Peninsula. In 1971, under the Alaska Native Claims Settlement Act (ANCSA), Alaska Native corporations were allowed to select lands from among federal and selected "tentatively approved" State holdings as settlement of all Native Alaskan land claims existing prior to statehood.[4] That 24,000-acre parcel of land within Kachemak Bay State Park was transferred to a Native corporation. Under ANCSA, a structure was imposed on Native Alaskans to represent their interests in the form of (for profit) Native corporations. That structure led the Native interests to select land based on profit potential—including development, timber and minerals.

Besides being in a State park, implying values for fishing and other recreation, the Kachemak Bay parcel was in the view shed of the city of Homer. Pressure was brought to bear on the State to acquire the land to prevent development, logging or mining in the park, so as to preserve the park and the view shed from Homer. Disagreement over the land's value, reflected in disparate appraisals obtained by the parties involved, resulted in the State Legislature voting against purchase of the land—they did not want to pay the price the Native corporation was asking. In the meantime, the Exxon Valdez oil spill occurred and an out-of-court settlement was reached that allocated $900 million to land and habitat restoration under the administration of a joint State and federal trustee council. Through a process that included a series of public meetings, it was decided that one use of that $900 million would be to purchase land within the area impacted by the oil spill to restore habitat and prevent further damage. The Kachemak Bay parcel was among the lands purchased by the trustee council and ownership was deeded to the State of Alaska.

The original interests of the federal constituency, as decided by Congress, were best served by giving the land to the State of Alaska at statehood. The State did not receive patent to the land by the time ANCSA passed, thereby making it available for selection as settlement of Native Alaskans' land claims. The interests of the Native Alaskans, driven by the Native corporation, were served best by selecting land near the city of Seldovia that could be used for development,

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[4]Under Federal law, the Bureau of Land Management can transfer unsurveyed lands to the State through what is called Tentative Approval. A patent (which carries with it certain rights of exclusivity) would be issued after BLM surveyed the land.

timber or minerals. The State constituency was best served, as decided by the Legislature, by declining to purchase the land. A coalition of State and federal constituencies, through the Exxon Valdez Oil Spill Trustee Council, were best served by purchasing the 24,000-acre land parcel for $22 million.

Effect

Consider a private landowner managing his or her land for timber compared with a public land manager. The private manager will sell timber at the market established price and must cover all costs of operation. He or she will remain in business in the long run only as long as total cost is covered. In the short run, he or she will remain in operation as long as total variable cost is covered (because fixed costs need to be paid even if the operation goes out of business, any excess of revenue over variable cost will contribute to paying fixed cost and the manager will continue to operate in the short run). If the price is not high enough, the private landowner can choose to sell fewer logs or no logs at all in any given time period.

The public land manager is bound by land-use plans or other management direction to make available a certain amount of timber. The price at which that timber can be sold is constrained by the market. If the price for timber on public land is too high, saw mills can buy from other sources because timber is a commodity and saw mills generally do not care where their logs come from. If market timber prices are low, the public manager typically does not have the option of withholding logs from the market. The logs are put up for bid regardless of whether all costs of (public sector) production are covered.

Reality is a good deal more complex than the preceding two paragraphs might indicate. Consider the situation in southeast and southcentral Alaska, which includes the Tongass and Chugach national forests and several large areas of State-owned land. The areas produce timber, commercial fishing, minerals, grazing, glacial ice/water, wildlife, recreation opportunities—all of which have a market or commercial component. The areas also produce a variety of nonmarket or noncommercial goods, including: recreation experiences (beyond the commercial tourism component that is captured in the market), scientific products (hydrological, ecological, biological—things like clean water, carbon sequestration, knowledge from research, ecological integrity that might provide things we don't yet know about, etc.), and cultural/lifestyle products (Alaska Native culture, logging lifestyle, etc.). The point is, these public lands are responsible for products beyond what are sold in markets and what people use directly and immediately.

Private landowners in such a situation can choose among those various outputs and sell whatever they want at prices they set, subject to principles of supply and demand. The private manager can sell timber at market prices, allow mining at terms which allow him or her to capture economic rent (or royalties) from those resources, allow people to use the land for recreation at access fees of his or her choosing. The land can be managed for whatever kind of wildlife is desired (subject to some regulations regarding exotic species, federally designated threatened or endangered species, and domestication of wild animals). Private landowners are free to charge whatever the market will bear and choose the mix of outputs and terms of exchange to maximize his or her return on investment. They are not bound to consider society beyond the constraint of existing law.

The public land manager faces a different situation. As in the simple case, the manager faces some scheduled level of timber production. He or she cannot set access fees for recreation or grazing, or royalties for mineral extraction. The mix of outputs from land under his or her management cannot be chosen with the degree of autonomy accorded to private land managers. Public land managers are constrained by a whole range of politically determined values for things society thinks are important. In addition to existing law (pollution laws, Endangered Species Act, etc.), which both public and private managers must follow, society has decided that public resource managers should follow several additional mandates. There are mandates for formal planning processes open to input from a wide variety of public and user groups, requirements for environmental impact statements, and established appeals processes to allow recognition and resolution of disputes over proposed resource uses, among others. All these mandates arose from a recognition that these are publicly owned resources and they need to be managed for a wide constituency with diverse social values (Rivlin 1993). One result of compliance with these additional mandates and guidelines is that the mix of outputs from public resource management might differ from that which would result from private management of the same parcel of land and resources. A second result might be that public resource management is inherently more costly than private resource management. Society pays a price for their politically expressed values in much the same way as prices are paid for market expressed values.[5]

In the process, society subsidizes a wide range of goods and activities. Society has decided it is important for all Americans to have access to public lands for recreation, so access fees are minimal or nonexistent, constituting a subsidy to recreational users. Society has decided that rural Alaskan culture and lifestyle are important, so subsistence users are given preferential treatment on federal lands with regard to access to fish and wildlife resources—another subsidy. Timber is sold below full cost of production, constituting a subsidy of loggers and certain other rural lifestyles and cultures; grazing fees typically are set below market rates, providing a subsidy for ranchers and ranching-related lifestyles; mineral royalties are low or zero, providing subsidies of miners and mineral extraction industries. Public resource managers are constrained to abide by these politically determined values—in effect, society tells managers "the market has not adequately valued these resource uses, so we will mandate values above and beyond those expressed in the market and require you to use them in your management decisions." These politically determined values and the resulting subsidies are inherently neither good nor bad, but they are real and constitute a very important difference between public and private land and resource management.

Resource managers often are provided with information, including laws, regulations, policies and scientific results, that leads to conflict. The previous section pointed out the conflict between the Alaska State Constitution's common-use clause and federal subsistence preference requirements. Beyond such legal conflicts, benefits to one use/user group are not necessarily benefits to others. Potential conflicts might be between consumptive and nonconsumptive resource uses/users or local and nonlocal uses/users. This latter conflict might be borne out in the distribution of benefits-economic impact of a particular policy might be felt at the local level, while benefits might accrue to many nonlocal constituents. Choosing between such conflicting resource uses is a policy decision. We do not advocate simply maximizing overall benefits and always choosing the path with the biggest bottom line, but advocate using all relevant information in reaching a decision. Consider the implications and tradeoffs inherent in each alternative, then make a choice. Decisions often are political; that will not change, but the tradeoffs and the costs and benefits to different uses and users resulting from political decisions need to be made explicit and transparent so everyone can see them and agree that that's what they, as a society, want to do.

An example helps illustrate some of the complexities of decision making in a multiple-use setting. Brown bears (*Ursus arctos*) occur on the Tongass National Forest in southeast Alaska in densities that are among the highest in the world. Timber harvest occurs on some portions of the Forest where brown bear densities are high and brown bear viewing and hunting traditionally have not been considered in weighing decisions about where to harvest timber. Such harvest may result

[5]Measuring differences in cost between public and private resource management might be one approach to estimating the magnitude of politically expressed values.

in lower densities of brown bears due to roading and associated access that result in higher brown bear mortality. Brown bear modeling (Schoen et al. 1994) and best professional judgment suggest that industrial forest lands may result in long-term declines and possible local extirpation of brown bears from some portions of the forest. For example, brown bear density on a nearly pristine portion of Admiralty Island is about 461 bears per 1,000 square kilometers, while the density on the intensively roaded and timber harvested northern portion of Chichagof Island is about 331 bears per 1,000 square kilometers (Titus and Beier 1993). Part or all of this lower density likely is associated with indirect effects of timber harvest and has resulted in regulatory changes in bear hunting seasons, curtailing some economic opportunity for brown bear guides. Guided brown bear hunts in southeast Alaska cost from $8,000 to $12,000 per individual. Timber harvest also has the effect of concentrating bear hunting and viewing on Admiralty Island National Monument which is nearly all designated as wilderness. Recently, concerns have been raised that Admiralty Island bears might be less "viewable" for hunting and viewing opportunities, resulting in concerns among some local residents and ecotourism businesses. Decisions to harvest timber are made by those with private land, the USDA Forest Service, local communities and various timber supply demands in the private sector. Conflicts arise between proponents of different land uses.

Consider an imaginary 100-acre tract of land on the Tongass National Forest over a 100-year period. An acre of land harvested on that Forest produced an average of 31,383 board feet of timber in fiscal year 1995. A recent timber sale on the Tongass was bid at $315 per thousand board feet (S. Brink personal communication: 1996). Accordingly, the imaginary 100-acre tract would produce 3.1 million board feet valued at $988,565. That represents the amount received by the USDA Forest Service (i.e., costs of harvesting the timber and producing lumber are netted out of the bid). The $315 figure came from a sale with more than one bidder, so we will assume it represents the full net value of the standing timber. Assuming a 100-year rotation, the treasury would receive $988,565 now and nothing more for timber during the 100-year period. Suppose brown bear density decreases by 28 percent as a result of the harvest.[6] There are an estimated 296 brown bear hunting trips by nonresidents and 171 by residents on an annual basis in southeast Alaska (McCollum and Miller 1994). Suppose the decreased bear density results in 10 fewer nonresident brown bear hunting trips per year, and that resident hunters just move their brown bear hunting to other areas instate, so no net change occurs in number of resident trips. Brown bear hunting trips to Alaska by nonresidents are valued at $11,283, of which $606 is net value (trip expenditures average $10,677, of which $6,636 is spent in Alaska) (McCollum and Miller 1994). Take an unrealistic, but simple case of zero inflation and zero discounting, so a dollar today is the same as a dollar tomorrow. Over a 100-year period, nonresident brown bear hunting would decrease in net value by $606,000 (10 trips times $606 times 100 years) if timber were harvested.

Alaska residents take an estimated 11,644 overnight trips annually to southeast Alaska for the primary purpose of viewing wildlife; an estimated 792 of those trips view brown bears (McCollum and Miller 1994). Suppose our 100-acre tract contains a popular bear viewing area, and the decreased bear density makes it harder to view bears so number of trips decreases by 40 per year (about 5 percent). Overnight primary purpose wildlife viewing trips by Alaska residents on which bears are seen are valued at $808 on average, of which $582 are expenditures in Alaska and $226 is net value captured by visitors. Over the 100-year period, a decrease of 40 trips per year means a net value loss of $904,000. Finally, suppose there would be no net change in the number of nonresident tourist trips to Alaska resulting from the decrease in brown bear density.

Several relevant considerations have been left out so far. One is the effect on brown bear viewing daytrips by both residents and nonresidents. We do not have net value or expenditure

[6]Based on the difference noted above between Admiralty and Chichagof islands. As also noted, some bear biologists think densities would decrease further over time, perhaps even to zero.

information for those. A reasonable conjecture might be that number of daytrips would decrease, especially if our imaginary area were close to a population center, resulting in further loss of net value attributable to timber harvesting. Brown bear hunting daytrips were left out; maybe a small loss of net value due to timber harvesting. People who continue to hunt or view brown bears in the area might derive less benefit from their experience because there are fewer bears; more net loss attributable to timber harvest. On the other side, timber harvesting might lead to better habitat for moose or deer, and hunting those species would increase. There is not much moose and deer hunting by nonresidents in southeast Alaska, so effects would be small but probably positive from timber harvesting. There may or may not be a net gain to resident hunters and viewers of those species. There undoubtedly are other "nonvalued" effects that we left out.

While they are not considerations in terms of *net* value gained or lost, expenditures and economic impact are distributional factors that managers need to consider. Expenditures for harvesting timber and producing lumber from our 100-acre tract would be about $2.2 million over the 100-year period (S. Brink personal communication: 1996). A lot of the expenditures would be for labor, transportation and mill operation, so assume all the expenditures would be made in Alaska. Expenditures in Alaska from nonresident brown bear hunting lost if the area were harvested would be about $6.6 million over the 100 years, and those from resident bear viewing would be about $2.3 million (McCollum and Miller 1994). In both cases, analyzing changes in expenditures is ambiguous because some, or maybe all, of the expenditures made by Alaska residents would be transferred to some other type of expenditure instate. If the area were managed for brown bears instead of timber harvesting, expenditures still would be made, just different types. Whether the final expenditure totals would be the same is an open question. Likewise, if Alaska residents did not take bear viewing trips to southeast Alaska, they might take more trips to Denali National Park. To the extent expenditures are transferred to other parts of the State rather than lost, comparisons between alternatives become more a matter of tradeoffs between different groups within the State. The only (instate) expenditures that would unambiguously be lost are those by nonresident brown bear hunters who decide not to take an Alaska hunting trip.

The Tongass is a national forest, so benefits and costs accruing anywhere in the U.S. are relevant. The resource manager is left with a dilemma. If he or she decides to harvest the 100 acres, there is a gain in net benefit of $988,565 from the timber, but a loss in net benefit of $1.5 million from nonresident brown bear hunting and resident overnight brown bear viewing trips. On balance, it appears there would be further loss in net benefit from timber harvesting due to brown bear viewing daytrips and decreased quality of hunting and viewing trips for people who continue to use the area. In terms of net benefit, the "no timber harvest" alternative appears to have a small advantage. More expenditures also appear to result from the "no timber harvest" alternative, though the exact magnitudes are uncertain because it is not immediately clear what other expenditures would be made if timber were not harvested.

On top of all this are policy emphases handed down to resource managers, such as scheduled timber harvest levels forest wide, and budget line items for specific programs. Interest groups of all kinds lobby for management practices beneficial to their point of view—some resulting in legal challenges. Private-sector resource managers can choose the alternative with the biggest bottom line. Public resource managers have a hard time deciding what the bottom line is.

Interpretation, Implications and Conclusions

Public- and private-sector resource managers must consider different guidelines, constraints and values in their decision making. Within the public sector, federal, state and local resource managers represent and answer to different constituencies.

A distinction needs to be made between economic impact and economic value. Economic impact measures market transactions resulting from a given activity or policy/management decision. Economic value goes beyond market transactions and measures the benefit received by people regardless of the amount they paid to acquire that benefit. Economic value and impact combine to reveal both the net benefits accruing to the whole relevant constituency and the real distributional consequences for local communities that might occur from a change in resource use. Private resource managers only need to focus on economic impact—that component of value that can be captured through the market. Consequently, production of public goods generally does not occur on private lands (Loomis 1993). Public resource managers additionally need to consider economic value, regardless of whether all that value can be captured in the market. Public policy and decision makers often focus only or primarily on economic impact. Such an exclusive focus is incorrect and carries the potential of misrepresenting the best use of society's resources.

Having said that, though, one needs to recognize that it is perfectly valid to choose policies or actions based on economic impact to local areas—i.e., give greater weight to distributional considerations than efficiency considerations. Such choices do not misrepresent the best use of society's resources as long as decisions are made recognizing the tradeoffs involved. If public resource managers (acting as agents for society) *knowingly* decide to give up efficiency (which is concerned with maximizing the size of the economic pie, as measured by total benefits) for distribution (which considers how big a slice of the economic pie goes to various groups in society), that's fine.

Economic value encompasses a wide range of things that people think are important. It is not limited to market behavior and jobs, but can include utility or benefits derived from such things as: the existence of wilderness and wildlife, even if one never intends to see or use those resources personally, and the spiritual uplifting one might receive from being able to view the mountains or drive through the forest while commuting to work. Economic values might conflict between different groups. One group might derive positive benefit from wolf control programs, while another might derive negative benefit. Such conflicts are among the tradeoffs that must be made clear.

Society mandates values beyond those expressed in markets which result in subsidies for various groups in society. Recreation is subsidized by charging zero or minimal access fees for recreation on public lands. Likewise, the logging culture and lifestyle is subsidized to the extent that timber on public land is sold below its full cost of production. Mining is subsidized by charging virtually zero royalties for minerals extracted from public lands. By mandating each of those policies, society implicitly says "we don't care that those activities do not cover their full cost, we think maintaining that culture and lifestyle is worth the difference." The same argument holds for grazing, hunting, endangered species and others. In some sense, everyone gets some kind of subsidy. Public resource management does not operate as it might under a strict (private) competitive market system, and there is no reason to expect it to.

Just as market values and constraints can change over time, so can politically determined values and constraints. That is evident from following debate in the legislature over time. Programs are reevaluated when they come up for renewal, legislative priorities can change after elections when a different political party or group gains power, etc.

The existence, availability and ease of collection of information traditionally has implied priorities of resource uses. In the 1950s, information on commodity uses of natural resources was readily available so market goods dominated resource decisions. The rise of the environmental movement led to a whole new set of information being brought to the table and pushed the economics profession to find ways to measure and evaluate that information. From that experience, we learn the lack of available information does not imply low or zero value, nor does it imply weights or priorities. We learn we need to keep pushing on the frontier of knowledge to learn how to measure and evaluate preferences and priorities. One means of doing so is to scrutinize resource allocation decisions (and public policy decisions in general) to recognize exactly what tradeoffs are being made, what is being gained and what is being given up.

There was a time when public resource managers could make decisions in isolation. For years, traditional uses of fish and wildlife, timber, and mineral resources went on and consumptive users dominated agency attention. That is no longer the case. Other uses and users have arisen for natural resources and are demanding a seat at the table. Resource managers are moving from a role as an independent decision maker to one of providing information and acting as a facilitator for public decision making. Likewise, economists have gone from a role of providing traditional benefit-cost analyses as a predictive tool to one of providing information about effects and tradeoffs of alternative policies to frame public debate. The role is to make tradeoffs transparent and hold them up to the public to facilitate their choosing of preferred alternatives.

One key to understanding the role of economic information is to distinguish between a bottom-line dollar value of net measurable benefits and the process of identifying and evaluating all relevant tradeoffs, some of which can be measured in dollars, others of which cannot. Economics is about allocation and tradeoffs. Economic information helps illuminate tradeoffs that are made in public policy. Its function is to show resource managers and the public what they are really doing and the implications of those decisions. The purpose of economic analysis is to make the tradeoffs in public decisions transparent, holding them up to the public and asking if this is what they really want.

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Sustaining Wildlife Values on Private Lands: A Survey of State Programs for Wildlife Management on Private Lands in California, Colorado, Montana, New Mexico, Oregon, Utah and Washington

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Amid the rising human population and subsequent development, wildlife and its habitat increasingly coexist in close proximity to human activities. Wildlife now must possess an inherent value, be it economic or aesthetic, to enable it to be competitive vis-à-vis alternate uses of its habitat. The fact of diminishing habitats accentuates the need to maintain good productive wildlife habitat on private lands. The significance of wildlife habitat on private lands is well-documented (U.S. Fish and Wildlife Service 1990, Louisiana Private Lands Team 1989), but this fact needs to be addressed in the arena of public policy. In view of present trends, conservation of natural areas, and wildlife management in particular, should not and cannot rely solely on public land. Such a policy would be politically, economically and ecologically unsound.

Market-based solutions to conserve wildlife and its habitat frequently are proposed by a growing school of resource economists (Anderson and Leal 1991). A recent study conducted by Edwards (1994) revealed well-developed nongovernmental institutions in the U.S., working to conserve natural areas with the aid of market mechanisms—that is, a conservation market through which goods and services are bought and sold (Edwards 1994). The new Political Economy Forum series "Wildlife in the Marketplace" (Anderson and Hill 1995) discusses how market forces of demand and supply can be harnessed to provide incentives for better wildlife management on private lands. Huffman (1995) argues that present political institutions hinder market forces from playing a significant role in wildlife management. Under prevalent public policies, in absence of a medium to recoup his/her investment, a private owner of habitat has little incentive to invest in wildlife. In view of these facts, western state wildlife agencies have embarked on cooperative programs with landowners to enhance wildlife habitat on private lands or Private Lands Public Wildlife (PLPW) programs. Most of the PLPW programs involve certain economic remuneration to the private landowner for being a good steward of the land. This paper provides a descriptive analysis of the relative merits of these programs as implemented in the states of California, Colorado, Montana, New Mexico, Oregon, Utah and Washington. These PLPW programs have met with varying degrees of success in attaining their objective and, I believe, each has contributed in its own way to a more progressive management strategy for wildlife resources.

History of Private Lands Public Wildlife Programs

State PLPW programs discussed here got their start in the 1980s, with the exception of New Mexico whose PLPW origins go back to the early 1920s. California's Private Lands Wildlife Habitat Enhancement and Management Area Program (PLM) was established by the State Legislature in 1983 (Bill AB 580). This action was the answer to a perceived need seen by the California Department of Fish and Game (CDFG) for programs based on biologically sound incentives to maintain and enhance wildlife habitat on privately owned lands (Mansfield et al. 1989). In 1985, the Colorado Wildlife Commission directed its Division of Wildlife (DOW) to investigate the potential for a cooperative private lands wildlife management program, such as the one implemented in California. The ensuing PLPW program was termed Ranching for Wildlife (RFW). Montana Department of Fish, Wildlife and Parks (MFWP), in an effort to ease the strained relationship between landowners and hunters, initiated the Block Management Program (BMP) in 1985. The objective of the BMP was to maintain free public hunting access on private lands and alleviate inconveniences to landowners from public use of his/her land. The success seen in private individual's participation in this program led MFWP to formalize the rules of the BMP in 1994. In 1993, the Oregon Legislative Assembly introduced House Bill 2538, "to improve Oregon's resource access and wildlife habitat through further involvement's of its citizens, through voluntary partnerships between the department and landowners to manage wildlife on private lands and through support by additional financial revenues." To address this question more closely, the Access and Habitat Board was established within the State Department of Fish and Wildlife, consisting of seven members appointed by the Wildlife Commission. After a trial period, Utah's Posted Hunting Unit Program was adopted by the Utah State Legislature in 1993. Washington Department of Wildlife (WDW), in an effort to protect remaining wildlife habitat and enhance wildlife recreational opportunities on private lands, initiated the program, "Partner's for the 90's: Public Resources, Private Lands" in the early 1990s. With these ideas in mind, the WDW started the Private Land Wildlife Management Area Pilot Program (PLWMA) which still is in the works.

The history of the Private Land Allocation System (PLAS) in New Mexico can be traced back to the 1920s, when the New Mexico Department of Game and Fish (NMDGF) started a policy of granting licenses to landowners who had elk on their property (Gonzales 1989). The system evolved over the years into a lucrative enterprise (in its present form). A summary of the relevant characteristics regarding these PLPW programs is illustrated in Table 1. Each state PLPW reflects the traditional culture of wildlife use by its residents.

Functioning of Private Lands Public Wildlife Programs[1]

PLPW programs historically have originated either out of legislative action or have been put in place by a department (state wildlife agency) initiative. The functioning of these programs involves an interested landowner holding consultations with the local PLPW biologist regarding the wildlife resources of the proposed area to be included in the program and the management objectives of both the landowner and the state agency. If the land meets established criteria, the next step is to prepare a management plan for the property, incorporating its salient features. Usually, special care is paid to the description of year-round and seasonal habitat use, particularly as this relates to landowners on winter range. A mutual agreement, based on both the private party's wildlife management plan and the state agency's management objectives, is worked out between the two entities. This agreement, among other things, entails specifications regarding number and type of landowner hunting permits, setting of the hunting season, and the boundaries of the specific parcel of land to be included in the program. Most landowners who want to participate in PLPW programs have to prepare a wildlife management plan for their area and get it approved by the state wildlife agency. As part of the agreement in most PLPW programs, the landowner receives a certain number of hunting permits derived from some mutually agreeable formula. The landowner then can sponsor hunting opportunities on his/her land and charge fees for hunting access and services provided. This fee charged by the landowner may vary, depending on factors such as

[1]Information in this section about seven state PLPW programs was assembled from state documents. Any errors or misrepresentations are the sole responsibility of the author.

Table 1. Summary of state private lands/public wildlife management programs.[a]

Program	Percentage private ownership in state	Number of landowners in program	Area enrolled in acres	Licenses allocated	Extended season	Public access to private land	Contingency against libel lawsuits for landowners
California							
PLM[b]	51	46	544,139	614[c]	yes	no	
Colorado							
RFW[d]	67	22	1,300,000	1,710	yes	yes	
Montana							
BMP	65	443	4,347,447	0	no	yes	yes
New Mexico							
PLAS[e]	44	1,250		7,600	yes	yes	
Oregon							
A&H	51[g]	33	1,000,000	0	no	yes	
Utah							
BGPHU[f]	29	15	1,000,000	440	yes	yes	yes
Washington							
PLWMA	69[g]	2	155,000		yes	yes	

[a]These are approximate figures obtained from office documents of respective state agencies. Any errors or misrepresentations are solely the author's. Those interested in current figures should contact PLPW administrators in respective states.

[b]1992 figures.

[c]Deer, elk and pronghorn licenses only.

[d]1993 figures.

[e]1992 figures for public licenses available on PHU lands.

[f]1989 figures.

[g]Percentage of non-federal lands in these states.

length of the hunt, level of service offered and quality of recreational experience provided. However, exceptions to this framework exist. The New Mexico PLAS does not require a detailed application or a wildlife management plan from the private landowner, but simply judges the number of hunting permits per ranch by assessing the size of the property and its elk use. Montana and Oregon, on the other hand, do not offer any special landowner hunting permits to participants in their respective PLPW programs. These two states offer technical and administrative assistance to facilitate administering of public hunt seasons on private lands.

Management activities on PLPW areas have focused primarily on game species, with special emphasis on wild ungulates. However, most state wildlife agencies have the discretion, during the review process of a PLPW wildlife management plan, to ask for habitat improvement activities which may benefit non-game species as well. Nesting habitat improvement for sandhill cranes in northern California is one result of such an approach (CDFG 1993a). Similarly, CDFG estimated that approximately 331 non-game species in hardwood-dominated habitats have benefited from habitat improvement practices on PLM areas (CDFG 1993b).

Usually, most PLPW participants in a state are concentrated in areas which boast wide open spaces related with large cattle operations. In California, the largest congregation of PLM areas is in the northern counties of Lassen, Modoc, Shasta, Siskiyou and Tehama. In Colorado, most RFW participants are concentrated in the southeast region, with some in the northwest section of the state and a couple in the southwest region. Most BMP areas in Montana are in the eastern part of the state. The majority of PLAS operators in New Mexico are situated in 15 counties in the eastern half of the state where 50 percent or more of the land is privately owned (Gonzales 1989). The Pacific Northwest states of Oregon and Washington are an interesting exception to this generality. In these two states, private forest owners have enrolled in the programs as well, hence, spatial distribution of participants in respective PLPW programs is quite varied.

Land area under private ownership in the seven states studied varies from approximately 29 percent in Utah to more than 60 percent in Colorado, Montana and Washington (Table 1). Of this area, the private lands under various forms of PLPW programs range from about 150,000 acres in Washington to 4.3 million acres in Montana. The number of landowners participating in such endeavors ranges from 2 in Washington, where the program still is in its trial phase, to 1,250 in New Mexico. The method of remuneration to landowners for preserving habitat on their property varies. For example California, Colorado, New Mexico, Utah and Washington provide landowner hunting permits to people enrolled in the program. Montana and Oregon motivate participants via free technical assistance and increased policing of their properties to assure sportsmen's adherence to hunting regulations. Consequently, the former five states, California, Colorado, New Mexico, Utah and Washington, also allow for a flexible hunting season on these private lands. The hunting season on PLPW private lands in Montana and Oregon is not flexible. In the six states excluding California, the cooperative agreement requires public access to those private lands during the hunting season. The exact number of public hunters to be allowed on a private property is decided by a set of formulae agreed on by the landowner and the state agency in the respective state. States such as Montana and Utah make provisions to limit liability responsibilities of landowners enrolled in PLPW programs.

The most prevalent habitat improvement measures undertaken by PLPW participants include reductions in livestock grazing by cutting back on herd size, use of progressive grazing systems and fencing off or non-use by livestock of sensitive habitat areas, such as sandhill crane nesting sites, elk parturition areas, trout spawning streams, etc. Several PLPW operators use prescribed burning and irrigation to improve forage. Seeding of herbaceous browse species also is a common activity among PLPW participants. Maintaining and improving water sources, with particular emphasis on riparian areas, is an integral part of most management plans. In California, constructing brush piles also is a common habitat-improvement practice.

Discussion

PLPW programs can be divided into two categories. In the first category, the emphasis in the cooperative agreement lies in preserving and enhancing wildlife habitat on private lands, as well as making these lands available for public access. In the second category, the emphasis is more to keep these private lands accessible for the public. California, Colorado, New Mexico, Utah and Washington PLPW programs belong to the first category, and Montana and Oregon represent the second category. Whatever the overriding purpose, the existence of these programs is a testimony to the importance state wildlife agencies place on wildlife habitat available on private lands. While PLPW programs are a step in the right direction, they represent a small step. The percentage of land area under these programs relative to the amount of private land existing in these states is approximately 5 percent. In other words, there exists a tremendous opportunity to expand the scope of these PLPW programs.

Most of these PLPW programs have faced varying degrees of opposition in their nascent stages, some of which still persists. The majority of opposition to PLPW programs stems from the perceived notion of the local sportsmen of privatizing state wildlife resources and the encroachment on their hunting access. These opposing views are greatly influenced by the average public hunter's emotional bias against fee hunting. It should be pointed out that the concept of fee hunting operates independent of PLPW programs. Market forces of demand for high-quality hunting opportunity and supply of this experience decide the status of fee hunting. The concept of fee hunting did not originate as a result of PLPW programs, nor will it end if these programs are discontinued. Sportsmen's organizations, as well as private landowners and state agencies, should be involved to the extent feasible in the formulation and implementation of a PLPW program. The merits and demerits of such a program should be made clear to them. The use and significance of wildlife habitat on private land also should be explained clearly. If properly planned and implemented, a PLPW program has the potential to benefit all parties involved. It makes wildlife an economically viable option for the landowner, enhances state wildlife agencies' ability to partake in wildlife management on previously "off-limits" private land, and has the potential to increase the harvest by and access of local sportsmen on private lands. Often, private lands previously closed to local sportsmen for hunting become accessible when the private landowner signs on to a PLPW contract and agrees to allow a certain number of local public hunters to hunt his/her land. A successful PLPW attracting non-resident hunters for a high-quality experience makes a positive contribution to the local economy and the state wildlife agency budget. Most importantly, an effective PLPW program can make a significant contribution to the health and sustainability of local wildlife populations and diversity.

A successful PLPW program should have three integral parts to its structure and implementation (Figure 1). First, an effective PLPW program should result in productive and diverse wildlife habitats and populations. Some of the most productive and significant wildlife habitats are found on private lands. The status of these lands will greatly influence the future of local wildlife resources in the state. Hence, preservation and enhancement of wildlife habitats on private lands should be one of the foremost objectives of any PLPW enterprise. Second, economic benefits given to landowners should at least cover the cost of providing wildlife habitat on their land, if not equal the benefits that society receives from having this habitat available on private lands. The most effective means of securing productive wildlife habitat on private lands is through tangible

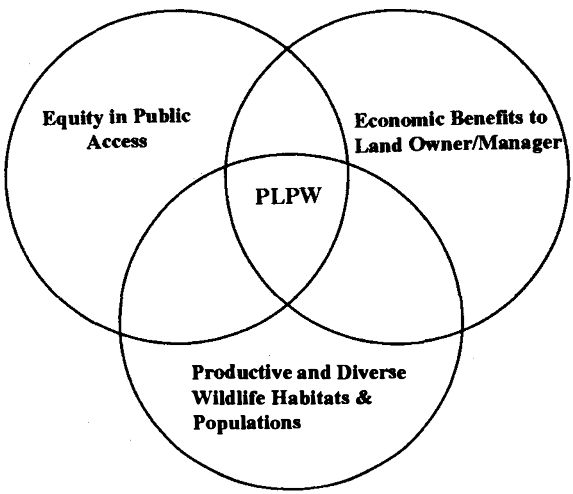

Figure 1. Integral components of an effective PLPW program.

and relevant rewards to landowners for being good stewards of the land and providing public benefits. Economic incentives available as part of PLPW programs are a welcome source of relatively stable income for livestock operators whose economy is characteristically prone to volatile fluctuations. And third, equity in public access should persevere in order to perpetuate the sporting tradition of this country and make these programs acceptable to local sportsmen. Enhanced recreational opportunity for local residents is an important ingredient for building a strong, local support base necessary for a PLPW program to be successful. Any PLPW programs lacking one of these three features will be ineffective in meeting its objectives.

There are two important pieces of information missing that will enable us to judge the effectiveness of these programs and ascertain whether PLPWs should be expanded or modified in order to be effective: 1) is the habitat on private lands maintained or enhanced in a measurable way; and 2) does economic remuneration received by the private landowner equal his/her contribution to society?. A related question is whether the economic incentives provided by different PLPWs result in changes in landowners' land-management practices and, if so, do these changes result in maintained or improved wildlife habitat on private lands?

A PLPW program is administered best under the tenets of Adaptive Management, where management policies are evaluated periodically for their effectiveness and modified as further information from research and monitoring becomes available. A strong monitoring component is conspicuously absent in each of the seven PLPW programs discussed in this paper. The primary reason for this presumably is lack of funds available in the state wildlife agencies. This is unfortunate, because monitoring provides the yard stick by which to measure the effectiveness of a PLPW endeavor toward meeting its goals. The responsibility for monitoring should be shared between the private landowner and state wildlife agencies. Ecological and social variables to be monitored should be stated in the wildlife management plan for the PLPW area. State wildlife agencies should provide the technical guidance and assistance to landowners in monitoring the agreed set of variables. The landowner is better placed to, and hence should, carry out the logistical responsibility of a monitoring program.

No single model of a PLPW program can be applied to all states. Each state, taking into consideration the tradition of wildlife use by its residents, should design a PLPW program accounting for the three integral components mentioned in Figure 1. To run an effective PLPW program, state wildlife agencies have to strive for a delicate balance between inviting private landowners to be involved in the management of the state's wildlife resources and not relinquishing the state's final authority over those resource. It is not an easy balance to achieve. Nevertheless, it is a step in the right direction in addressing a concern raised by Aldo Leopold (1930) when he asked us to "recognize the landowner as the custodian of public game on all private land, protect him from the irresponsible shooter, and compensate him for putting his land in productive condition. Compensate him either publicly or privately, with either cash, service, or protection, for the use of his land and for his labor, on conditions that he preserves the game seed and otherwise safeguards the public interest. In short, make game management a partnership enterprise to which the landowner, the sportsman, and the public each contributes appropriate services, and from which each derives appropriate rewards."

People on the ground and, thus, in close contact with wildlife, are the most effective conservators of that resource. These folks are best-equipped to ensure the existence of diverse and healthy wildlife populations for the future. Wildlife conservation around the world has attempted to enroll the assistance of local communities living in close proximity to wildlife by extending economic incentives for doing so, e.g., Zimbabwe's CAMPFIRE program and similar programs in other eastern and southern African countries. The true success of PLPW programs will be judged on the basis of how many private landowners partake in this exercise and what happens to wildlife resources and public access on their lands as a result. That will decide how much private land ultimately will be maintained in productive wildlife habitat, rather than be converted to developments incompatible with wildlife values or uses.

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Investments in Wildlife Enhancement through Widespread Implementation of Sustainable Agriculture for Social and Economic Benefits

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Farming in the North Carolina coastal plain is intensive and profitable. Clearing and drainage efforts in past decades have produced large tracts of tillable land from forests and swamps. Using modern farming technology, producers seek to maximize production on these hard-won areas by cultivating all available acreage (Robinson 1991, Doering 1992, Johnson et al. 1993). As a result, early successional habitats available to wildlife on these and other grain farms are greatly limited and wildlife associated with these habitats have declined over the last 30 years (Graber et al. 1983, Berner 1988, Brennan 1991, Rodenhouse 1992, Warner 1994, Knopf 1995). Survey data for Wilson County, North Carolina show that early successional habitats comprise less than 2.5 percent of the farm landscape (Palmer 1995). Economic and social barriers exist to increasing investment in wildlife habitats on farms.

Current land-use practices are culturally, technologically and economically based (Gerard 1995). How individuals farm their land reflects their personal values, as well as the values of their rural community. Landowner decisions to invest in long-term conservation improvements appear dependent on farm size, income and type of farming practice (Featherstone et al. 1993, Miller et al. 1990). Farm-management practices are governed partly by the technical expertise and abilities of the individual producer. The production potential of a farm is further constrained by current economic realities in the marketplace, government incentives and regulations, and by a producer's ability to acquire and utilize new information. Knowledge about the costs of enhancing habitat is an expected key determinant in the level of habitat investment (Williams 1994). In this environment, wildlife agencies are frustrated by an inability to impact investment in wildlife habitat on individual farms. This frustration is exacerbated when significant improvement in wildlife populations requires landscape-scale changes in habitat. Traditional wildlife enhancement programs have not recognized the economic and cultural incentives for clean farming practices. Consequently, these programs provide insufficient information to landowners evaluating habitat-investment decisions. Wildlife management efforts also are made difficult by conflicts between economic and environmental policies and between environmental policies concerned with different resources (Lakshminarayan et al. 1995). To be effective at the landscape scale, wildlife polices cannot be piecemeal attempts to effect change on isolated and shifting locations. Rather, these policies must include consideration of other environmental resources as well as the technical, economic and cultural realities of modern farming and rural life. The farm wildlife issue is a special case of the larger social problem of integrating farming, the rural community and urban interests within progressive social policy (Wimberley 1993). Current sustainable agriculture ideology provides an environment where policies resolving these problems can be developed.

In the 1990 Farm Bill, Congress defined sustainable agriculture as "an integrated system of plant and animal production practices having site-specific application that will, over the long-term: satisfy human food and fiber needs; enhance environmental quality, and the natural resource base upon which the agriculture economy depends; make the most efficient use of non-renewable resources and integrate, where appropriate, natural biological cycles and controls; sustain the economic viability of farm/ranch operations; and enhance the quality of life for farmers/ranchers and society as a whole." This definition recognizes the interaction of economic, ecological and cultural factors in the production and conservation of resources. It emphasizes the use of integrated, site-specific approaches to enhance human and environmental well-being over long-term planning horizons; precisely the things lacking from past wildlife policies. The sustainable agriculture movement promotes research and information transfer, and emphasizes interagency cooperation in addressing complex issues and reducing policy conflicts. Specifically, this movement is an opportunity for the development of influential and far-reaching wildlife habitat and environmental conservation policies. Why, then, does landowner incorporation of wildlife habitat on production areas remain a problem?

This question was asked to a group of producers attending a focus group meeting. They responded that, without adequate information and motivation, landowners will persist in currently profitable farming patterns. For these producers, farming methodologies which maintain production levels and annual profitability represent sustainable agricultural practices. Participants stated that investments in wildlife habitat may not occur on farms even when growers would like (have no objections) to increase wildlife, such as bobwhite quail. The reasons for this are financial risk and outcome uncertainty.

Ecological and Financial Risk Assessment

Responses from focus group participants indicate that landowners perceive various types of risk when evaluating and implementing investments in wildlife habitat. One group of risks is ecologically based. These result from uncertainty about how particular practices will benefit various species and to what degree. Food plots, protective cover and nesting structures, for example, do not guarantee results of a certain magnitude. This package of risks can be described as outcome uncertainty. The second group of risks faced is economically based and can be termed financial risk. Often, there is uncertainty about the costs of establishing and maintaining habitat areas. There also may be uncertainty associated with the value of the commodities a landowner may be trying to produce, such as quality quail hunting opportunities. Taken together, outcome uncertainty and financial risk represent a formidable roadblock to producer investment in habitat enhancement projects. This problem is further magnified when such projects are to be established on land already under cultivation. While producers may be willing to enhance habitat on unused areas in meeting their stewardship obligations, the land ethic alone is insufficient to ensure such investments on production areas. To encourage establishment of wildlife habitat on production areas, research and management recommendations must reduce outcome uncertainty and financial risk. We are working to resolve these problems.

Eastern North Carolina is a productive crop and livestock region. Poultry, swine, tobacco, corn, wheat, cotton, peanuts and soybeans are produced on family farms and large corporate farming operations. This also is the most productive area in North Carolina for bobwhite quail, although even here the same decline is seen as in other southeastern states (Sharpe unpublished data). We have been researching northern bobwhite quail on production farms in the coastal region to test the wildlife benefits of field border systems and no-till farming techniques. Use of filter strips between tilled fields and drainage ditches was shown to generate and enhance habitats utilized by quail during the growing season. Flush-count surveys found 4.3 times the number of quail on farms with field border systems as on those without (Puckett 1995). The costs to establish and maintain such areas under various vegetative and maintenance regimes have been quantified (J.T. Morris unpublished data, J.R. Anderson unpublished data). Fields planted to no-till soybeans after winter wheat where found to provide insects to quail chicks at rates equal to insect availability in fallow fields (Palmer 1995). Integrated pest management practices are capable of reducing the direct and indirect impacts of pesticides on wildlife (Palmer et al. 1992). Furthermore, many conservation practices, particularly no-till and field border systems, can reduce sediment and nutrient loading of waterways. These reductions in non-point source pollutants benefit humans and wildlife both on-site and downstream (Allen 1993).

Eastern North Carolina Research Design

Currently, in eastern North Carolina, 15 cooperators volunteering 12,000 treatment and control acres are participating in a study of the wildlife and water quality benefits of both naturally vegetated and fescue field border systems. Our work is focused in four subregions, each of which is characterized by its own combination of crops and rotations. These experiments will allow assessment of reductions in nutrient and sediment loading of field ditch and canal networks and insights into the response of quail populations, as well as the benefits for other wildlife species in the farm landscape. Monitoring of the installation and maintenance of the field borders under various regimes will provide precise cost estimates. These estimates will be combined with calculations of the lost crop production from land removed from cultivation in each subregion. These costs will be compared with financial incentives available under current government-sponsored programs. These comparisons will contribute to determining the net costs of establishing habitat and highlight conflicting incentives between agriculture, conservation and wildlife policies. When provided to producers in a usable form, this information will reduce the financial risk associated with investments in field border systems. To reduce financial risk further, we will characterize the demand for high-quality, wild quail hunting on private lands in eastern North Carolina. This will provide producers with information on possible income opportunities from quail hunting leases. Income from such leases is another important factor in determining the net cost of establishing wildlife habitat on production areas.

The economic benefits from enhancing quail habitat and leasing hunting rights are difficult to determine due to a lack of price and market signals. There is a lack of information on how such factors as habitat extent and quality influence hunter demand. To quantify the benefits of habitat enhancement, the demand for high-quality, wild quail hunting must be examined in conjunction with the willingness of landowners to enhance wildlife populations and lease hunting rights. It is essential that the results of these analyses be useful to the individual landowner. Past data on demand for wildlife resources have been produced to meet state and regional policy needs. These data do not satisfy the site-specific planning requirements of individual producers.

Value of Nonmarket Goods and Characteristics of Hunter Demand

Enhanced quail populations generally are considered a positive economic good. Prices for such a good, however, cannot be determined simply by observation in the market place. In addition, recreational amenities, such as quail hunting, are composite in nature and, thus, are goods produced by combining other goods. To understand the value a quail hunter will derive from enhanced hunting opportunities produced through landowner adoption of sustainable agricultural practices requires an understanding of the various attributes desired in a hunt and the marginal rates of substitution between these attributes. We will characterize hunter demand by identifying the various hunt attributes desired, as well as the relative importance of these attributes in determining the overall value of a hunt. These attributes include the type of cover on the land, the ability to hunt with dogs, the distance to the site, the number of birds harvested and others.

Past efforts to value recreational amenities have utilized nonmarket, primarily contingent valuation methods (CVM), and related-market approaches, such as the travel cost, hedonic and household production methods. Problems with respondent biases, nonresponse and inconsistent estimators, however, have limited the value of these results. In addition, the travel cost model traditionally has assumed that an appropriate value for travel time is the foregone wage rate. Rigidities in the labor market, however, likely distort such valuations of leisure time (Bockstael et al. 1987), causing the travel cost model to underestimate the value (cost) of travel time.

The conjoint analysis method builds on the closed-end CVM (MacKenzie 1992). In the closed-end CVM, respondents are asked if they would be willing-to-pay or willing-to-accept some dollar value for a given increase or decrease in environmental quality, respectively. The conjoint method breaks down a composite good into its various attributes and then surveys respondents regarding their preferences for different attribute bundles when several attributes are varied simultaneously. Unlike the CVM, the conjoint method does not directly ask respondents for a dollar valuation, rather the price of a recreational outing is included as an attribute. This helps to reduce the confusion of respondents generated when they are asked to value goods which they do not normally purchase directly or at all. The conjoint approach differs from the travel cost method in that travel time is valued as lost time at the site rather than time foregone at work (MacKenzie 1992). This is intuitively appealing when one imagines a recreationist who finds he/she has available a fixed block of time for a recreational trip. In this scenario, all of this block is to be spent away from work, thus, each hour of travel time to and from the site directly reduces the on-site time available.

We will use conjoint analysis to investigate the potential recreational income opportunities available to landowners enhancing wild quail populations in eastern North Carolina. North Carolina Quail Unlimited members and participants in the North Carolina Wildlife Resources Commission's *Avid Quail Hunter Survey* will be surveyed to determine the marginal values held for various trip attributes and the marginal rates of substitution between these attributes. When price is included as an attribute, hunter demand for various quail hunting opportunities can be estimated. Cooperating farmers will be surveyed using conjoint analysis and focus group meetings to understand how they will respond to this demand. We will investigate what attributes landowners desire from leasees of hunting rights and what types of hunting opportunities those landowners will be able or willing to supply.

Conclusion

The economic and social factors that will determine the creation and availability of habitat on private lands in eastern North Carolina can only be understood by focusing on the decisions made by private landowners. We believe that wildlife habitat has not been created or maintained by farmers because of their reluctance to accept unknown levels of ecological and financial risk. Our work seeks to reduce these uncertainties by simultaneously demonstrating the environmental benefits, and the economic costs and benefits, of early successional wildlife habitat within four agronomic regions. On a farm-by-farm basis, the landowner will be able to add the economic values from recreational use to funds available from government conservation programs to make informed decisions on establishing early successional wildlife habitat.

Wildlife managers traditionally have been good practical ecologists who had strong ties to the agricultural community. In recent decades, however, agriculture has become a highly intensive and technologically advanced industry. Simultaneously, demand for environmental quality and recreational access from urban and rural communities has increased, creating challenges for policy makers at the state and federal levels (Wimberley 1993). Implementation of these policies ultimately resides in the hands of the private landowner. To effectively represent the wildlife resource, wildlife managers must be prepared to show how investments in wildlife habitat simultaneously achieve environmental, social and economic objectives.

We believe the information age will equip the field biologist better to handle complex issues. Geographic information systems, government data bases, and production, wildlife population and recreational demand models all will be used to forecast the costs and benefits of establishing field borders and other conservation agriculture and forestry practices to yield desired wildlife benefits. The wildlife biologist will become a site-specific wildlife investment analyst.

Our work will help identify conflicts between existing agriculture, environmental and wildlife policies. The interactive effects of these policies may provide unclear or conflicting incentives to producers. These effects are likely to increase the levels of risk and uncertainty producers perceive and, hence, impact farm-management decisions toward the status quo. To encourage incorporation of early successional habitats on production areas, wildlife programs must overcome both outcome uncertainty and financial risks by providing adequate information for site-specific management planning. To do this, wildlife programs must work within the cultural and economic realities of modern farming.

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Sustaining Wildlife Values in the Public Sector: An Overview of State and Federal Management Issues

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At the 50th North American Wildlife and Natural Resources Conference, pollster Lou Harris (1985: 70) presented a paper titled, "Current Public Perceptions, Attitudes, and Desires on Natural Resource Management," in which he summarized the results of several public opinion polls on environmental issues: "...the dynamic of change in recent years has always been in one direction: the American people get tougher and tougher and more adamant and more shocked about the state of environmental clean up. And they are literally furious that there has been so much perceived foot-dragging on the part of those with power to get things done. Thus, the majorities in any sound poll conducted on this subject are simply huge and staggering. They parallel nothing less than belief in free elections, in the right to free speech, the right to worship, and the right to private ownership of property. If any of these were believed to be in dire peril, you would hear about it in a hurry.

"Yet, somehow, the cries and demand of the populace to their leaders on environmental matters fall on relatively deaf ears. The word somehow does not quite get through."

Based on extensive survey and focus group research during the past decade by Responsive Management—an organization developed to assist natural resource, environmental and outdoor recreation agencies and companies better understand and work with their customers and constituents—we can unequivocally state that, a decade later, Harris' observations still hold true.

Results of each Responsive Management telephone survey referenced here are based on random-digit dialing, computer-assisted telephone surveys of adult residents. Telephones were selected as the preferred sampling medium since nearly all U.S. residents have access to a telephone. In addition, a central polling site allowed for rigorous interviews and data collection. The random selection procedure used within each household was the "last birthday" procedure. This means that when someone answered the phone, the interviewer asked to speak to the person over 18 that had the most recent birthday. This procedure is easy for the respondent to understand. Randomly generated telephone numbers coupled with the "last birthday" method ensure that the survey results can be projected to the adult, resident population of each sampled area as a whole.

Following are the results of several surveys conducted by Responsive Management over the past few years that confirm the public's support for fish and wildlife conservation and environmental protection.

Public Attitudes toward the Reintroduction of Large Predators

In a survey conducted for the Florida Advisory Council on Environmental Education, an overwhelming majority of Florida residents (91 percent) supported efforts to save the Florida panther from extinction (Duda and Young 1995c). Most Floridians (83 percent) supported reintroducing panthers into the Osceola National Forest region of north Florida. Ninety-two percent of Florida residents agreed with the statement: "Although I may never see a Florida panther in the wild, it is important to know they exist in Florida."

In a survey administered to local, regional and national samples to assess opinions of grizzly bear reintroduction, a majority of respondents from each sample supported reintroducing grizzly bears to the Bitterroot Mountains region of central Idaho (Duda and Young 1995f). Sixty-two percent of local residents supported, 74 percent of regional residents supported and 77 percent of national residents supported reintroducing grizzly bears to the Bitterroot Mountains. Seventy-one percent of local residents, 81 percent of regional residents and 85 percent of national residents disagreed with the statement: "I dislike the idea of grizzly bears being present in the Bitterroot Mountains."

The League of Women Voters of New Mexico recently commissioned Responsive Management to conduct a survey of New Mexico residents to assess attitudes toward Mexican wolf reintroduction (Duda and Young 1995e). Sixty percent of New Mexico residents supported reintroducing Mexican wolves into southern New Mexico's White Sands Missile Range. In those counties surrounding the proposed reintroduction site, 52 percent of residents supported reintroducing Mexican wolves into southern New Mexico's White Sands Missile Range. In New Mexico, support for Mexican wolf reintroduction was consistent across political boundaries, that is, Republican respondents (53 percent) were as likely as Democratic respondents (58 percent) to support reintroducing Mexican wolves into southern New Mexico's White Sands Missile Range. Seventy-four percent of New Mexico residents agreed with the statement: "Although I may never see a Mexican wolf in the wild, it is important to know they exist in New Mexico." Almost three quarters of New Mexico residents (73 percent) disagreed with the statement: "Maintaining wolf populations in the wild is a threat to the economic prosperity of New Mexico."

Public Attitudes Toward Wetlands

In a survey of Salt Lake and Utah county residents conducted for the Utah Division of Wildlife Resources, support for efforts to protect Utah's wetlands was measured (Duda and Young 1995a). More than half (56 percent) of the residents in this region of Utah said it is very important for the state to protect wetlands in Utah, an additional 35 percent said this is somewhat important. Seventy-seven percent of the residents of Salt Lake and Utah counties supported the government spending time and money protecting wetlands.

Similarly, Indiana residents also are concerned and supportive of wetlands conservation efforts (Duda et al. 1995). Seventy-nine percent of Indiana residents supported efforts to protect Indiana's wetlands. Half of Indiana residents said it is very important for the state to protect wetlands in Indiana; an additional 38 percent said this is somewhat important. Seventy-eight percent supported the concept of state regulations designed to protect wetlands.

In 1995, the Florida Game and Fresh Water Fish Commission contracted Responsive Management to assess trends in public attitudes toward wildlife (Duda and Young 1995d). We found that Floridians are supportive of wetlands conservation as well. More than half (55 percent) of Florida residents said that more time and money should be spent protecting wetlands. Similarly, 55 percent of Florida residents thought Florida laws protecting wetlands should be strengthened; another 31 percent thought wetlands protection laws should remain the same. Florida Republicans and Democrats alike supported wetlands conservation. Specifically, 78 percent of Florida Republicans and 82 percent of Florida Democrats supported spending more or the same amount of time and money protecting wetlands. Eighty-nine percent of Florida Republicans and 91 percent of Florida Democrats thought Florida wetlands protection laws should be strengthened or remain the same.

Public Opinion on Hunting, Trapping and Fishing

In a nationwide survey for the U.S. Fish and Wildlife Service, Responsive Management found that Americans support the rights of others to participate in traditional fish- and wildlife-related activities (Duda et al. 1995). Seventy-three percent of Americans approved of legal hunting, while 81 percent of the American public agreed that hunting should continue to be legal. Eighty-four percent of Americans agreed that people should have the freedom to choose to hunt if they want.

However, public opinion of hunting varies when the motivation for hunting is considered. In a Responsive Management (1993) survey conducted for the Maryland Wildlife Division, hunting for meat was the most acceptable form of hunting to Maryland residents. Sixty-six percent of Maryland residents approved of hunting for meat; 62 percent approved of hunting for animal population control; 25 percent approved of hunting for recreation; and only 10 percent approved of trophy hunting.

Nationwide, 95 percent of Americans approved of legal fishing (Duda et al. in press). Ninety-six percent of the American public agreed that fishing should continue to be legal.

A survey for the Illinois Department of Conservation to provide baseline information for a furbearer education outreach initiative found that, similar to hunting, public opinion of trapping varies when the motivation for trapping is considered (Duda and Young 1994b). Seventy-one percent of Illinois residents approved of trapping for animal damage control; 70 percent approved of trapping to control animal populations; 63 percent approved of trapping as part of a biological study; and only 15 percent approved of trapping for recreation.

Public Priorities for State Fish and Wildlife Agency Programs

In general, Americans are extremely supportive of state fish and wildlife agency activities that protect human health, such as monitoring water quality; very supportive of activities that benefit the resource, such as protecting endangered species; very supportive of efforts to provide fish- and wildlife-related education; and moderately supportive of activities that provide recreational benefits for people, such as hunting and fishing opportunities.

In a survey conducted for the Florida Department of Environmental Protection, Division of Marine Resources, Florida residents rated inspections of shellfish processing plants (87 percent said very important) and monitoring water quality (86 percent) as the most important activities for the Department of Environmental Protection (Duda and Young 1995b). Following these two activities in order of importance as ranked by Floridians were the management of endangered species (78 percent said very important), management of fisheries for commercial use (71 percent), research (70 percent), education programs (69 percent), and the statewide Aquatic Preserves, Research Reserves, and Marine Sanctuary Program (69 percent).

A Georgia Game and Fish Division survey conducted by Responsive Management in 1991 found that residents were most supportive of endangered species management, with 72 percent of Georgia residents indicating more time and money should be spent on this activity (Duda and Colquitt 1991). This activity was followed by information and education programs (70 percent), habitat acquisition (67 percent), law enforcement (65 percent) and urban education programs (58 percent) in terms of what percentage of Georgia residents indicated each program should receive more time and money.

In a survey conducted for the South Carolina Wildlife and Marine Resources Department, South Carolina residents were presented with 18 Department activities, four of which were related to education (Duda and Young 1994c). The top four activities, as ranked by state residents in terms of wanting to spend more time and money on the activity, were providing educational opportunities to children through schools (79 percent), providing education and safety training to boaters (76 percent), providing education and safety training to hunters (73 percent), and educating and informing residents about fish, wildlife and marine resources (69 percent).

Florida residents, in a Responsive Management survey conducted for the Florida Game and Fresh Water Fish Commission, responded similarly when eight programs were presented. The program which received the highest percentage (84 percent) of residents rating it very important was protecting habitat.

Idaho residents ranked 13 programs in a survey conducted for the Idaho Department of Fish and Game (Duda and Young 1994a). Idaho residents were most supportive of protecting, conserving and enhancing Idaho's water resources, with 65 percent of residents indicating more time and money should be spent on this activity. This activity was followed by educating and informing residents (54 percent), managing and protecting Idaho's fish resources (53 percent), and managing and protecting Idaho's wildlife resources (52 percent) in terms of what percentage of Idaho residents indicated each program should receive more time and money.

In a survey conducted for the Vermont Department of Fish and Wildlife, nine programs were ranked (Duda and Young 1995g). Vermont residents were most supportive of the public lands program, with 47 percent of residents indicating more time and money should be spent on this activity. This activity was followed by endangered species management (46 percent), law enforcement (42 percent), educating and informing residents (42 percent) and restoring and conserving native fisheries (42 percent) in terms of what percentage of Vermont residents indicated each program should receive more time and money.

Conclusion

Harris (1985) concluded his paper by stating that his experience with polling on environmental matters "has been almost a strange and eerie experience over the past several years" because, on many other issues, public opinion tends to swing back and forth, but on environmental and natural resource issues, public opinion has been shifting in only one direction. At Responsive Management, we, too, have seen these numbers move in only one direction. A full decade later, the American public continues to care deeply about the nation's wildlife, natural resources and a clean environment, and are demanding something be done.

Little *has* changed on the issue of current public perceptions, attitudes and desires on natural resource management in the decade that has passed. It is eerie, indeed, to end a 1996 presentation with a quote from a 1985 paper on public opinion. But, we will conclude where we began, by quoting Harris' (1985: 71) North American Wildlife and Natural Resources Conference presentation: "Basically, what people are asking and pleading and demanding out there is that there be a new wave of commitment by those who purport to speak for the people, who speak the words that they care about the quality of the human experience. The challenge is to the leadership to catch up with the governed. To catch up now, not later, before it's too late."

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Economics of Wolf Recovery in Yellowstone National Park

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This paper examines the economic benefits of investment in wildlife management on public lands. The case study presented is gray wolf (*Canis lupus*) recovery in Yellowstone National Park.

In January 1995, 29 gray wolves were relocated from Canada into Yellowstone National Park and the wilderness areas of central Idaho. This action was the culmination of an extensive planning effort that began with the listing of the gray wolf as an endangered species in most of the contiguous United States in 1973. Gray wolves were common in the northern Rocky Mountains prior to 1870; however, by 1930, government predator control programs had eliminated wolves from the western United States. In the 1980s, the U.S. Fish and Wildlife Service (FWS) approved several wolf recovery plans for the Northern Rockies that identified central Idaho and Yellowstone National Park as suitable habitat for wolves (U.S. Fish and Wildlife Service 1980, 1987). In 1991, Congress directed the FWS to prepare an Environmental Impact Statement (EIS) on wolf reintroduction into Yellowstone and central Idaho. The draft EIS (U.S. Fish and Wildlife Service 1993) generated more comments (more than 160,000 were received) than any other previous federal proposed action. The final EIS (U.S. Fish and Wildlife Service 1994), published in April 1994, recommended the reintroduction of nonessential experimental populations in central Idaho and Yellowstone. It was anticipated that approximately 30 wolves per year would be captured in Canada for each of five years (1994-1998) to be released in central Idaho and Yellowstone. This action is expected to result in wolf population recovery (10 breeding pairs, about 100 wolves per area for three successive years) by 2002. Legal action delayed the first-year reintroduction from November 1994 to January of 1995. However, the first-year reintroduction went better than planned, with a total of nine pups born to packs in Yellowstone and wolves in both areas generally staying within the primary recovery areas. In January of 1996, another 37 wolves were relocated from Canada into central Idaho and Yellowstone National Park.

While wolf reintroduction in central Idaho and Yellowstone has been successful to date from a biological standpoint, the program remains controversial. Some legislators from Idaho, Montana and Wyoming are critical of the program and have questioned the FWS's estimated costs. The program also is being challenged in court by livestock interests. This paper provides a summary of the actual costs of wolf recovery and compares these costs with the measurable economic benefits. The analysis reported here is largely derived from the authors' contributions to the central Idaho and Yellowstone wolf reintroduction EIS documents. For purposes of brevity, the discussion here is limited to the Yellowstone reintroduction; however, the methods and findings for central Idaho are similar. In the remainder of this paper, reference to the "Yellowstone area" is to the 25,000-square mile primary analysis area including Yellowstone National Park and contiguous national forests. Readers who are interested in more detail on methods and findings are referred to the EIS (U.S. Fish and Wildlife Service 1994), particularly the "Impacts on Economics" sections in Chapter IV, Environmental Consequences.

The primary benefit of wolf recovery in the Yellowstone area is the value that potential visitors and others place on having a recovered wolf population. The primary costs of wolf recovery include wolf management costs, foregone hunter benefits and the costs of wolf predation on domestic livestock. Each of these benefits and costs are discussed in turn in the following sections. A final section provides conclusions.

Benefits of Wolf Reintroduction in Yellowstone

Most previous estimates of the nonmarket value of wildlife have been concerned with consumptive uses, such as hunting. Walsh et al. (1988) reviewed 120 separate studies providing 285 site- and/or activity-specific estimates of recreational value. However, there also is an emerging literature on the potentially considerable value associated with indirect uses and nonconsumptive uses, such as viewing wildlife. As first articulated by Krutilla (1967), existence value is the value associated with knowing that a species or ecosystem exists, independent of actually visiting or using a given site. For example, it is possible that some individuals place a high value on knowing that wolves exist in Yellowstone National Park, independent of any expectation of ever seeing these animals. Studies of eagles in Wisconsin (Boyle and Bishop 1987) and whooping cranes in Texas (Bowker and Stoll 1988) indicate that both nonconsumptive and existence values for wildlife may be considerable. The first economic studies of wolf reintroduction (Duffield 1991, 1992) were undertaken as part of a larger set of primarily biological studies of wolf recovery in Yellowstone National Park (Varley and Brewster 1992). Using a contingent valuation survey of park visitors, willingness to pay for wolf recovery was estimated to average $22.87 for a one-time donation to a trust fund to support wolf recovery.

As part of the studies undertaken in support of the Yellowstone and central Idaho wolf EIS, a more comprehensive study of the possible economic benefits of wolf reintroduction was undertaken. This study, implemented in 1993, drew on a national random sample of households, as well as a subsample of all listed phone numbers in the three-state region (Idaho, Montana and Wyoming) where wolf recovery was proposed to occur. Individuals in these samples were contacted and surveyed as to their understanding of and attitudes about wolf reintroduction in the Yellowstone area. Because wolf reintroduction is a potentially contentious and divisive issue, it was anticipated that two distinct groups of respondents would respond to the survey: those who support wolf recovery and attach a value to wolf existence in the Yellowstone area, and those who oppose recovery and attach a value to the absence of wolves from the area. In order to determine the value that each of these unique groups attached to the recovery of wolves (or their absence), respondents were asked whether they favored or opposed efforts to reintroduce wolves. Respondents then were asked if they would be willing to buy a lifetime membership in a trust fund established to support or oppose efforts to help reintroduce wolves to the Yellowstone area. Respondents were presented with varying dollar costs for trust fund membership. The responses concerning membership in the trust funds were analyzed to estimate the average amount those favoring or opposing wolf recovery in the Yellowstone area would be willing to pay to support or oppose wolf recovery. This approach to estimating willingness to pay is called dichotomous choice contingent valuation. The analysis of the valuation question responses followed the methods of Hanemann et al. (1991) and Duffield and Patterson (1991).

The survey was implemented by telephone in April 1993 by the Social and Economic Sciences Research Center at Washington State University. A split sample frame was used with both a random-digit-dialed component and a listed component; the latter received a prior contact letter explaining the purposes of the study. A total of 335 completed surveys were obtained from the regional subsample, resulting in a cooperation rate of 81 percent, a completion rate of 70 percent and a sampling error of 5.5 percent. A total of 313 completed surveys were obtained for the national sample, for a cooperation rate of 65 percent, a completion rate of 48 percent and a sampling error of 5.6 percent.

Highlights of the survey findings are as follows. The survey showed that, on a national basis, supporters of wolf recovery outnumbered opponents by a 2:1 ratio (57 percent favored, 29 percent opposed and 14 percent didn't know). However, within the three-state region, opinion was closely divided (49 percent favored, 43 percent opposed and 8 percent didn't know). As one would expect, regional residents were more familiar with the wolf reintroduction proposal (90 percent were somewhat or very familiar), whereas nationally, only 48 percent were either somewhat or very familiar with the proposal.

With regard to economics, Table 1 shows the average willingness to pay to support or oppose wolf reintroduction into the Yellowstone area for both the three-state residents and the national sample. The standard errors on the valuation estimates were derived using a simulation procedure with 5,000 iterations suggested by Krinsky and Robb (1986). Table 1 also shows the calculation of the total net economic existence value per year of wolf reintroduction in Yellowstone. This value is based on the estimated mean lifetime willingness to pay to support wolf reintroduction times the number of households with phones in the relevant population (United States as a whole or three-state region, and supporting or opposing reintroduction) times the real interest rate. The individual values were aggregated to the number of households with phones because the sample was drawn randomly from all households with phones in the relevant population. A real interest rate of 7 percent was used to convert a lump-sum donation to a wolf recovery trust fund into a yearly income stream. The rate of 7 percent is consistent with current federal guidelines for cost/benefit analysis (U.S. Office of Management and Budget 1992).

Table 1. Estimated mean values of wolf reintroduction in the Yellowstone area.

Welfare measure/statistic	Three-state region (WY, MT, ID)	Out of region	All U.S. residents
Mean value for supporters[a]	$20.50	$8.92	
(Standard Error)	($1.43)	($0.74)	
Mean value for opposed	$10.08	$1.52[d]	
(Standard Error)	($1.48)	($0.55)	
Population of supporters	391,204	50,152,416	
Population opposed	340,522	25,774,280	
Aggregate net economic value per year[b]	$321,201	$28,572,785	
Scaler[c]	0.286	0.286	
Estimated net economic value per year	$91,863	$8,171,817	$8,263,680
(Standard Error)	($9,179)	($811,470)	($811,522)

[a]The mean values are calculated as a truncated mean with the truncation level at $50 for three-state residents and at $25 for out-of-region residents.

[b]Values are calculated assuming a perpetual benefit stream from a one-time trust fund deposit amortized at a 7-percent real interest rate.

[c]This factor is an estimate of the ratio of the amount individuals actually would contribute to the amount they state they would contribute, based on Ward and Duffield (1992).

[d]Due to an inadequate sample size, the estimated mean value for central Idaho was used.

These measures of the net value individuals place on having recovered wolf populations are based on what survey respondents say they would be willing to donate. There is a considerable discussion in the economics literature concerning the interpretation of these survey responses

(Hanemann 1994, Diamond et al. 1994). In a study of donations to improve stream flows for endangered fisheries in Montana (reported in Ward and Duffield 1992), it was found that about one-third (28.6 percent) of the stated willingness to pay can be collected relatively easily from individuals. In order to take into consideration this difference between stated and actual willingness to pay, value estimates for wolf recovery were scaled by this factor (28.6 percent). This calibration is preliminary, since the relationship between the amount hypothetically and actually paid may vary across resources and the population sampled. The exact relationship between stated and actual willingness to pay for wolf recovery in the Yellowstone area is not known. The mean net economic value associated with wolf recovery in the Yellowstone area is estimated to be $8.3 million (Table 1), with a 95-percent confidence interval of $6.7 to $9.9 million. These values possibly are quite conservative. Although the respondents to the willingness to pay questions were asked to speak for him or herself, the values were not aggregated on the number of total adult individuals in the United States, but rather on the number of households.

Costs of Wolf Reintroduction in the Yellowstone Area

Value of Foregone Benefits to Hunters

One of the potential effects of wolf reintroduction to the Yellowstone area is on big game hunting opportunities in hunting districts adjacent to the park. A reduced number of big game animals available for harvest directly affects the available hunting opportunities. Reduced hunting opportunities translates into a reduced number of hunters and hunter days in the field. This reduction in big game hunting activity represents a social cost associated with wolf reintroduction.

Two independent studies examined the projected effect of a recovered wolf population in the Yellowstone area on ungulate populations and hunter harvest in the area. Mack and Singer (1992) estimated that the hunter harvest of big game species on the Northern Yellowstone Range may be reduced by about 27 percent for antlerless elk (*Cervus elaphus*), 100 percent for antlerless mule deer (*Odocoileus hemionus*) and 100 percent for antlerless moose (*Alces alces*). If these reductions are achieved primarily through reductions in existing special permit hunts for antlerless animals, elk populations could decline by 5 to 30 percent, mule deer populations could increase and moose populations could remain stable. It is assumed that reduction of hunter harvest of other big game due to wolf recovery would be negligible. Boyce and Gaillard (1992) estimated that a recovered wolf population in the Yellowstone area would have the effect of reducing hunter elk harvest in two specific areas. Boyce and Gaillard predict that elk harvests would decline by 5 to 10 percent for Wyoming's Jackson elk herd (a decline of 165 to 330 elk harvested) and 1 to 2 percent for the North Fork Shoshone elk herd (a decline of 6 to 13 elk harvested). Boyce and Gaillard predict that reduced hunting opportunities associated with wolf reintroduction will be limited to elk in the two areas noted above. The estimates of reduced hunting opportunities provided by Mack and Singer (1992) and Boyce and Gaillard (1992) are presented together to offer a range of expected value losses to big game hunters associated with wolf recovery in the Yellowstone area.

A relatively simple methodology was used to estimate the reduced net social benefits and reduced hunter expenditures that could be associated with wolf recovery in the Yellowstone area. This methodology is likely to overstate these reductions. Given harvest reductions, reductions in hunter days are based on hunter success and days hunted per hunter (Montana Department of Fish, Wildlife, and Parks 1987). The simplifying assumption is made that the reduction in hunter days equals the reduction in harvest divided by success rate and times the average number of days per hunter. This assumption may be appropriate for special permit hunts, but likely will overstate the reduction in hunter days during general seasons if hunters continue to hunt but with lower success rates.The total expected reduction in hunter days due to wolf recovery is 2,439 to 4,879 days.

Average willingness to pay and actual expenditures per hunter day for hunting districts adjoining Yellowstone National Park are derived from previous economic studies of Montana deer and elk hunting (Brooks 1988, Duffield 1988). It is assumed that net willingness to pay for a day of moose hunting is double that for elk, but that expenditure levels are the same as those for elk. The reduction in aggregate net social benefits is computed by multiplying the estimated reduction in hunter days times the net willingness to pay per day. The reduction in total hunter expenditure is computed in a similar way. This approach overstates these losses to the extent that hunters do not actually hunt less but, instead, turn their attention to substitute sites and species.

Reduced hunter harvest of elk, mule deer and moose in the Yellowstone area due to wolf recovery could result in lost net social benefits on the order of $187,000 to $465,000 per year. Additionally, an estimated $207,000 to $414,000 in hunter expenditures would be lost to the three-state region.

Lost Value Due to Livestock Depredation

A second area of potential costs associated with wolf reintroduction to the Yellowstone area is the possibility of livestock depredation by the recovered wolf population. The calculation of lost value due to this depredation is straightforward. The lost value per year is equal to the estimated number of lost animals per year times the market value of those animals. Projected livestock depredation in the Yellowstone area was computed based on wolf predation rates over the last several decades in other North American sites, including Alberta, Minnesota and northwestern Montana where wolf populations are well-established in livestock range. Fritts et al. (1992) and Mack et al. (1992) provide overviews of this literature. The main finding is that the rate of wolf depredation on domestic livestock, across large geographic areas, is very low, averaging usually less than 0.1 percent of livestock within wolf range.

Wolf depredation on domestic livestock in the Yellowstone area likely would be minimal during the first five years of reintroduction. After that period, as recovery level wolf populations are approached and achieved, depredation losses are expected to be in the range of 1 to 15 cattle per year and 38 to 121 sheep per year. Average values per head are $715 for cattle and $69 for sheep, based on an average value for all cattle and all sheep in Montana, Idaho and Wyoming as of January 1, 1993 (Montana, Idaho and Wyoming Departments of Agricultural Statistics personal communications: 1993). It is estimated that between $1,887 and $30,470 in livestock predation losses would occur under wolf reintroduction to the Yellowstone area. It is noteworthy that a private conservation organization, Defenders of Wildlife, has a private trust fund in place that compensates ranchers for the market value of all confirmed wolf predation on livestock in the Northern Rockies (Fischer 1995).

Wolf Management Costs

The estimated management and wolf control costs associated with reintroducing a nonessential experimental population of wolves into the Yellowstone area total $3,077,500 (U.S. Fish and Wildlife Service 1994) during the 1994 to 1998 reintroduction years. For the four-year period 1999-2002, monitoring costs are estimated to be $316,250 per year, for a total of $1,265,000. Because the reintroduction has been so successful to date, it is possible that only two years of actual transport and capture of wolves may take place so that the 1994 to 1998 budget will be somewhat less (E. Bangs personal communication: 1996). On the other hand, the costs of monitoring and wolf control will, in fact, go on into the future beyond the year 2002. Assuming management costs continue at the estimated 1999 levels ($316,250 per year) into perpetuity, the total present value of reintroduction and management from 1994 on is $6.3 million. At a 7-percent discount rate, the annual cost corresponding to this lump sum is $441,000. The latter is the public investment in wildlife management needed to achieve the benefits previously discussed.

It may be noted that there are additional "sunk costs" that have been incurred over the years in wolf research and planning previous to reintroduction, including the costs of the EIS. The previous funding for all agencies for wolf recovery related work in the Northern Rockies has been estimated for 1973 to 1994 at $5.5 million (E. Bangs personal communication: 1996). While the focus of this paper has been on the EIS-preferred alternative, in fact, four additional alternatives were examined extensively. It is noteworthy that the management costs of these alternatives varied dramatically from no wolf recovery ($100,000), to natural recovery ($15 million), to the wolf management committee alternative (estimated $111 million to $129 million). The FWS-preferred alternative (the implemented alternative) is the most cost-effective of the alternatives considered for wolf reintroduction.

Conclusions

As detailed above and summarized in Table 2, it is estimated that wolf recovery in the Yellowstone area will lead to total benefits of $6.7 to $9.9 million per year and total costs of $0.7 to $0.9 million per year. A major component of total costs is the public investment in wolf reintroduction at $441,000 per year. The conclusion is that wolf recovery in Yellowstone National Park appears to be a case where the benefits of investment in wildlife management exceed the costs by a substantial margin. While beyond the scope of this paper, wolf reintroduction also may result in beneficial economic impacts in the Yellowstone region. As described in the EIS (U.S. Fish and Wildlife Service 1994), wolf recovery is expected to generate increased visitation, resulting in additional annual expenditures of $23 million. Already, in the first year of recovery, it has been estimated that 5,000 Yellowstone National Park visitors have seen wolves in the park (primarily in the Lamar Valley), and there is some evidence that visitation through the northeastern park entrance has increased (R. McIntyre personal communication: 1996).

Table 2. Annual social benefits and costs of Yellowstone wolf recovery.

	Annual value in thousands of 1992 dollars	
	Low estimate[a]	High estimate[a]
(A) Benefits associated with wolf recovery		
Annual net economic value	$6,673.1	$9,854.3
(B) Costs associated with wolf recovery		
Foregone value to hunters	187.3	464.9
Value of livestock losses	1.9	30.5
Annual wolf management cost	441.0	441.0
Total costs	630.2	936.4
Net benefits of wolf recovery[a]	6,042.9	8,917.9

[a]For the gross benefits estimates, the low and high estimates represent a 95-percent confidence interval on the estimates of net willingness pay. For the individual costs, the low and high estimates represent the best estimates of minimum and maximum costs associated. The final net benefits figures represent a plausible range of benefits.

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Economics of Endangered Species: Bald Eagles on the Skagit River Bald Eagle Natural Area, Washington

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This paper compares the economic value of various public land uses on the Skagit River in northwestern Washington that affect a wintering population of bald eagles (*Haliaeetus leucocehalus*) in the Skagit River Bald Eagle Natural Area (SRBENA). The SRBENA is the spawning grounds for winter chum salmon and provides a critical food source for bald eagles that feed on the spent carcasses. Many of the salmon never reach the spawning grounds due to commercial harvest downstream. This results in limited bald eagle numbers. Because of the concentration of bald eagles at SRBENA, people come to view them and the human activity further limits the number of eagles.

The Skagit River Bald Eagle Natural Area is located on the Skagit River in northwestern Washington, 100 miles northeast of Seattle. The SRBENA covers 1,000 acres, was established in 1976 by The Nature Conservancy and the Washington Department of Game, and lies along the river between the towns of Rockport and Marblemount; a road distance of 10 miles. The Skagit River is the largest drainage in northwestern Washington, originating in Canada and emptying into the Puget Sound approximately 60 miles west of the Natural Area. Within the study area, extensive gravel bars and low turbidity water flows provide ideal feeding stations for bald eagles.

Although the SRBENA was created with the intention of protecting a winter feeding area for the migrating bald eagles, several factors pose a potential threat to the current tranquil state.

Human Disturbance

The 10-mile stretch of prime feeding habitat is adjacent to Highway 20—a well-traveled road. A survey by Knight et al. (1980) indicates that 91 percent of recreationists at SRBENA are either viewing eagles or studying nature. The other 9 percent are sport anglers. Use in the area is heavy, as suggested by an estimated 160 boats carrying 1,300 people in the winter of 1980-81 (Knight and Knight 1984). Human activity is high in January, intermediate in February and low in December. Two-thirds of the activity occurs on weekends and in the afternoon. By coincidence, eagles feed throughout the day in December, reduce feeding in afternoons in January and show midday feeding depressions in February (Stalmaster 1986).

Salmon Harvest

Eight species of salmon or sea-running trout enter the Skagit River for autumn spawning. Only salmon are eaten by the bald eagles and, of the five species of salmon, only three are potential food sources for the bald eagles; of which chum salmon are the most numerous at the SRBENA (Skagen 1980). Further, only natural spawners contribute to the eagle food source, since artificially spawned carcasses are sold and not returned to the river.

Salmon harvest occurs downstream from SRBENA, thus limiting spawning salmon availability for consumption by bald eagles. Since eagles congregate for the purpose of feeding on the salmon, eagle numbers are directly limited by downstream harvest. In turn, eagle viewer numbers and the values they place on viewing fluctuate based on eagle numbers. The number of returning adult salmon in four years also is directly related to the number of spawning salmon. Therefore, salmon harvest affects salmon recruitment numbers which in turn affect current and future eagle numbers, salmon harvest and eagle viewer numbers value.

Methods

The objective of this study is to maximize the present value of visitor willingness to pay to view bald eagles, together with the present value of salmon harvested, over an infinite horizon:

$$(1)\ \mathrm{MAX} \sum_{t=0}^{\infty} \delta^t\{[W(E_t, V_t)*V_t] - C(V_t) + (P_t - K_t)H_t\}.$$

subject to,
(2) $E_t = f(R_t, V_t)$
(3) $V_t \leq V_t$
(4) $H_t + R^t = T(R_{t-4})$
(5) $H_t, V_t, E_t, R_t, N_t \geq 0$
(6) $R_{t-1}, R_{t-2}, R_{t-3}, R_{t-4}$ are given

here:

δ = annual discount factor, $1/(1+r)$
$W(E_t, V_t)$ = mean daily willingness to pay of SRBENA visitors
E_t = number of eagles at SRBENA
V_t = number of people on-site
$C(V_t)$ = cost of managing the SRBENA
P_t = dock price of chum salmon
K_t = cost of harvesting chum salmon
H_t = number of salmon harvested
R_t = number of spawning salmon available to bald eagles

Equations (2) through (5) specify the biological state relationships affecting the objective function. Equation (2) expresses eagle numbers as a function of spawning salmon and visitor numbers; equation (3) expresses a visitation site capacity; and equation (4) expresses four-year salmon recruitment stock, which either is harvested or allowed to spawn. A discrete maximum principle can be applied to solve this discrete-time dynamic optimization model.

These relationships are inherently dynamic. The fish population or biomass can be viewed as a capital stock capable of yielding a sustainable commercial harvest and a food source for bald eagles. Today's harvest decisions will, by the impact on the stock level, have implications for future harvest and bald eagle numbers. The resource management problem thus becomes one of selecting optimal steady-state equilibrium levels of salmon harvest and spawning, and developing a management strategy to achieve the equilibrium levels. See Clark (1976) and Kennedy (1986) for reviews of applied studies.

Economic Value

The Contingent Valuation Method was used in this study to elicit individuals' willingness to pay to preserve eagles at the SRBENA. The Contingent Valuation Method (CVM) elicits value data directly by designing an exchange situation in which individuals' contingent choices reveal the total value of a current (proposed) policy impact. By confronting individuals with various price increases, a compensated demand curve can be derived for the particular policy issue.

Substantial evidence exists to support the reliability of CVM results. The Water Resources Council accepts CVM as an appropriate method to use when analyzing policy impacts.

Cummings et al. (1986) and Mitchell and Carson (1989) provide evidence which concludes that well-conceived applications provide good results.

In autumn 1989, 1,455 surveys were handed out to visitors of the SRBENA. By March 1990, 747 surveys had been returned (51-percent response rate). Respondents were offered a life-time membership into a foundation which would buy land and manage the area for protection of bald eagles. Lifetime members could enter the area free of charge; non-members would have to pay an entrance fee. The discrete choice question was of the form: "Suppose the life-time membership cost $__ and provided the necessary money to buy additional lands and support a wintering population of ____ bald eagles at the natural area. Would you become a member to ensure the continued existence of this population of bald eagles?"

Respondents were told the foundation would not be formed unless enough people became members. This format is similar to one used by Boyle and Bishop (1987) to value bald eagles in Wisconsin.

Bald eagle viewing value. Based on the resource setting and economic theory, estimation of willingness to pay is expected to be a function of membership price, eagle numbers, a measure of visitor congestion, income, number of trips a visitor makes to the area and a measure of visitor commitment to the resource/site:

WTP = F (PRICE, POPULATION, PEOPLE, INCOME, YEAR1, EXIST).

Several functional forms for willingness to pay were tested (Swanson 1993). A Gompertz growth equation was found to be the most appropriate:

$$WTP = k/(1 + c*\exp[-B*PRICE])$$

where: k = vector of explanatory variables
c = exponential coefficient
B = coefficient on price

the estimated equation:

WTP = (266.55 - .00061*INCOME + 4.59*EXIST + .507*EAGLE
(asymp s.e.) (103.40) (.001) (1.64) (.517)
+ 17.22*YEAR1)/(1 + 9.10e$^{-.0066*PRICE}$)
(11.28) (2.47) (.0019)
$R^2 = .389$.

The estimated willingness to pay function represents a lifetime membership and is based on expectations of seeing eagles on any given day. To allow discussion of management concerns about daily visitation, willingness to pay needs to be expressed for a typical day. Mean willingness to pay is $220.08, or $105 on an annual basis (assuming a 5-percent discount rate). Respondents reported taking 2.75 trips (YEAR1) in 1989, resulting in a daily value of $37.00.

Economic theory suggests that, at some point along the willingness to pay function, diminishing marginal utility for additional eagles will result. To account for this and also incorporate a site carrying capacity of approximately 500 eagles, a squared term on eagle numbers was added. The objective function also shows willingness to pay as a negative function of visitor congestion. To account for the effect of visitor congestion, a negative coefficient needs to be derived. Respondents saw fewer people than they expected, indicating that they enjoyed a higher quality experience than expected. The primary motivation for visiting SRBENA is eagle viewing and, at current average levels of visitor encounters, congestion is not a deterrent. Therefore, visitor coefficient was selected such that its effect does not outweigh the eagle coefficient until eagle numbers are approaching declining marginal utility (approximately 150) and visitor numbers are reaching expectations (70). Income, existence motivation and yearly trips are set at their mean values and the daily willingness to pay portion of the optimization model is complete:

$$W(E_t,V_t) =(90.418 + .101*E_t - .00021*E_t^2 -.24*V_t)/2.176.$$

Site Management Costs

The second equation necessary to define the objective function is the cost of managing SRBENA. In 1989, the site did not have a full-time manager and maintenance was done by employees as needed. No site-specific data are available for the cost of managing the SRBENA; therefore, a conservative cost equation is proposed:

$$C(V_t) = 80 + 0.3*V_t.$$

Salmon Harvest Value

The final relationship necessary for specification of the objective function is the value of harvested salmon, $(P\text{-}K)H_t$.

Yearly harvest and escapement rates of Skagit River Chum salmon are collected by the Washington Department of Fisheries. Yearly harvest since 1968 has varied greatly from a low of 5 percent (1969, 1970, 1971) of total chum entering the river to a high of 88 percent (1983). Harvest is predominately commercial (99 percent) and, of that commercial harvest, 50 percent is by local, Native tribes. The dock price of a chum salmon is \$12.75 and harvesting costs are approximately 10 percent of dock price (Huppert and Fight 1991). Therefore, the net value equation for commercial chum salmon harvest can be written as:

$$\begin{aligned}(P\text{-}K)H_t &= (\$12.75 - \$1.28)H_t \\ &= (\$11.47)H_t.\end{aligned}$$

Bald Eagle Thermodynamics

With the objective function (1) fully defined, it now is necessary to provide empirical estimates of the state equations, (2), (3) and (4). State equation (2) specifies the relationship between bald eagle numbers at SRBENA with spawning salmon, visitor numbers and eagle numbers in the previous year. Empirical estimates of these relationships are drawn from Stalmaster (1976, 1981, 1983), Stalmaster and Newman (1978) and Stalmaster and Gessman (1984) research on bald eagle wintering populations on the Nooksack River in Washington. The area resembles SRBENA as related to eagle carrying capacity as a function of chum salmon availability and human recreation impacts.

Carrying Capacity. Carrying capacity is defined in terms of eagle days; the number of eagles that can be sustained per day given the available chum salmon biomass. Stalmaster (1983) estimates that 11 percent of edible biomass of spawning salmon actually will provide a potential food source. Accounting for competition, decomposition and carcass availability, carrying capacity for the SRBENA is defined as:

$$E_t = 0.328*R_t.$$

This equation can be delineated further into environmental factors affecting carrying capacity (Stalmaster 1983, Stalmaster and Gessaman 1984).

Human disturbances. People come to the SRBENA to view bald eagles. The number of people has increased over time (Skagen 1980) and, as shown by their willingness to pay, the more eagles they see the higher the value they place on the experience. Therefore, as eagle carrying capacity increases, the value associated with eagle viewing also will increase.

According to Stalmaster (1981), natural and avoidance flight accounts for 5.3 percent of daily energy expenditures. Out of total flight expenditures, 5.3 percent of the energy expended is avoidance flight due to human activity. Reductions in eagle numbers due to human activity can be incorporated into the eagle carrying capacity equation:

$$E_t = 0.3285*R_t - .2427*V_t.$$

With increasing visitation, bald eagle numbers can only be maintained if more spawning chum are available. If more food ingestion does not occur, eagles will move to other wintering areas, winter survival will be lower and/or subsequent breeding success will decrease. Some loss of overall eagle winter survival is likely; if a superior food source is available elsewhere, eagles currently would be using it instead of the SRBENA.

Site Visitation

Visitation to SRBENA is increasing and Skagen (1980) reports peak visitation of 450 viewers. The majority of use occurs on the weekends (Stalmaster 1986, 1987). Current management of the site does not limit use; however, the peak of 450 was associated with high crowding and visitor congestion. Therefore, equation (3) is of the form:

$$V_t \leq 450.$$

Salmon Recruitment

The final state equation, (4), captures the recursive nature of salmon recruitment; the number of salmon spawning this year directly impacts the number of adult salmon in the subsequent time period. Of the eight species of salmon and sea-running trout that spawn in the Skagit River, only the chum salmon runs are critical to the winter feeding of the bald eagles (Skagen 1980). Drawing from Washington Department of Fisheries data on salmon stock and recruitment for the years 1968 through 1989, a four-year daily spawner-recruitment cycle was estimated:

$$S_t = 1.927*R_{t-4} - .000503*R_{t-4}^2$$

(t-stat) (2.79) (.59)

$R^2 = .80$

where S_t = returning adult salmon in time t.

This quadratic form is typical of a family of salmon-recruitment equations known as Ricker Curves (Ricker 1975, Huppert and Fight 1991 and Clark 1976). A recruitment model for the Oregon coast (Huppert and Fight 1991) shows a maximum yearly recruitment of 704,000 coho salmon resulting from a spawning stock of 281,000 fish. Assuming the Skagit River chum salmon show this type of recruitment behavior, the spawning stock has only been within 50 percent of the maximum twice since 1968 (1972, 1974).

A salmon balance equation is necessary to link the harvest and recruitment equations in any year t. This is a simple additive equation of the form, $S_t = R_t + H_t$, and can be combined with the recruitment equation to form the state equation (4):

$$H_t + R_t = 1.927*R_{t-4} - .000503*R^2_{t-4}.$$

All equations in the dynamic system have been estimated, thus setting the stage for dynamic simulation.

Dynamic Simulation Results

A projected Lagrangian computer simulation algorithm was applied to derive empirical steady-state estimates of net present value of SRBENA, salmon harvest levels, salmon spawning numbers, bald eagle numbers and visitor numbers using the equations derived above. In addition, the intertemporal time path to equilibrium is derived.

Current Conditions

Research by Servheen (1975) suggests that, in February, a daily average of 350 spawned carcasses are available to bald eagles in SRBENA. Restricting spawning salmon to 350 per day at SRBENA, the equilibrium level of bald eagles is 68 eagles, the socially optimum level of visitors is 92 daily and the socially optimum level of salmon harvest is 263 salmon daily. The combined viewing and harvest values result in a daily net economic value of $7,312.

Social Optimum Base

The current condition model now can be compared with a model that does not restrict salmon spawning numbers. As such, the model will be unconstrained and allowed to arrive at the equilibrium that provides highest net benefits. Under the unconstrained model, net benefits increase to $9,312 daily, due to increased numbers of spawning salmon (756) resulting in more eagles (197) and a greater level of visitation (209). Access must be restricted to this level of visitation, otherwise, too many people will visit the site and total benefits will decrease.

The socially optimum level of daily harvest of salmon also increases (413). However, to achieve this level, no salmon harvest can occur until year nine. Further, the optimal harvest level is not achieved until year 13 and, due to the nonexclusive nature of this resource, harvest restrictions must be strictly enforced to arrive at the optimal level and to maintain that level.

Steady-state equilibrium does, in fact, result in a higher level of salmon harvest and increased welfare (daily salmon value increases from $3,017 to $4,737). As such, all harvesters benefit from achieving the long-run, steady-state equilibrium, but only if all harvesters limit their short-term use of the resource.

Sensitivity Analysis

The equilibrium results obtained above are conditional on the equations used to express the relationships among salmon, eagles and viewers. Care was taken to express these relationships using the best available data, but drawing policy conclusions based on these relationships must be done keeping in mind the process by which the relationships were formed. One way to judge the stability of the results is to perform sensitivity analysis on such things as non-use values, salmon cohort strength, dock price of salmon, discount rate and salmon recruitment equation (see Swanson 1993).

Policy/Management Implications

Based on the dynamic optimization framework outlined and the dynamic simulation results, the following site management recommendations are proposed:

1. Salmon spawning and harvest levels should be chosen to maximize total net social values at SRBENA. At a minimum, harvest should be curtailed for weak cohort years until spawning levels reach these social optimums. Because the salmon fishery is non-exclusive, regulations will have to be enforced strictly to achieve and maintain the equilibrium harvest levels.

2. To minimize short-term income effects of salmon harvest restrictions, Native American and commercial harvesters should be subsidized by a combination of tax revenues and eagle-viewer entrance fees.
3. Harvest should be limited early and late in the spawning run to stabilize bald eagle numbers over a longer period of time. This will increase viewing values.
4. The social optimum level of visitation is less than the private optimum and, as such, site visitation should be restricted to the social optimum level.
5. Visitor mitigation measures should be explored. The cost of each measure should be compared with the benefits that result from decreased eagle disturbance. Those mitigation measures with the greatest net benefits should be implemented.
6. Weekday visitor use should be encouraged.

Conclusions

This study combined biological and economic relationships into a dynamic optimization framework. This research successfully demonstrates how real-world relationships can be modeled simply and, from those relationships, general management recommendations can be drawn. Empirical results depend on data quality and the adequacy of the model, and this research has limitations in both respects. The numbers derived are not as important as the relative direction and magnitude of the dynamic relationships.

Applying an economic framework to biological relationships is a useful tool to show how management decisions can be made to maximize net public benefits. Often, biological goals, such as maintaining bald eagles at SRBENA, appear to be in direct conflict with revenue goals, such as salmon harvesting. This research shows that applying an economic framework often can result in achieving both goals in long-run equilibrium. As issues of wildlife scarcity continue to appear as a direct challenge to economic viability, the ability to capture both in a common economic framework will become more vital. A simplified economic model, such as the one presented in this research, can expose management options.

Future research in the area of dynamic optimization needs to concentrate on how biological relationships can be translated into economic effects to allow derivation of long-run, economically efficient equilibrium conditions. Identification and measurement of cost relationships need extensive attention. Cost functions for salmon harvest are not readily available nor are cost relationships for the management of a wildlife recreation area. The relationships used in this research were best guesses based on little data.

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The Role of Elk Conservation in Sustainable Development: Past, Present and Future on Montana's Rocky Mountain Front

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Montana's Rocky Mountain Front (Figure 1) is a place of extremes: eastern plains collide with western mountains, cattle ranches abut wildlife refuges, wilderness areas roll up to the edges of civilization and preservation activists live alongside traditional ranchers. The richness of the topography and ecology is equaled only by the complexity of the dynamic social and economic tapestry that has shaped the land in the past and will continue into the future. Competing, seemingly mutually exclusive interests vie for primacy in determining the future: traditional industries such as open-range grazing and intensive agriculture are giving way to more sustainable agricultural practices and new service industries such as ecotourism; falling cattle prices are forcing traditional ranches to subdivide into ranchettes for second homes; the remaining ranchers are increasingly pressured to give over prime grazing habitat to wildlife to support the burgeoning recreational industries and preservation programs. Pressures to change are not exclusively external; diverse local interests also seek to rearrange the economic, ecological and social patterns of the Rocky Mountain Front (Front).

The challenge for land managers, county planners and local residents is to balance these competing interests in a way that neither impairs the ecological or social base, nor leaves local residents without a livelihood (Boone and Crockett Club 1993). This challenge is complicated further by the clash between public and private interests that results from a land ownership system in which private and tribal lands are intermixed with multi-jurisdictional state and federal lands. All of these factors create a challenge for ecosystem-based management on the Front. To date, the perceived problems and solutions have been framed in exclusionary language: either people or wilderness, cattle or elk, tourism or ranching, a healthy economy or a functioning ecosystem. The landscape, social structure and economy all bear testament to this fragmented, "purist" approach to resource management. The Boone and Crockett Club's Wildlife Conservation Program has a different outcome in mind (Salwasser et al. 1994). An ecosystem-based approach to sustainable development, by insisting on a holistic view, incorporates socio-economic realities into the search for sustainable solutions to natural resource dilemmas. In doing so, managers envision an alternative formulation of both issues and solutions that is inclusive: both people and wilderness, cattle and elk, tourism and ranching, based on healthy ecosystems that support a human economy that also provides for desired lifestyles and livelihoods.

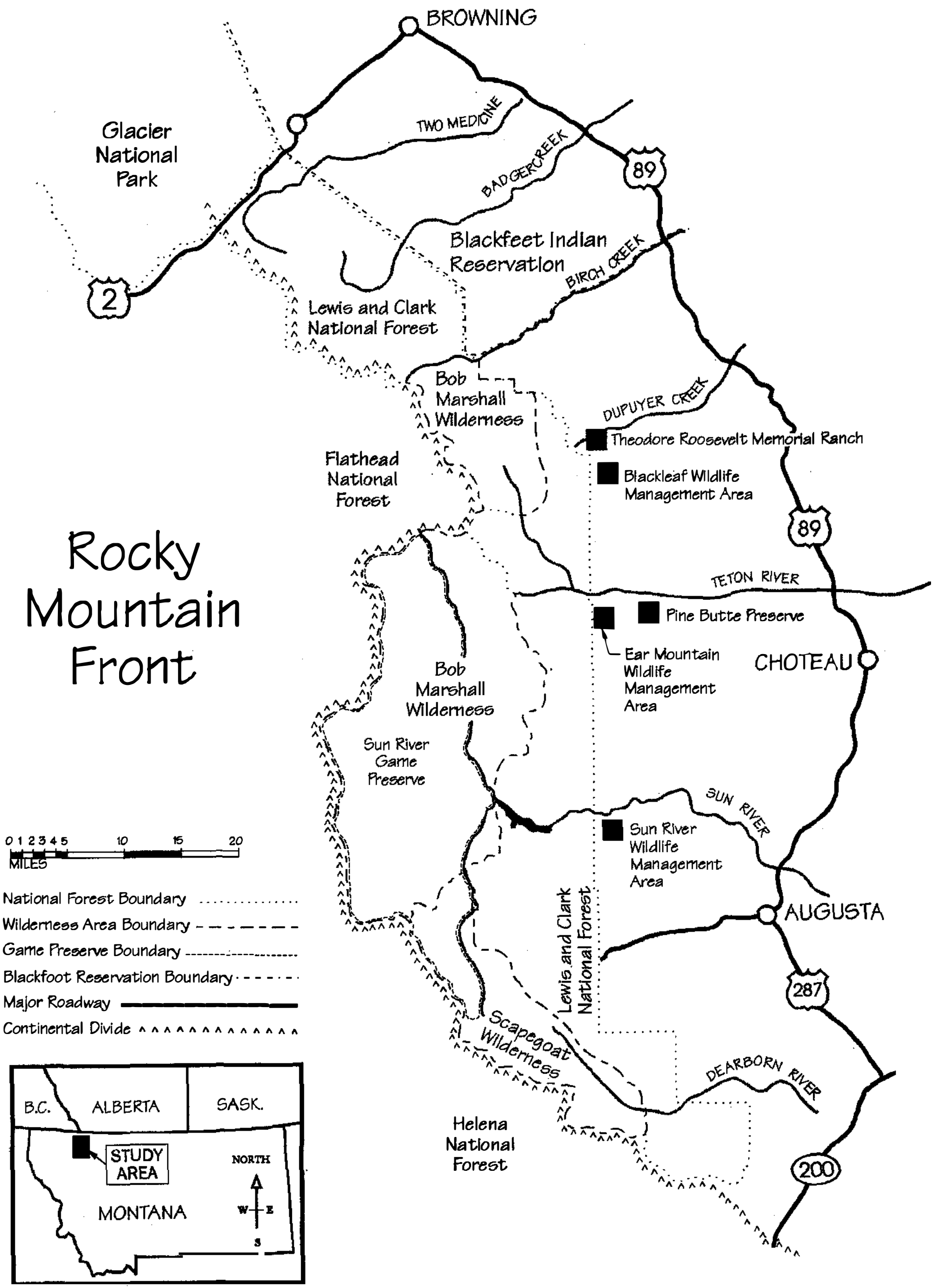

Figure 1. Montana's Rocky Mountain Front.

Human/land relationships change over time and space and across cultures. We recognize four phases in the evolution of the relationship between humans and the environment (Salwasser 1993): 1) a subsistence phase in which people live tight on the land, depending on and revering the wild plants, animals and natural materials they use daily for food, clothing, shelter and commerce; 2) a development phase in which people change the character of land and resources to promote crops, livestock, timber, energy or minerals, and create the industries they need to support communities and economies at densities ecosystems cannot support; 3) a protection phase in which people restrain the negative effects of subsistence and development activities to maintain or restore the long-term productivity of soils, waters and biotic resources, or the essential character and function of particular ecosystems; and 4) a synthesis phase in which people attempt to blend and balance subsistence, development and protection to sustain or enhance their material well-being, and the healthy, resilient and productive ecosystems that supply all the requisites of life on earth. This phase is known under various related concepts: conservation, multiple-use and sustainable development among them.

These four phases are not independent. Nor do they evolve in a linear fashion from one phase to the next, never to return to the former. They are interwoven within any culture. Each phase is championed by certain elements of that culture, often in a competitive way that poses different challenges to people and the stewardship of their environments and communities.

For the purposes of this paper, the last three phases—development, protection and synthesis—are of most interest. Using the long and conflict-ridden history of elk (*Cervus elaphus*) conservation on Montana's Rocky Mountain Front as a case study, we explore its evolution from the period of Euro-American settlement and development through early efforts at protection to current approaches that aim to integrate protection with development. In the first part of this paper, we illustrate how local people have struggled to balance people, land and resources in a variety of frameworks ranging from unrestrained human development to wilderness preservation. What becomes clear is that neither extreme—a human-dominated landscape or a wildlife-dominated landscape—is sustainable over any length of time. We devote the second portion of the paper to exploring the prospect of designing a future that combines goals for biological diversity with goals for economic and social diversity. In other words, despite the historical legacy of social polarization and biophysical fragmentation on the Front, we now have an opportunity to integrate human communities with natural communities in a manner that does not unduly impair the viability of either one.

Early History

Development

The early history of the Front might be characterized as a phase of unregulated development in which settlers altered the character of the land and resources to produce livestock, crops and timber. The *Saga of the Sun* (Picton and Picton 1975) chronicles the history of Euro-American settlement and development of the Front following the forced removal of Blackfeet Indians and their subsistence lifestyle. Cattle ranching was established in the productive prairie foothills between 1860 and 1880. And by the 1880s, extirpation of bison and the presence of railroads fueled the growth of the livestock industry. By 1885, habitat loss, combined with unregulated exploitation of elk for subsistence and markets, reduced herds in the prairie habitats along the Front to mere remnants of their former size (Cooney 1940).

Year-round sheep and cattle grazing took their toll on the foothill vegetation and the severe winter of 1886-87 decimated these herds. In the years following, ranchers in search of forage for their cattle and loggers in search of wood pushed deeper into the interior mountains of the Front. Temporary communities and extensive road networks accompanied this westward expansion and, as a consequence, elk herds further declined in the vicinity of these developments. The few elk that remained by the turn of the century were only found deep in the interior mountains along the Continental Divide, where they competed with encroaching cattle for scarce forage. The homesteading boom reached northcentral Montana in 1910, and the already overgrazed range was further taxed by the establishment of numerous, small-scale ranching operations and the conversion of massive tracts of fertile native prairie to dry-land farms (Keller in preparation). More than half of the new operations had been foreclosed by 1925 due to prolonged drought. But, before it ended, prairie elk habitat was almost entirely eliminated.

Protection

The conservation movement also was growing in the first decades of the twentieth century with the aid of such prominent individuals as Gifford Pinchot, John Muir, Theodore Roosevelt and George Bird Grinnell. Conservation-minded sportsmen in Montana, recognizing the threat that human settlement posed to elk, organized themselves into politically active clubs. Members tended to be prominent, affluent and politically influential; noticeably absent from the membership rolls of these clubs were local citizens who worked the land for a living.

Sportsmen portrayed the elk not only as an important recreational resource, but as a symbol of the pioneer heritage; its loss would be incalculable (Brownell 1987). In 1910, with the fate of the bison in mind, sportsmen effectively employed the threat of extinction to lobby the State legislature for an elk preserve (Picton 1973). It was the height of the Progressive era, and conservationists viewed legislative action as the only means to achieve strong wildlife conservation. Despite protest from local citizens and concerns of Forest Service personnel about the impacts to local economies, in 1913, the Montana legislature passed a bill to create the 200,000-acre Sun River Game Preserve on the Lewis and Clark National Forest in the interior mountains of the Front. All livestock grazing within its boundaries was terminated. The preserve, accompanied by strictly enforced game laws, brought to a close the era of unregulated wildlife exploitation on the Front and introduced the first reduction of livestock grazing on public lands.

Elk numbers along the Sun River increased rapidly under favorable habitat conditions and regulated hunting (Youngs 1916). By 1925, the original herd of roughly 1,000 in 1913 had increased to more than 2,500. Overpopulation of elk on the preserve itself and stiff cattle competition on adjacent national forest lands began to force elk from the preserve; the elk reestablished traditional migration routes to wintering grounds on the prairie foothills of the Front. The reappearance of elk in large numbers on privately owned foothill habitats opened a new chapter in the preservation/development debate, as ranchers felt pressured to devote privately owned resources to the support of publicly owned wildlife.

Forest Service investigations in the 1930s concluded that the preserve presented a substantial impediment to effective herd management (Cooney and Howard 1935, Howard and Neal 1936). The small portion of marginal winter range on the preserve was severely overgrazed and winter die-offs were frequent. Heavy hunting pressure outside the preserve proved ineffective as a population control measure because elk avoided hunters by remaining within preserve boundaries until deep snow forced migration to the winter range. Over the same period, an aggressive fire-suppression policy effectively halted the natural regeneration of suitable habitats which had been created during the initial phase of elk recovery by extensive logging and frequent fires. Without non-human predators, and with low harvests and scarce forage, winter die-offs of elk continued and productivity was subsequently low.

Throughout the Depression years of the 1930s, recommendations by state and federal agencies to alter preserve boundaries to increase hunting opportunities were successfully opposed by sportsmen (Cooney 1940). Sportsmen accomplished their goals through two avenues: they capitalized on an unstable political structure and laid the blame for past elk declines squarely on the cattle industry. Political instability was a result of: (1) power struggles between state and federal agencies for authority to manage wildlife; and (2) attempts within the agencies to shift from simple law enforcement to scientifically based population management. Although the Pittman-Roberston Act of 1937 affirmed state stewardship of wildlife resources and their right to regulate wildlife populations, the science necessary to achieve these objectives still was unavailable. Instead, the state wildlife agency engaged in unsuccessful herding and feeding programs to keep elk from wintering on private lands. The bulk of elk management continued to fall on federal agencies and professional foresters with one exception: rancher and farmer complaints of wildlife depredation on private lands were registered with the state. Predictably, struggles over appropriate elk and preserve management flared up each time a new complaint triggered proposals to modify management techniques or preserve status.

The cattle industry provided a convenient scapegoat for conservationists; they charged that grazing caused large-scale disruptions of habitat and that it relied too heavily on public lands and extensive outside capital (Keller in preparation). Anti-cattlemen sentiments intensified and, by 1934, conservation interests had succeeded in pressuring the Forest Service to terminate all cattle grazing on national forest lands adjacent to the Sun River Game Preserve to provide forage relief for elk (Willey 1935). Creation of the Sun River Primitive Area in 1934—forerunner to the Bob Marshall Wilderness Area—finalized this move.

An increasingly strong political component in natural resources management eventually impeded change and well-entrenched political institutions continued to resist state and federal agency attempts to implement scientifically based management programs. Government's persistent unresponsiveness to local concerns about the effects of growing elk herds on livelihoods and the land base on which they depended further strained relations between the public and private sectors, and between conservationists and ranchers. From the locals' perspective, government, at the behest of politically influential regional interests, appeared to favor the preservation of the Front's wildlife over the welfare of its human inhabitants. Additionally, the irrevocable segregation of humans and human activities from nature and natural functions, viewed as essential to the survival of wildlife and the character of wilderness, further fragmented the social and biophysical landscape. The exclusionary, single-resource approach (i.e., elk first) of early protective efforts spawned a backlash in local communities whose economies and lifestyles were built on other single-resource approaches (i.e., cattle, timber or minerals first).

In the winter of 1939, in an act that would transform the debate between public wildlife and private rights, an irate rancher shot an elk on his land. In a landmark decision, the Montana State Supreme Court ruled in favor of the rancher, affirming the right of an individual to resort to force to protect property from wildlife damage when other means have proven to be ineffective. Following this incident, the landowner/elk conflict became bitter in the early 1940s and, in 1943, the Sun River Conservation Council formed in an attempt to resolve these conflicts. The Council was a grassroots organization composed of members from the local livestock industry, ranchers and local sportsmen. Representatives from the state wildlife agency and Forest Service were permitted to vote but not to hold office. The desire to perpetuate preferred lifestyles and resist politically influential regional interests that threatened livelihood motivated local involvement.

Council members recognized that habitat acquisition was key to sustaining high numbers of elk while ensuring a future for people living on the Front. As early as 1940, the Forest Service proposed to use public funds to purchase crucial winter range for elk (Cooney 1940). Identifying and securing these lands, however, was difficult because most of it was in private ownership and distrust of government motives was widespread (Roberts no date). Compared with past activities in which political pressure was exercised by external interests to influence conservation programs, the Council members realized that broad public support, focused into a local working group, was needed to overcome resistance to this idea. Direct personal involvement of local people eventually overcame the ambivalence of other residents and, in 1947, 20,000 acres were carved out of private lands in the foothills to become the Sun River Game Range. The most striking facts about this event were that a broad base of consensus-minded people worked hard to overcome the objections of their fellows and, when federal funds failed to materialize in a timely fashion, Council members temporarily provided the funds necessary to complete the purchase. While revolutionary in its own way, the solution provided by the Sun River Game Range was temporary at best; with increased grazing opportunities and protected status, elk herds continued to grow (Janson 1961).

Recent History

The tug-of-war between protection and development interests on the Front continues to this day, as hunters are joined by diverse parties with a common interest in conservation and preservation. Each land conversion or acquisition by preservation and conservation interests on the Front is viewed by ranching residents as a direct threat to their livelihood and lifestyle. Public support for the wilderness movement in the 1960s and 1970s added more than 1,500,000 acres to Montana's Wilderness system. Mindful of the critical role that productive prairie lands on the Front play in wildlife conservation, individuals in both the public and private sector continue to work to secure fee title to critical habitat in private ownership. In addition to the Sun River Game Preserve and the Sun River Game Range, much of the most valuable habitat already has been acquired for conservation purposes: Montana Department of Fish, Wildlife and Parks acquired the Blackleaf Wildlife Management Area (WMA) (10,000 acres) in 1980 and Ear Mountain WMA (3,000 acres) in 1983; the BLM set aside a total of 12,000 acres as Outstanding Natural Areas; in 1979, The Nature Conservancy purchased the 13,000-acre Pine Butte Swamp Preserve; and, in 1986, the Boone and Crockett Club acquired the 6,000-acre Theodore Roosevelt Memorial Ranch. In keeping with conventional conservation wisdom, which held that human development activities were antithetical to wildlife conservation, cattle grazing on public lands initially was terminated or substantially curtailed on most of these lands, and stiff regulations on use and access were enforced. Today, the prospect of oil and gas development in the last multiple-use, mostly unroaded 330,000 acres of non-wilderness public land on the Front has spurred preservation efforts to designate this area as wilderness. Low economic value of existing timber stands and the low revenue returns of livestock grazing leases (used primarily by local ranchers), coupled with a growing interest in service industries, such as ecotourism and recreation, have been added to the argument favoring wilderness designation (Power 1987).

Historical Synopsis

At issue here is the survival of two myths: one of the rancher, the independent pioneer wresting a living from an unforgiving land; and the other of wildness, untamed expanses populated by large predators and vast herds of elk and bison (*Bison bison*). Each myth has its adherents who fight hard to preserve the myth from defilement, often at the expense of the real ranchers and wild lands.

The fundamental differences between how the land is valued and perceived by those who are fighting over its future is best exemplified in the incentive program of The Great Bear Foundation (Olsen 1991). In 1985, the Foundation set up a program to compensate ranchers for grizzly bear damage to livestock. In one instance, a rancher refused payment because it sent the wrong message about the place that ranching occupies in the social and economic fabric of the Front. Acceptance of compensation, in his view, was tantamount to admitting that the primary value of the land lay in large predator conservation; all other uses, such as those that contributed to people's well being in other ways, were secondary and their diminishment compensable with mere money. The final portion of this paper is devoted to exploring ways to repair this schism and providing avenues in which both wildlife and people are primary.

Current Conditions

Elk are no longer in immediate danger of extinction on the Front and have not been for many decades (Figure 2). Nor, for that matter, are grizzly bears. In fact, the strength of wildlife populations has spawned a new sector of the local economy based on services revolving around wildlife. For both viewing and hunting, elk are one of the most highly valued species on the Front and their presence alone has brought national renown to this region known for its wildlife diversity (Posewitz et al. 1991). Elk herds have grown since the early 1980s, and new herds have established permanent residence on the Front. This increase in resident elk is due to a number of factors, including spill-over from areas in the interior mountains where elk often are subject to heavy hunting pressure, favorable habitat conditions due in part to low-intensity livestock grazing and conservative hunting seasons. Even though some elk move into the mountains during summer, others, mainly cow/calf groups, stay in the prairie foothills and graze on private alfalfa fields (Olson et al. 1994). In autumn, starting with the rut or the onset of winter, up to 3,000 elk gather in these low-elevation habitats to winter (Q. Kujala personal communication: 1996) as resident herds are joined by migratory elk that summer in the rugged mountain habitats along the Continental Divide.

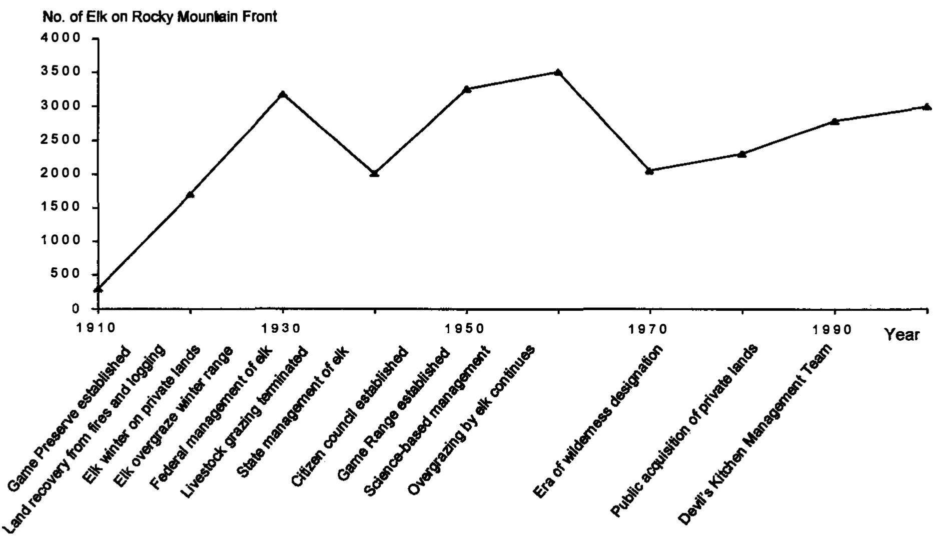

Figure 2. Time line of events and elk herd counts on Rocky Mountain Front (after Picton and Picton 1975, Q. Kujala and G. Olson personal communication: 1996).

About 200,000 acres of elk habitat are located on private lands; lands, incidentally, which are not necessarily irrevocably committed to providing habitat to elk. The viability of elk within the wildlife conservation areas scattered along the Front range is dependent on the matrix of private lands that connect them. The existing land ownership pattern prevents sufficient connectivity to secure the value of most of these wildlife areas, especially if private lands are shifted to incompatible uses. Strong competition in the marketplace and limited funds make large-scale public acquisition of these private lands for conservation purposes—a popular solution in earlier decades—an unsustainable solution. Then, too, the long-standing rancor between the ranching community and the conservation community has driven many ranchers to call developers rather than conservationists when seeking solutions to financial difficulties (M. Sexton personal communication: 1996).

Recent studies of range ecology on the Front, however, provide unexpected alternatives to old dilemmas: livestock grazing need not be incompatible with the creation and maintenance of elk habitat (Jourdonnais 1985). Only recently have we gained knowledge of the relationship between human-altered habitat and wildlife. Conservationists, resource managers and ranchers now recognize that the best winter habitats currently available to elk on the Front are those seasonally grazed by cattle (Baumeister 1994, Olson et al. 1994, Dagget 1995). Not only do fire suppression and no-grazing practices reduce grassland productivity (Jourdonnais 1985), these policies also communicate the wrong message about the relationship between ranching practices and the quality of wildlife habitat. This new knowledge, when deployed in a social context that increasingly values non-extractive uses of the land, allows for a broader array of opportunities to integrate livestock with elk management.

Blackleaf WMA is a good example of how moderate land use can provide quality habitat for wildlife and people. Starting in 1990, after 10 years of rest, a rest-rotation cattle grazing system was implemented to stimulate regrowth of palatable bunchgrasses by removing accumulated, dead forage. Privately owned cattle from a nearby ranch were used to graze the area with the landowner paying negotiable grazing fees. In addition to promoting private/public cooperation, expanding grazing to state lands improved the economic well-being of the landowner and relieved some of the grazing pressure on private lands. As a result of this cooperative management program, elk use of the area has increased four-fold in the grazed pastures compared with ungrazed pastures (Olson 1995). The increase, in turn, has generated additional hunting opportunities for the public, as well as eased the elk depredation problem on nearby ranches. Moderate activities associated with natural gas exploration also have been successfully integrated with the character and use of the land by people and wildlife since 1980.

Future Options

The limitations of the preservation approach to wildlife conservation are well known today, as are the dangers of unregulated development. In segregating humans and nature, preserves fragment the biophysical and socioeconomic landscape on whose integrity both humans and wildlife depend. Development, on the other hand, when unregulated, has destroyed ecosystem functions and structures needed to support healthy wildlife populations. Clearly, a different paradigm is needed, one that neither precludes human endeavor nor ignores biophysical limits. We believe that, in the case of elk conservation, a balance can be struck between the goals of preservation and development if certain key factors are present in the negotiation process.

Elk management on the Front is at a crossroad. Herd size now is limited more by social than biological constraints, and by a need to increase public hunting while minimizing impacts on private landowners. Shifts in sportsmen's attitudes and a dwindling supply of quality hunting opportunities on public lands have put pressure on elk and the wildlife agencies managing elk. Meeting the production challenge has become increasingly more difficult and, as a consequence of existing maximum sustainable hunting opportunity policy, elk herds in many backcountry units on the Front are becoming less diverse in age structure, especially within the male segment (Brown 1986). Even though elk use of private lands continues to be primarily a function of landowner tolerance, demand among hunters for controlled access and quality experiences provides an additional incentive for landowners to continue their tolerance. Fee hunting is on the rise.

Necessary Conditions for Success

For the synthesis phase of sustainable development to proceed, five conditions must exist (Table 1). One of the most basic, obvious prerequisites for any discussion about conservation (no matter how "integrated" with development) is a degree of material well-being that allows people to invest—financially, emotionally or otherwise—in their environment and their future (Salwasser 1993). An additional ingredient is not only a clear understanding of the costs and benefits, but a scheme to distribute those costs and benefits equitably among participants. In the past, ranchers felt that they had no share in the revenue generated by sales of hunting permits for elk, but that they bore the brunt of the cost of supporting those elk. To create an environment that supports diverse natural and human communities, all members of a community must have the sense of accruing some benefit that outweighs his or her share of the costs.

Table 1. Necessary conditions for success of wildlife-based sustainable development.

1. Relatively affluent culture that can "afford" conservation.
2. Conservation programs that provide benefits (economic, social or spiritual) to practitioners that outweigh incurred costs and distribute them equitably.
3. Social acceptance of wildlife uses and conservation practices.
4. Availability of scientific information on factors of production and tradeoffs among different options.
5. A commitment to "win/win" outcomes for regulating agencies, landowners and users of wildlife.

To that end, a second condition for success is that wildlife uses and values must provide significant, direct benefits to individual livelihoods and local economies that exceed the costs of those activities. Specifically, the income generated from wildlife must exceed the value foregone by not maximizing other alternatives, such as livestock grazing, development of timber or mineral resources, residential subdivision, or other uses. However, for a public resource to generate income for a private individual, that individual, in this case a landowner, must be able to exercise some limited form of property right over the resource, in this case the elk (Davis1995). Take hunting for example: in the current regulatory system, the state assigns elk ownership to the hunter through the purchase of a hunting permit—a hunter executes the right by killing an elk—thereby effectively bypassing the landowner whose lands/means support the elk. The landowner, not benefiting from this arrangement, has no incentive to tolerate, much less encourage elk on the property.

Limited property rights might be assigned to the landowner by means of transferable hunting permits (Davis 1995). To be economically feasible, however, voluntary, mutually beneficial agreements will have to be entered into between neighbors; elk are a wide-ranging species and the existing land ownership pattern of 500- to 10,000-acre ranches precludes the possibility that one landowner has sufficient habitat to support a viable population of elk without a neighbor's help (Wenders 1995). Such agreements, while aimed ostensibly at distributing the costs and benefits, will have the added benefit of uniting people and, hence, the landscape in a common pursuit.

Mere affluence and economic incentive, however, are insufficient to initiate or sustain an alteration in land-use practices if community values do not support it. Integrating wildlife-oriented industries with traditional industries, such as stock-raising or farming, leads to alterations in livelihood as well as lifestyle. The social dynamics, no less than the economic ones, are critical in holistic approaches to resource conservation. This means that wildlife uses, such as viewing and hunting of elk, must become (or remain) integral parts of the cultural and economic fabric. Widespread public support is necessary as a third condition to promote the production of marketable goods on private lands. Despite high demand for quality elk hunting and a well-established outfitting industry on the Front (mostly on public lands), the economic and social implications of diversifying enterprises on private lands that involve user fees for public wildlife are controversial.

For example, incentive programs in Montana and other western states that would give landowners more rights to wildlife have generated strong political and ideological opposition from sportsmen, state wildlife agencies and environmentalists, to name a few (Governor's Advisory Council on Private Land/Public Wildlife 1994). Opposition stems from the not unrealistic fear that too many rights will be granted to landowners, leading to the commercialization, privatization and exploitation by special interests of a public resource (Geist 1988). For example, liberal hunting seasons and unrestricted access to public lands provided the foundation for a flourishing outfitting industry in the interior mountains of the Front. Over time, by virtue of sheer numbers, outfitters have acquired considerable political power which they exercise to further their interests. Such power by one group can limit the ability of state agencies to pursue alternative management strategies that have as their primary objective the health of the resource.

Outfitters have benefited from the long-standing conflict between sportsmen and landowners that occurred as hunting shifted from a largely subsistence activity to a recreational one. Sportsmen's preference for trophy animals, coupled with the more conservative regulations on harvests, however, has further undermined landowners' ability to control herd size through the use of sport hunting. Frustrated landowners have resorted to restricting public access to private lands. Outfitters, seeking unique hunting venues to attract clients have capitalized on the situation by arranging to lease private lands for hunting. The outfitting industry now has a vested interest in protecting the productivity and availability of habitat on private lands from incompatible uses and unrestricted public access hunting. Although, in some instances, this form of fee hunting has added to the economic well-being of individuals, the existing regulatory mechanisms and the widespread opposition to privatization of wildlife prevent landowners from truly diversifying their economic base by integrating elk management into their overall operations.

A fourth key ingredient is access to and a willingness to employ scientific information in the management of wildlife resources. Most decisions regarding resource use and management are made in the marketplace or political and social arenas. Decision makers must have scientific information about ecosystem condition and must be committed to use that information in the decision-making process to ensure a sustainable future.

Fifth, regulatory agencies and institutions must see a direct benefit in promoting wildlife conservation on private lands because their support is necessary for "privatization" of wildlife to be an acceptable method of meeting public interests (Davis 1995). The state wildlife agency is in the business of providing and maintaining productive wildlife populations that offer a wide variety of public uses. Securing public access to wildlife on private lands has been one of the major program objectives of the state wildlife agency over the last 10 to 15 years (Governor's Advisory Council on Private Land/ Public Wildlife 1994). For the state to consider cooperative agreements with private landowners, additional opportunities for public hunting must be one of the products of the agreement. Hence, from the state's perspective, the potential for an agreement hinges on at least two factors: (1) the amount of access to wildlife a landowner controls; and (2) the amount of access the landowner is willing to trade. On the other hand, for private entrepreneurs to feel comfortable entering into these agreements, the state wildlife agency must be willing to shift in some instances from a management policy of maximum yield to one of maximum economic value (Wenders 1995).

A Case Study

South of the Front in the northern Big Belt Mountains, voluntary agreements among private landowners, sportsmen, state wildlife agencies and conservation groups already are emerging to address the problems associated with the equitable distribution of the costs and benefits of wildlife management across ownership boundaries. The "Devils Kitchen Management Team" is one such grassroots organization that is dedicated to integrating the needs of ranchers with those of others in managing elk.

With the exception of a state-owned wildlife management area, most of the southern portion of the land is in private ownership, and most of that is divided among four large ranches. In addition to supporting extensive livestock operations, these ranches harbor large herds of both resident and migratory elk. As early as 1988, landowners complained of an increase in elk numbers on their lands, and frustrations rose dramatically in 1990 after a fire that burned more than 80 percent of the WMA forced even more elk onto private lands. Landowner complaints to the state wildlife agency focused on two issues: (1) excessive elk numbers on private lands; and (2) a lack of compensation for providing habitat. The existing system of hunting permit allocation through lottery made it impossible for the landowner to effectively obtain economic gain from the wildlife resource.

In 1988, visionary landowners got together with other interested parties in an attempt to avoid the looming "train wreck" between the state agency, landowners, conservation groups and sportsmen over the controversial issue of elk management. The Devil's Kitchen Management Team builds consensus around a "win/win or no-deal" philosophy, meaning that every participant had to perceive a benefit from the decisions. Four major issues relating to elk management within the larger context of ranching operations were addressed by the team. These include: (1) providing public access to private lands; (2) simplifying the hunting permit allocation process; (3) adopting measures to control herd growth; and (4) promoting a more diverse herd age structure while maintaining a viable outfitting industry on private lands.

In 1993, the Montana Fish and Wildlife Commission approved a proposal by the team to liberalize hunting regulations. A "five-week antlerless" and a "three-week, permit-only antlered" elk hunting regulation was issued with the stipulation that participants would adhere to self-imposed quotas. Quotas on males were designed to promote a more diverse age structure, while those on females were designed to reduce herd size. In exchange for this modified season, landowners agreed to allocate a share of hunting opportunities to the public for both male and female elk within the limits established by the quota system. To date, the program has been successful in reducing herd size while improving age class diversity, providing additional public access to private lands, and formalizing the economically beneficial sportsmen/landowner/outfitter relationship (J. Williams personal communication: 1996).

The success of this grassroots organization has been recognized by the Montana Fish and Wildlife Commission. The Devil's Kitchen Management Team has been given a formal voice in local elk decision making equal to that of Department staff (Dagget 1995). The "appointment" is contingent upon the Team's continuing incorporation of ideas from all interested parties. In addition to their elk management plan, the group also has implemented a rest-rotation grazing system that encompasses private land as well as a portion of the wildlife management area. Improved grassland productivity and forage conditions have resulted in a redistribution of elk, a reduction in risk of fire, and the WMA is once again a major winter range for the region, alleviating some of the depredation problems on adjoining private lands (J. Williams personal communication: 1996).

The Devil's Kitchen Management Team brings together diverse parties committed to finding a win/win solution to a long-standing problem: the place of elk in a ranching community, or of public wildlife on private lands. The solution is unique in the annals of Montana conservation history; landowners retain control of their property, but concede limited access rights in exchange for a secure opportunity to derive benefits from a public resource. The public gains access to previously closed areas without the expense of acquiring fee-title to the lands. The ecosystem concept that views the land as an integrated whole and human communities as part of the fabric of that landscape was the essential common ground.

Conclusion

Our basic premise (and that of ecosystem management) is that any scheme to conserve natural resources that ignores local interests or unduly threatens preferred lifestyles is destined to fail unless maintained by external coercive force of law, regulation or power. Its corollary is assumed to be equally true, namely, that any scheme to develop social or economic programs that ignores the ecological component also will fail unless maintained by imports of energy or other materials. A largely intact, diverse ecosystem provides the Front with a more sustainable option. Historical circumstances, economic institutions and patterns of social development, however, present formidable obstacles to its realization. The politics of polarization (Wuerthner and Peebles 1994) now is the limiting factor.

People and wildlife on the Rocky Mountain Front have an opportunity to enter a new phase in their relationship; a synthesis phase of sustainable development in which people blend economic development with environmental protection to sustain or enhance their well-being. Choices to develop or protect resources and ecosystems tend to become ideological hegemonies that obscure such a middle path. Arriving at this middle path of achieving sustainable development requires several things: a level of affluence, a system for distributing costs and benefits equitably among participants, a commitment to science-based management, broad public support and participation, and an "irretrievable commitment" to a "win/win or no-deal" solution. In aspiring to sustain as much of the natural diversity and productivity of ecosystems as possible, conservationists also must take care not to impair the economic and social systems that support human diversity and productivity.

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Special Session 5. *Recruiting, Retaining and Training Consumptive Users of Fish and Wildlife*

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Facing Realities in Recruiting, Retaining and Training Consumptive Fish and Wildlife Users

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Fiscal realities of the 1990s are forcing public agencies to reexamine the dynamics of recruiting, retaining and training consumptive fish and wildlife users, who still contribute the overwhelming majority of funds to accomplish resource management to benefit populations, habitats and people. Fish and wildlife agencies and recreation industries are concerned about potential declines in participation and reduced license revenues available for management (Duda and McElveen 1991). Perhaps even more importantly, as proportionately fewer people are introduced to consumptive activities and the stewardship ethics developed in conjunction with these activities, constituency support for fish and wildlife management may erode. The loss of utilitarian users of the resources could cause agencies to lose historically supportive constituencies with strong conservation and environmental attitudes at the same time new constituencies with differing perspectives are emerging.

Several factors may contribute to reductions in traditional fish and wildlife users, including changing demographics, such as increasing urbanization, aging population, fewer youth due to smaller family size, and lack of interest in fish and wildlife by urban residents. Additional factors may include competition from other recreation opportunities, family changes (e.g., increases in single-parent families and families with two working parents, changing family values), economic reasons, habitat degradation, loss of access and agency operations (e.g., increasing regulations and restrictions) (International Association of Fish and Wildlife Agencies 1992). In addition to coping with such a multitude of possible factors, agencies are also faced with limited budgets and the need to demonstrate both program effectiveness and efficiency. Today more than ever, there exists a need to understand better the relationships between recruitment, retention and training of fish and wildlife users, and the development of users' commitment to the complex stewardship missions of agencies. A weakening of constituency support may be avoided if administrators, managers, researchers, educators and private sector organizations continue working together to understand these relationships.

Historical Context for Today's Realities

In the earliest eras of North American history, consumptive uses of fish and wildlife were vital to cultures inhabiting, exploring and settling the various regions of the continent. During this early period, sometimes referred to as the "Era of Abundance" (Shaw 1985), native cultures and settlers utilized the resources for their sustenance and trade. Recruitment and retention of users was not an issue, and training occurred through traditional, cultural means (e.g., via kinship or family groups).

By the 1800s, however, hunting, fishing and trapping had evolved into commercial enterprises driven by regional, national or even global market demand (Gray 1993). Over exploitation of resources occurred. Fortunately, at the same time, the fish and wildlife consumptive recreation community also was evolving. By the mid-1800s, "sportsmen/naturalists" were writing about the need for a new ethic toward wildlife (Regier 1978). From the late 1800s into the early 1900s, other writers, recreationists and political leaders (including, most notably, Theodore Roosevelt) represented the first wave of conservationists. Conservation leaders (including organized sportsmen's groups) aided in the proliferation of laws protecting fish and wildlife, supported enforcement of these laws, and developed the early infrastructure for land and resource management programs, such as the USDA Forest Service and the National Park Service. Still, throughout this era there was no emphasis on formalized recruitment, retention or training of fish and wildlife users.

By the turn of the century, fisheries agencies were well-established and the American Fisheries Society had been in existence for nearly 30 years; by the 1930s, wildlife agencies and programs had been formed (Sparrowe 1995) and The Wildlife Society was begun. Even 60 years ago, at the first North American Wildlife Conference in 1936, several speakers commented on issues related to recruitment and development of fish and wildlife users. Senator Harry Hawes described the "four vital factors in the wildlife conservation movement" as including the federal government, states, farmers and sportsmen. He stressed the necessity of cooperation among these factors in order for the conservation movement to achieve "practical success." He described the criticisms of hunting and fishing from the non-participating sectors of the U.S., and he promoted an ethic of cooperation with farmer-landowners and of intolerance for violators of wildlife laws. Finally, he admonished the group to "let open the door for everyone who wants the return of the great outdoors....whether he wants to camp and not shoot and fish, whether he is a sportsman or a nature lover....[let us] all pull together for the benefit of the boys and girls that are coming after us for a better America" (Hawes 1936: 168).

Several other speakers at this first Conference focused on the importance of exposing youth to nature study and conservation ethics through the activities of hunting and fishing. Roberta C. Lawson (1936: 36), then-President of the General Federation of Women's Clubs of America, noted that "when one has camped, hunted and fished...one fully recognizes the full value of wildlife preservation in the social and recreational program of this continent." She went on to state, emphatically, "Get our boys and girls out into the open. Help them to learn such things...." Yet, she also notes that "all human beings are not hunters and fishermen. Some get great joy from going out in the woods just to watch the animals at play and to study their habits of life (1936: 38-39)." Several other speakers mentioned the importance of recruitment of young people into outdoor activities through Scouts, 4-H and Junior Audubon clubs (Barclay 1936, Smith 1936, Baker 1936).

Shortly after this first Conference, World War II introduced profound social changes, technological advances, and alterations in environmental quality that changed fisheries, wildlife and human responses to the resources. By the 1940s, most of the present-day federal, state, scientific and private resource management agencies were in place (Heberlein 1991).

During the 1950s and 1960s, post-WWII "boom" effects were felt nationwide. The 1961 theme for the North American Wildlife and Natural Resources Conference, "Planning for Population Pressures," highlighted the important trends of the era. Development "boomed," and the suburb became the place where "marriages and children that were deferred during the war" were found (Gutheim 1961: 58). Whereas most of the U.S. population had lived in rural areas prior to WWII, by 1960, more than two thirds of the national population lived in metropolitan areas (Gutheim 1961, Gray 1993). Problems of suburban sprawl, urban blight, loss of open spaces and land access, and disintegration of local governments and social systems were noted by several speakers (Caldwell 1961, Wirth 1961, Gutheim 1961). Demographers, however, predicted that these trends would slow as migration to urban areas from farms declined and as marriage and birth rates declined (Gutheim 1961). These same demographers noted that "of the many social and economic changes...probably the most important is the changing age composition of the population" (Gutheim 1961: 60). They foretold of expected increases in "old households" composed of retired individuals, and noted that no recurrence of the "spectacular rates of family formation that characterized the period 1947-50" was expected until after 1980. Today, we know this post-WWII era as the "Baby Boom" era, and we refer to the age cohort born during this time as "Baby Boomers." At the time, fish and wildlife managers did not fully imagine the effects of these phenomena on future resource demand patterns. Instead, for two decades during the 1960s and into the 1970s, researchers and managers focused on urbanization and reductions in recreational access as important to fish and wildlife participation and other habitat- and population-related issues.

Interestingly, though, it was during this era that one of the first human dimensions research efforts focused on describing "The Hunter—Who is He?" (Peterle 1961). Peterle even took a marketing approach, so common to today's resource management thinking, and commented that "the more we know about our 'consumer' [the hunting-license buyer, wildlife photographer, bird watcher], the better chance we will have of selling our 'product' [conservation]" (Peterle 1961: 255). One major product developed during the late 1940s and through the 1960s was hunter education—initiated to help "the masses" become safe hunters as they took part in the still relatively accessible recreation opportunities which existed.

The 1969 North American Conference likewise emphasized the theme of "Conservation in an Urbanizing Society." Environmental quality issues became more evident, and one session featured a panel discussion of "Pesticides—New Facts and Old Problems." Hunter/landowner relationships and access issues still were important foci of the research and management community, particularly those professionals working in areas related to education of fish and wildlife users. Some new themes had emerged, however. Several presenters discussed ways of measuring wildlife values, quantitatively using economic indicators and qualitatively focusing on emerging issues of user conflicts. In addition, one presenter described the need for "Broadening Conservation's Constituency" (Clusen 1969).

By the 1970s, environmental quality issues were established as important topics at the North American Conference. Yet, an entire session in that year dealt with conservation communications to a variety of constituency groups. Human dimensions and communications were emerging as important components of fish and wildlife research/management. Participation in consumptive fish and wildlife activities still was on the rise, and the major demographic effects of the Baby Boom cohort were yet to be felt. Little attention was paid to recruitment and retention, but education programming experienced a resurgence in the 1970s. Hunter education programs were growing, and both trapper and bowhunter education programs were initiated (Samuel and Jones 1987). Yet, at the same time, observers of recreation trends noted the "impending increases in appreciative recreation rather than hunting and fishing" (Hendee 1969).

The 1980s were pivotal years for resource managers wrestling with issues of recruitment, retention and training of consumptive users. From 1955 to 1980, the numbers of anglers in the U.S. had doubled and the number of hunters had grown by 50 percent (Ashe 1986). Since the 1980s, however, no substantial growth in these activities has occurred. In fact, numbers of anglers, total days spent fishing and total days spent hunting have declined since about 1980 (Flather and Cordell 1995, Cordell et al. 1995). The major bright spot in the 1980s and into the early 1990s was gains made in aquatic education program offerings, funded in large part through the Wallop-Breaux Amendment to the Federal Aid in Sport Fish Restoration Act (Lemon et al. 1987).

The historical context for today's agency interest in recruitment, retention and training of consumptive fish and wildlife users paints a long and diverse picture. Early in the course of fisheries and wildlife professions, both consumptive and nonconsumptive recreation values were discussed. With the emergence of the subdiscipline of human dimensions of resource management, our understanding of recruitment, retention and training has increased, yet, we have not been able to "stem the tide" of broad-ranging social trends which have been in effect for decades. Understanding this historical context can assist fisheries and wildlife professionals to know from where we have come, avoid bad decisions, assess the future, and initiate strategic planning by reviewing past trends and documentary data (Nielsen 1995).

Today's Realities and Impending Paradigm Shifts

By the early 1990s, demographic realities had begun to set in and influence fish and wildlife agency policymaking and research efforts. Murdock et al. (1992) utilized U.S. census data to describe four demographic changes with implications for fisheries managers: reduced rates of population growth, aging of the population, increases in minority populations and changes in household composition. When these demographic trends are applied to sportfishing participation projections, several patterns emerge; rates of growth in sportfishing recruitment will vary among race/ethnicity groups, and the population of anglers will become noticeably older (Murdock et al. 1992). For example, the proportion of anglers who will be 60 years old or older is expected to double between 1990 and 2025, while the number of "traditional" anglers age 40 and under will decline by 10 percent during the same period (as the Baby Boom cohort ages). Researchers conclude that such influences will change the characteristics of populations who use our goods and services, and impact the characteristics of the clientele seeking services, and the social, economic and political environments for resource management (Murdock et al. 1992, Dwyer 1995, Godbey 1995, Backman et al. 1995). Heberlein (1991), in a similar analysis of projected hunter numbers, considered patterns of increasing urbanization, decreasing agricultural communities, aging of the population, increasing numbers of female-headed households, changes in education levels of Americans and the fact that nearly 20 percent of children are living in poverty. His conclusions were that these forces will reduce the potential pools for recruitment of new hunters and eventually lead to a major decline of sport hunting in the U.S. His work has been cited as foretelling of the extinction of sport hunting among males in the U.S. (Nudel 1995).

But what of angler and hunter retention? With the aging population nearing retirement, isn't there the potential for a flood of participation in consumptive fish and wildlife activities? Researchers and other observers would say no. Various studies have noted that days afield and number of trips afield decline with increasing age, and that the only segments which offer the potential for growth in participation are females, minority/racial/ethnic groups and segments which have deserted or quit the activity (Duda 1996, Mangun 1996, Harrington Market Research and AFTMA 1990). Furthermore, studies which track and make projections of participation trends are very scanty, probably due to limited availability of user databases. A few notable exceptions provide some insight into longer-term participation trends and retention. Data collected under the auspices of the National Survey of Hunting, Fishing and Wildlife Associated Recreation have been examined by several investigators (e.g., Mangun 1996, Duda 1996, Flather and Cordell 1995, Heberlein and Thomson 1996). Some state-level and regional projections and analyses have been made as well (e.g., Brown and Connelly 1994, Adams et al. 1993). As large database management capabilities and computerized license databases become more accessible to the research community, we should see an improved ability to understand better the dynamics of retention of consumptive users of fish and wildlife resources.

Other realities have become apparent, too. Although the diversity of constituency interests was noted at the earliest North American Conferences, this reality now is "coming home." An increasing number of recent studies have focused on so-called "non-consumptive" users (Mangun et al. 1992, Gray 1993, McFarlane 1994, 1996). Numbers of individuals travelling to observe, feed or photograph wildlife have increased over the last 10 years at an annual rate of increase exceeding all other wildlife-oriented activities (Flather and Cordell 1995). In addition, there has been substantial growth in recreation activities which are not directly dependent on fish and wildlife resources (e.g., bicycling, day hiking, swimming, boating), perhaps due to a complex combination of socioeconomic and resource factors (Cordell et al. 1990). The large number of individuals pursuing both "traditional" forms of consumptive activities, as well as those pursuing so-called nonconsumptive activities, illustrates the wide range of benefits sought from the resource base and the growing diversity of constituency interests. In fact, there is considerable overlap in participation in these activities, since many individuals participate in more than one type of activity—thus, indicating there is no clear demarcation between consumptive and nonconsumptive recreationists. No matter the activity, there are benefits "consumed" by the users, and implications for resource sustainability that managers must take into account, particularly as ecosystem management becomes a more prevalent paradigm.

Finally, and perhaps most importantly, changing patterns of recruitment, retention and training of consumptive users are forcing agencies to wrestle with serious funding realities. The current era of widespread skepticism regarding public agencies' effectiveness and efficiency probably is the "straw that will break the camel's back" and thrust agencies into a new paradigm for resource management. A paradigm shift may be defined as a change in the fundamental attitudes, beliefs and philosophies about how things are or should be; furthermore, paradigm shifts tend to occur rapidly (Kuhn 1970). Hamilton (1992: 124-125) argues that "The new funding paradigm [for management agencies], focused on getting the job done, carries many implications about how agencies will operate in the future. Less certain 'support' from any one source is the likely norm. Agency life-style will thus demand more flexible, less certain, and less controlled budgets." Likewise, Heberlein (1991) notes the disappearance of the "golden age of the sportsman" and proposes that a period of relative stability in wildlife management is nearing its end. He suggests that "Twenty-five years from now sport hunting and the financial support from the sport hunter with its benefits for wildlife and habitat will look much different than they do now. How they look depends on us" (Heberlein 1991: 529). Perhaps most notably, he challenges the current efforts to sustain recruitment and retention by posing that "more is not always better." Heberlein argues that fewer, more knowledgeable hunters may be a desired management goal in order to provide a sustainable funding base.

Ditton (1995), however, argues that fisheries management agencies can either let population trends dictate their futures or intervene strategically; he makes four recommendations for agency action: 1) managers should consult with demographers; 2) agencies need to enhance human dimensions capabilities to learn about population segments with historically low participation with the resource; 3) agencies must participate in more public/private partnerships to enhance participation of under-represented segments; and 4) agencies should develop programs to socialize youth into fishing.

Whatever the agency goals in recruitment and retention of fish and wildlife users, there will be increased public demand for agency accountability; publics and agencies are examining program effectiveness (i.e., do programs "hit the target" in reaching intended audiences, target markets or customers?) and efficiency (i.e., are programs achieving the "biggest bang for the buck," by achieving desired specific outcomes and investing limited financial resources wisely?). This work to demonstrate effectiveness and efficiency must, by necessity, have a strong research basis—building from what we currently know about recruitment, retention and training of fish and wildlife users.

Summary: Research Needs and Putting Knowledge into Practice

The depth and breadth of the current research into recruitment, retention and training of fish and wildlife users should make very obvious the centrality of these issues to the future functioning of resource management agencies. Yet, the work of understanding fish and wildlife clientele is just beginning, and education programs still are in early stages of evolution. More work is needed. Specifically, resource management agencies and their increasingly diverse partners will need more research which provides:

- detailed descriptions of "non-traditional" audiences for fish and wildlife recreation (women, racial/ethnic minorities, particular age cohorts which may be ceasing to participate, such as teens);
- evaluations of long-term as well as short-term behavioral impacts of education/intervention programs;
- theory-based descriptions of the complex processes of recruitment, retention and intervention strategies to enhance these processes; and
- development of predictive tools and other modelling tools (using new technologies and innovative database management) to help agencies in strategic planning and programming.

To accomplish these broad research goals, state and federal agencies and their partners will need to work together to design complementary research and evaluation programs. Some of this type of coordination already has begun under the auspices of hunter and aquatic education programs. No one state or organization will be able to address all of the critical areas in which more knowledge is needed.

Once knowledge is gleaned through such efforts, putting that knowledge into practice is the next challenge. More specifically, there will be increasing needs to:

- make even better use of marketing theory and approaches in understanding customer needs, designing products and services, targeting specific markets, and reaching the previously unreached and underrepresented with messages about opportunity related to fish and wildlife resources; and
- conduct rapid information transfer and application within the community of partners, in order to strengthen both program efficiency and effectiveness.

Finally, very critical policy and program questions linger for fish and wildlife agencies and their partners. These are the questions reverberating within both the fisheries and wildlife communities (Heberlein 1991, Ditton 1995). Have we heeded the voices of the past which predicted such profound changes? Will we heed the voices of researchers and practitioners in this session? How much effort should be invested in recruiting users, and what are the trade-offs between numbers of resource users and quality of resource-related experiences? Is there a connection between direct contact with resources through so-called "consumptive" fish and wildlife recreation and the development of stewardship behaviors and ethics? Some evidence for this connection does exist (Dann 1993), and it is this relationship between participation and stewardship which often is cited as the rationale for investing in recruitment, retention and training programs. Yet, our fish and wildlife clientele have changed and are changing; these changing constituencies and paradigm shifts within fisheries and wildlife management are the focus of recent issues of *Fisheries* and *The Wildlife Society Bulletin*. Clearly, we are at a critical crossroads in fisheries and wildlife management; the questions addressed in this session pertaining to realities in recruiting, retaining and training fish and wildlife users are at the core of who we are as professionals, who we serve and where we are headed in providing long-term societal benefits from public fish and wildlife resources.

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Factors Related to Hunting and Fishing Participation in the United States

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This paper summarizes the major findings and implications of a three-year study on the factors related to hunting and fishing participation in the United States. There were five phases to the project: 1) a comprehensive literature review (Duda 1993; hereafter "Phase I"); 2) a series of eight focus groups with active hunters, inactive hunters and non-hunters (Bissell and Duda 1993; hereafter "Phase II"), and a series of five focus groups with active and inactive anglers (Bissell and Duda 1995: hereafter "Phase III"); 3) a multivariate analysis comparing screener data from the *National Survey of Fishing, Hunting and Wildlife-Associated Recreation* (NSFHWAR) (1980, 1985, 1991) and a nationwide telephone survey of the general population, active and inactive hunters, and active and inactive anglers (Duda et al. 1995b; hereafter "Phase IV"); and 5) a final report summarizing the results and implications of the study (Duda et al. 1995a; hereafter "Phase V").

Methods

A comprehensive literature review was conducted, consisting of an in-depth examination of more than 700 previous works on participation in hunting and fishing, hunting and fishing recruitment and desertion, hunting and fishing satisfaction, factors influencing hunting and fishing participation, and social and demographic trends. Many other subjects regarding hunting and fishing were examined as well (Phase I).

Thirteen focus groups were conducted to develop an understanding of the perceptions, motivations and factors influencing hunting and fishing recruitment, participation and desertion (Phase II, Phase III).

Focus groups contained 10 to 12 people recruited to represent hunters, nonhunters, exhunters, anglers and exanglers to provide new insights, new hypotheses and understanding through the interaction process. The use of focus groups is an accepted research technique for qualitative explorations of attitudes, motivations and behavioral predispositions and practices.

Hunting Focus Groups

Participants in the hunting focus groups were selected based on their association with the issue of hunting participation. Specifically, hunters, exhunters and nonhunters. Only one category of individuals was included in any one focus group. The following definitions were used: 1) a hunter is a person who purchased a hunting license and/or went hunting in the previous three years; 2) an exhunter is a person who purchased hunting licenses and/or hunted in the past, but has not purchased a hunting license or hunted in the previous three years; and 3) a nonhunter is one who has not purchased a hunting license or hunted in the past. The participants were drawn from urban, suburban and rural populations. Other than recruiting participants who were 18 years of age or older, no effort was made to differentiate participants by age, gender, income or residence.

Two of the focus groups were conducted in Scottsdale, Arizona (AZ), two in York, Pennsylvania (PA), two in Manchester, New Hampshire (NH) and two in San Francisco, California (CA). Two groups were conducted at each location, one drawn from one category of the public and the second from a different category.

Fishing Focus Groups

The selection of participants for the five fishing focus groups was based on participation in fishing recreation. Individuals were recruited by phone and consisted of active anglers and inactive anglers. Active and inactive anglers were defined based on frequency of license purchase and number of fishing trips taken. Among the inactive anglers interviewed, there were individuals with varying levels of avidity for fishing, including people who had only fished as children or had fished very casually once or twice.

One focus group of active anglers was conducted in Great Falls, Montana (MT), one focus group of active and inactive anglers was conducted in Seattle, Washington (WA), one focus group of active anglers and one focus group of inactive anglers were conducted in Tampa, Florida (FL), and one focus group of African-American active anglers was conducted in Richmond, Virginia (VA). The participants were drawn from urban, suburban and rural populations. Other than recruiting participants who were 18 years of age or older, no effort was made to differentiate participants by age, gender, income or residence. All but the African-American group in Richmond consisted of mixed ethnic backgrounds and all of the groups were mixed in terms of age, income and gender.

Telephone Survey

The telephone survey was a random-digit dialing (RDD) computer-assisted survey of U.S. residents, including Alaska and Hawaii, aged 18 or older. Telephones were selected as the preferred sampling medium, since nearly all U.S. residents have access to a telephone. In addition, a central polling site allowed for rigorous quality control over the interviewers and data collection.

Active and inactive hunters and active and inactive anglers were screened from the general population. These individuals were asked additional questions about their hunting and/or fishing participation, satisfactions and dissatisfactions.

The survey questionnaire was developed cooperatively between Responsive Management and several state fish and wildlife agencies. A pretest of the survey was conducted which consisted of 50 completed interviews. Based on the pretest, several revisions and clarifications were made to the survey. A total of 2,085 surveys were completed with randomly selected adult U.S. residents. Subgroups of the general population included: active hunters (n = 376), inactive hunters (n = 351), active anglers (n = 942) and inactive anglers (n = 529).

Multivariate Analysis

The goal of the multivariate analysis was to identify the factors associated with changes in hunting and fishing participation between 1980 and 1990 using NSFHWAR interview screening data.

Screener data from the NSFHWAR was used to estimate participation rates which require random samples of nonparticipants as well as participants. Although changes in methodology (annual recall versus trimester recall) have taken place between the 1980 and 1990 NSFHWARs, the screener surveys continue to use annual recall for the key indicators of participation. Thus, data are comparable across surveys.

Sampling from Data Sets

The number of records sampled was 10,144 (1980), 8,069 (1985) and 7,839 (1990). When noninterviewed households were excluded, the 1980 records were reduced to 9,322. The number of persons age 16 and older (analytic samples) was 7,508 (1980), 6,079 (1985) and 5,390 (1990).

Exhaustive tests were constructed for interaction between effects of socioeconomic variables across time and for differences between males and females. If effects of age, for example, differ across surveys, then straightforward predictions cannot be made of change in hunting and fishing participation from the pooled effect of age on hunting or fishing and changes in age across survey years. In most cases, effects of independent variables were not different across survey year (i.e., did not interact with year of survey), a necessary basis for the summary multivariate analyses. Determinants of hunting and fishing participation vary by sex, so separate models were presented for males and females.

Ordinary least squares regression was used to predict hunting and fishing participation for the three survey years combined. Models included survey year (1985, 1990 contrasted with 1980), age, education, income, region of residence, marital status, race and rural place of residence at 16 years of age. As noted above, and described in full in the Phase IV report, researchers were unable to include current rural/urban residence in the model because measures were not comparable across surveys. The multiple regression analysis was conducted by Elizabeth Thomson and Thomas Heberlein of the University of Wisconsin at Madison.

Results

Hunting Participation

Hunting is an important and traditional recreational activity for millions of Americans. Each year, 14 million Americans 16 years old and older hunt (Phase I). Every two years, 18 percent of Americans over the age of 18 hunt (Phase IV).

Participation in hunting as a percentage of the U.S. population has remained stable between 1980 and 1990. In 1980, 10.2 percent of the population hunted. In 1985, 9 percent hunted and, in 1990, 9.3 percent hunted (Phase IV). The relative stability in the percentage of Americans that hunt masks a very important interaction by gender. Hunting among American males is decreasing, while hunting participation among American females is increasing.

The percentage of males who reported hunting in the screener survey of the National Survey of Hunting, Fishing and Wildlife-Associated Recreation declined between 1980 and 1990 from 19.5 percent to 16.4 percent; a 16-percent decline off the 19.5 percent base. However, the percentage of females that hunted more than doubled between 1985 to 1990 from 1.3 percent to 2.7 percent (Phase IV).

The largest effect on hunting participation for males is associated with growing up in rural areas. This was positively associated with hunting. However, fewer people are growing up in rural areas. When small towns were excluded from the multivariate analysis (Phase IV), the decline was from 25 percent to 20 percent from 1980 to 1990. Age is the second biggest influence on the decline in male hunting. As the population ages, there are fewer male hunters within that population. Minority race-ethnicity has a negative effect. White men (and women) are more likely to hunt. However, in Phase IV, the proportion of white men in the survey declined.

Only two factors are acting to offset the decline among hunting participation among males. Income is increasing and male hunters have higher incomes. The proportion of the male population in the Mountain region is increasing and a higher proportion in that region hunt (Phase IV).

The increase in participation in hunting among females is due to social changes. Socioeconomic variables had almost no effect on hunting participation among females over the 10-year period analyzed in the multivariate analysis. The largest effect was the decline associated with age (Phase IV).

Fishing Participation

Fishing is an important and traditional recreational activity for millions of Americans. Each year, 36 million Americans 16 years old and older fish (Phase I). Every two years, 45 percent of Americans over the age of 18 fish (Phase IV).

Participation in fishing as a percentage of the U.S. population has increased slightly between 1980 and 1990. In 1980, 26 percent of the population fished. In 1985, 25.7 percent fished and, in 1990, 27.4 percent fished (Phase IV).

The slight increase in the percentage of Americans that fish masks a very important interaction by gender. Fishing among American males has remained stable, while fishing participation among American females is increasing. The percentage of males who reported fishing in the screener survey of the National Survey of Hunting, Fishing and Wildlife-Associated Recreation remained stable between 1980 and 1990. In 1980, 37.6 percent of males fished. In 1985, 37.1 percent fished and, in 1990, 37.7 percent fished. The percentage of females fishing from 1980 to 1990 increased from 15.0 percent to 17.7 percent, or an 18-percent increase off a base of 15.0 percent (Phase IV).

The largest determinants of male fishing decline in the U.S. are increasing age, fewer men growing up in rural areas and a decreasing proportion of white males. The factors influencing a decrease are offset by increasing income and more men living on the southern coasts (primarily Florida and California) (Phase IV).

Age, education and urban socialization all tend to reduce female participation in fishing. Based on the results of the multivariate analysis, there appears to be a strong role of social factors outside demographic variables on increased participation of female anglers from 1980 to 1990. Although there was an overall increase in female fishing participation from 1980 to 1990, age, education and urban socialization slightly affected female fishing participation rates negatively.

Public Opinion on Hunting

Most Americans support legal hunting. Almost three quarters of Americans approved of legal hunting. Forty percent of Americans strongly approved and 33 percent moderately approved of legal hunting. Eleven percent moderately disapproved and 11 percent strongly disapproved of legal hunting; a total of 22 percent disapproved. Five percent did not know or had no opinion (Phase IV).

Most Americans believe hunting should remain legal. Eighty-one percent of Americans agreed that hunting should continue to be legal. Fifty-three percent strongly agreed, 28 percent moderately agreed, 3 percent neither agreed nor disagreed, 6 percent moderately disagreed and 10 percent strongly disagreed (Phase IV). The survey results from this study match closely the results of a survey conducted by *USA Today* in 1992 where 80 percent of Americans felt hunting should remain legal, while 17 percent said hunting should be illegal (Phase I).

Although the American public supports legal hunting in general, the level of support or opposition varies based on the expressed reason for hunting. The majority of Americans support legal hunting (in general), as well as hunting for food, and hunting for food and recreation. However, opposition increases toward hunting only for recreation and hunting for a trophy (Phase I). Although the American public supports legal hunting as an activity, the public has concerns regarding hunter behavior. A majority of Americans feel that a lot of hunters violate hunting laws or practice unsafe behavior while hunting. Moreover, the American public feels that when a hunter violates a hunting law, the hunter knows the law, but violates it anyway. Alcohol is considered a problem. Half of the American population believes a lot to a moderate number of hunters drink alcohol while hunting.

Rohlfing (1978: 408) has noted that "the public has no axe to grind to lop off hunting, but sure feels differently about the hunter...no amount of advertising to the general public could work to change these beliefs unless some fundamental changes were made in the preparation of hunters and in the ethical manner in which hunters conduct themselves."

A majority (62 percent) of Americans agreed that a lot of hunters violate hunting laws or practice unsafe behavior while hunting. Thirty-five percent of Americans strongly agreed that a lot of hunters violate hunting laws or practice unsafe behavior while hunting, 26 percent moderately agreed, 12 percent neither agreed nor disagreed, 17 percent moderately disagreed and 10 percent strongly disagreed (Phase IV). Active hunters were split on this issue, with almost half agreeing and the other half disagreeing that a lot of hunters violate hunting laws or practice unsafe behavior while hunting: 23 percent strongly agreed, 26 percent moderately agreed, 5 percent neither agreed nor disagreed, 26 percent moderately disagreed and 21 percent strongly disagreed (Phase IV).

When asked, "In general, when a hunter violates a hunting law is it because the hunter does not know what the law is or do you feel the hunter knows what the law is but violates it anyway," 74 percent of the public felt that the hunter knows the laws, but violates them anyway. Sixteen percent of the public felt that hunters break laws because hunters do not know what the laws are (Phase IV).

Drinking alcohol is considered to be a problem. Respondents were asked specifically if they thought a lot, a moderate amount, a few or no hunters drink alcohol while hunting. Twenty-five percent of Americans felt that a lot of hunters drink alcohol while hunting and 25 percent felt a moderate amount of hunters drink alcohol while hunting. Thirty-two percent stated a few hunters drink alcohol while hunting and 3 percent stated no hunters drink alcohol while hunting (16 percent had no opinion or did not know) (Phase IV).

Concerns over illegal and unethical hunter behavior, coupled with the perception that hunting is inherently unsafe, are the primary reasons many Americans believe hunting is an unsafe activity and why the majority of the public strongly favors mandatory hunter education. Eighty-nine percent of active hunters and 93 percent of nonhunters agreed that all new hunters should be required to pass a hunter education course before they hunt. Eighty-two percent of nonhunters and 50 percent of active hunters felt that all current hunters should be required to pass hunter education refresher courses (Phase IV).

In the telephone survey, almost 40 percent of the general population felt that hunting is an unsafe recreational activity (Phase IV). Safety was a concern for active hunters, exhunters and nonhunters in the focus groups (Phase II). The use of firearms with the intent to kill is seen as making hunting unsafe as compared with activities which do not involve such behavior. An issue that often was raised by participants of focus groups was that of hunter carelessness, specifically hunters and drinking.

Public Opinion on Fishing

Almost all Americans support legal fishing. Ninety-five percent of Americans approved of legal fishing. Sixty-five percent of Americans strongly approved and 30 percent moderately approved of legal, recreational fishing. Two percent moderately disapproved and 1 percent strongly disapproved of legal, recreational fishing (3 percent total disapprove) (Phase IV).

Most Americans believe fishing should remain legal. Ninety-six percent of Americans strongly or moderately agreed that fishing should remain legal. Seventy-three percent strongly agreed, 23 percent moderately agreed, 1 percent neither agreed nor disagreed, 2 percent moderately disagreed and 1 percent strongly disagreed with the statement, "Fishing should continue to be a legal activity" (Phase IV).

Most Americans agreed that fishing is a safe recreational activity. Seventy-two percent strongly agreed, 25 percent moderately agreed (total: 96 percent agreed), 1 percent neither agreed nor disagreed, 2 percent moderately disagreed and 1 percent strongly disagreed (total: 3 percent disagreed) with the statement, "In general, fishing is a safe recreational activity" (Phase IV).

More than a third of Americans believe that a lot of fisherman violate fishing laws and that these laws are broken consciously. Fishing over the creel limit and catching under-sized fish are considered the major offenses. The American public was split on the issue of angler compliance with regulations; 40 percent of the general population agreed while 39 percent disagreed that a lot of fisherman violate fishing laws. Seventeen percent strongly agreed that a lot of fisherman violate fishing laws, 23 percent moderately agreed, 21 percent neither agreed nor disagreed, 26 percent moderately disagreed and 13 percent strongly disagreed. Among active anglers, 18 percent strongly agreed that a lot of fisherman violate fishing laws, 24 percent moderately agreed, 11 percent neither agreed nor disagreed or did not know, 30 percent moderately disagreed and 17 percent strongly disagreed. Of the people who agreed that a lot of fisherman violate fishing laws, 41 percent stated fishing over the creel limits, 27 percent said catching under-sized fish, 15 percent said fishing without a license, 12 percent said drinking alcohol, 10 percent said catching fish out-of-season and 6 percent said fishing in restricted areas were the laws violated most often.

When asked, "In general, when an angler violates a fishing law is it because the angler does not know what the law is or do you feel the angler knows what the law is but violates it anyway," 64 percent felt that the angler knows the laws, but violates them anyway. Twenty-four percent responded that anglers break laws because anglers do not know what the laws are. Twelve percent did not know.

Hunting Initiation

It takes a hunter to make a hunter. Almost all hunters are initiated into hunting before the age of 20, usually by the father or other father-figure, in a rural environment. Hunters who are initiated in this manner hunt more frequently and are more likely to hunt avidly throughout their lifetime. The presence of other family members that hunt, amount of exposure to hunting and the presence of the "hunting culture" are of utmost importance in hunting initiation. Rarely does hunting initiation occur outside these parameters (Phases I and II).

Fishing Initiation

Fishing participation among youth in the U.S. is an extensive and pervasive recreational activity. More than 80 percent of Americans fished at least once as a child (Phase IV). Most anglers were introduced to the activity by their father (Phases I, III and IV). The issues of family surrounding fishing initiation are strong and pervasive, and any understanding of fishing activity must begin within the context of childhood memories and initiation (Phase III).

Hunting Satisfaction

Hunting satisfaction is high among U.S. hunters. Almost all active hunters are either very or somewhat satisfied with their hunting experiences during the past two years. Active hunters were asked, "Overall, how satisfied were you with your hunting experiences over the past two years?" Fifty-one percent were very satisfied, 33 percent were somewhat satisfied, 2 percent were neither satisfied nor dissatisfied or did not know, 10 percent were somewhat dissatisfied and 5 percent were very dissatisfied (Phase IV).

Active hunters are satisfied with their state fish and wildlife agencies' efforts to provide hunting opportunities. Active hunters were very favorable when rating state fish and wildlife agencies' efforts to provide hunting opportunities. Among active hunters, 24 percent stated excellent, 46 percent stated good, 21 percent said fair, 5 percent said poor and 4 percent did not know or had no opinion of their state fish and wildlife agency's efforts to providing hunting opportunities (Phase IV).

Hunters hunt for a variety of reasons. Most hunters hunt primarily for the sport/recreation or for meat. The percentage of hunters hunting for the meat is decreasing, while the percentage of hunters hunting to be close to nature is increasing. Forty-three percent of hunters hunt for the sport and recreation, 25 percent hunt primarily for the meat, 21 percent hunt to be close to nature and 12 percent hunt to be with friends and family (Phase IV). In the past 15 years, the percentages of hunters hunting primarily for the sport and recreation, or to be with friends and family have remained relatively stable. The percentage of hunters hunting primarily to obtain meat has decreased, while the percentage of hunters hunting to be close to nature has increased (Phase IV).

Hunters derive many different types of satisfaction from hunting, including being close to nature, camaraderie, using special equipment, exercising, bagging game, developing skills, and planning and remembering the hunt. Developed by John Hendee (1974), the multiple satisfactions approach has direct and important implications to wildlife managers: game bagged and days afield are important, but other aspects of the hunt should be managed as well to ensure and increase hunter satisfaction. Hendee's work suggests that the quality of a hunting experience and hunting satisfaction are dependent on the extent to which a hunter finds the desired mix of satisfactions he is seeking from the sport (Phase I).

For many hunters, motivations change throughout their hunting career. Bryan's (1979) "specialization theory" contends that recreationists move from activities of low specialization to high specialization. Overall, it appears recreationists go through careers in their sport, with the earliest stages typified by less-specific demands on the resource and the later stages typified by more-specific demands. For example, in the early stages, any game, such as small game, may suffice, whereas later, only spring turkey hunting will suffice, or a hunter may begin using a shotgun and move toward rifle and, ultimately, bow and arrow. Overall, Bryan notes that it appears newcomers to a recreational activity, such as hunting, fishing and wildlife viewing, are intent on getting results from the activity, such as catching a fish or harvesting a buck. Numbers become important as an activity becomes an established behavior, such as catching several fish or harvesting several birds. Once the numbers stage has been reached, specialization begins. At the extreme end of specialization, the activity itself becomes important for its own sake (Bryan 1979). Seeing game and the possibility of harvest are more important than killing game to most hunters. Most studies indicate that killing game is not as important to hunter satisfaction as many other aspects of the hunt, including the beauty of the area and the possibility of seeing game (Phase I).

Some of the most important values surrounding hunting are those centered on the family. Values centered on the family are integral to all aspects of hunting, including initiation, frequency, satisfaction, desertion and re-entry (Phases I and II).

The value of hunting as a traditional family activity or as a way of furthering social bonds was a major feature of Phase II. Repeatedly, focus group participants expressed the satisfaction of hunting within the context of family issues.

Fishing Satisfaction

Fishing satisfaction is high among U.S. anglers. Almost all active anglers are either very or somewhat satisfied with their fishing experiences. Active anglers were asked, "Overall, how satisfied were you with your fishing experiences over the past two years?" Thirty-eight percent were very satisfied, 41 percent were somewhat satisfied, 2 percent were neither satisfied nor dissatisfied or did not know, 12 percent were somewhat dissatisfied and 7 percent were very dissatisfied (Phase IV).

Active anglers are satisfied with their state fish and wildlife agency's efforts to provide fishing opportunities. Twenty-seven percent rated the agency as excellent, 46 percent stated good, 18 percent stated fair, 4 percent said poor, while 6 percent did not know or had no opinion of their state fish and wildlife agency's efforts to provide fishing opportunities (Phase IV).

Anglers fish for a variety of reasons. Most anglers fish for relaxation. Fishing to catch large fish is the primary reason for fishing for only 3 percent of active anglers. Among active anglers, 33 percent fish primarily for relaxation. Twenty-five percent fish to be with family and friends, 18 percent fish for the sport, 13 percent fish primarily to catch fresh fish, 7 percent fish to be close to nature and 3 percent fish to catch large fish (Phase IV).

Among active anglers, the percentages that fish for the primary purpose of relaxing or to be with friends and family have increased. The percentage of anglers that fish for the primary purpose of catching fresh fish and the percentage that fish to catch large fish have decreased. The percentages of anglers that fish for the sport or to be close to nature have remained relatively stable (Phase IV).

For many anglers, motivations change throughout their fishing career. Bryan (1979) also developed a categorization for anglers. Beginning participants are occasional anglers. Occasional anglers fish infrequently. They are new to the sport and fishing has not become a major interest. The second category, the generalist angler, has moved beyond the occasionalist stage and established fishing as a regular part of their activities. Generalist anglers use a variety of fishing techniques. The third group are technique specialists. These anglers specialize in specific methods of fishing, largely to the exclusion of other techniques. Overall, Bryan (1979: 44-46) concluded: "Fishermen tend to go through a predictable syndrome of angling experiences, usually moving into more specialized stages over time. But increasing specialization does not necessarily imply narrowing or restriction of activities outside the specialty. Instead, an ever increasing commitment to the sport in general may be found. The more specialized fishermen tend to have high knowledge and commitment to a variety of angling pursuits as an outgrowth of high time and skill commitment to the sport generally" (Phase I).

The most important values surrounding fishing are naturalistic and those values center on the family. A major benefit of fishing is having undivided time and attention with their children. Fishing is part of a broad and complex social environment, especially related to family relationships. Fishing does not stand alone as a recreational activity which can be explained independent of other factors. Anglers in the United States value the experience of being outdoors and being with friends and family above all other factors. While it appears that naturalistic values are of greater importance in terms of proximal satisfactions, it is difficult to separate the two issues with any certainty (Phase III).

Other factors of importance are the utilitarian value of catching fish and the skill of learning how to fish. These issues are secondary to socialization and naturalistic values. These factors should be considered only in relation to socialization and naturalistic values.

Catching fish and skill development are important values, but it is important to keep them in the proper perspective (Phase III).

Neither the number of fish caught nor the size of fish caught are significant factors for a majority of anglers in fishing satisfaction. The number and size of fish caught are important to some segments of the angler population. However, we found no evidence that catch rates or size of fish explain initiation, retention, drop-out, recruitment or significant long-term satisfaction rates (Phases I and III).

Hunting Dissatisfactions and Desertion

Not enough access, not enough places to hunt, work obligations, poor behavior of other hunters and too many hunters in the field were the five issues that took away most from hunting satisfaction among most active hunters. It is important to note, however, that the potential dissatisfaction cited most frequently by active hunters as having "strongly taken away from enjoyment of hunting" was expressed by only 22 percent of the active hunters, further indication of overall hunter satisfaction in the U.S. (Phase IV). Problems with access appear to be self-induced by some hunters. A complaint from landowners, and a reason for posting land or limiting access, is poor hunter behavior (Phase I).

Although important issues for a minority of active hunters, mandatory hunter education, the feeling of causing pain to animals, harassment from antihunters in the field, finding a place to buy hunting licenses, the perception that hunting endangers animal populations, not having anyone to go with, family obligations, personal health, having to travel in order to hunt, other people's negative opinions toward them as hunters, restrictive bag limits or season lengths, not having enough trophy animals to hunt, frequent changes in regulations, not enough law enforcement officers where they hunt and complex regulations are not taking away strongly from active hunters' enjoyment of hunting to any significant degree (Phase IV)

The top five issues that strongly influenced inactive hunters not to hunt were amount of free time, lost interest, work obligations, family obligations and the perception of causing pain to animals. However, it must be noted that the potential dissatisfaction cited most frequently by inactive hunters as having "strongly influenced their decision not to hunt as much or at all" was expressed by 26 percent of the inactive hunters (Phase IV).

Although important issues for a minority of inactive hunters, harassment from antihunters in the field, not enough trophy game, mandatory hunter education, restrictive bag limits or season lengths, other people's negative opinions toward them as hunters, frequent changes in regulations, complex regulations, not having enough game animals to hunt in general, the cost of hunting equipment, the cost of hunting licenses, not enough law enforcement officers where they hunted, pollution or litter where they hunted, having to travel in order to hunt and the perception that hunting is endangering animal populations do not strongly influence hunters to hunt less or to cease hunting to any significant degree (Phase IV).

Antihunting sentiment is not impacting hunting participation in the U.S. There was no compelling evidence that antihunting activities or sentiments were having an impact on hunting initiation, continuation or desertion (Phases I, II and IV).

A major reason hunters quit hunting is because of a breakdown in the social support system among hunters. Most current, active hunters continue to surround themselves socially with other active hunters. This is in sharp contrast to exhunters who have "fallen out" of a social circle of hunters.

Hunters hunt with other hunters. As hunting partners move away, pass away or become involved with other activities, participation by others in the group declines as well. This also happens when an avid hunter moves to a new area. Hunting activity often does not resume because the hunter does not have the social support system he used to have (Phase II). This suggests values in the familial and social context have become greater than other values derived from hunting.

Familial and social constraints are important considerations when developing programs to maintain participation in hunting. Without a strong social support system in place, efforts to recruit new hunters, especially individuals who do not come from traditional hunting families, will not be effective.

Exhunters' motivations were similar to active hunters in many respects. They shared utilitarian, naturalistic, dominionistic, aesthetic and ecologistic values. However, using an economic metaphor, active hunters were more elastic in their expectations about hunting, i.e., they derived multiple satisfactions. Active hunters could easily substitute one value for another, or derive satisfactions from a wider range of values than exhunters. Those hunters whose satisfaction stemmed primarily from one value tended to become exhunters more often than hunters who derived satisfactions from multiple values. Exhunters often were inelastic in their expectations about hunting.

Safety was an important concern for many exhunters, nonhunters and, to an extent, active hunters. Safety combined with the perceived carelessness among many hunters make a powerful deterrent to exhunters and nonhunters (Phases I and II).

Fishing Dissatisfactions and Desertion

The three issues that took away most from fishing satisfaction among active anglers were pollution or litter, work obligations and interference from people doing other recreational activities where they fish. However, it is important to note that the potential dissatisfaction cited most frequently by active anglers as having "strongly took away from enjoyment of fishing" was expressed by only 19 percent of active anglers (Phase IV).

Although important issues for a minority of active anglers, finding a place to buy fishing licenses, strictness of law enforcement officers where they fish, personal health, complex regulations, cost of fishing equipment, restrictive creel limits or season lengths, the perception that fishing is endangering fish populations, frequent changes in regulations, having to travel in order to fish, not enough law enforcement officers where they fish, cost of fishing licenses, not having enough trophy fish to catch, too many fishermen where they fish, poor behavior of other fishermen and not having anyone to go with are not taking away strongly from active anglers' enjoyment of fishing to any significant degree.

The top five issues that strongly influenced inactive anglers not to fish were amount of free time, lost interest, family obligations, work obligations and not having anyone to go with. Interestingly, the six dissatisfactions noted most frequently as strongly influencing anglers' decision not to fish were not resource-based issues, but were based on social or economic variables. It should be pointed out that the potential dissatisfaction cited most frequently by inactive anglers as having "strongly influenced the decision not to fish" was expressed by 30 percent of inactive anglers (Phase IV).

Although important issues for a minority of inactive anglers, strictness of law enforcement officers where they fish, restrictive creel limits or season lengths, finding a place to buy fishing licenses, frequent changes in regulations, not having enough trophy fish to catch, not enough law enforcement officers where they fish, complex regulations, too many fishermen where they fish, poor behavior of other fishermen, cost of fishing equipment, not having enough game fish to catch, cost of fishing licenses, interference from people doing other recreational activities where they fish, the perception that fishing is endangering fish populations, not having enough places to fish and not having enough access to places to fish are not significant factors in the decision not to fish.

Implications and Recommendations

This project comprises the most exhaustive review, data collection and analysis of any nationwide study of hunting and fishing to date. While there are numerous important and salient individual points herein, one factor is most evident. Hunting and, to a slightly lesser extent, fishing are primarily activities that can be understood best as sociological phenomenon centered on and about the American family.

While biological considerations are of importance as well, this study suggests that traditional fisheries and wildlife management programs, which focus on the resource and treat the legal hunter and angler as a secondary factor, will not promote continued utilization, but may contribute to the decline in participation and reduced satisfactions.

Family issues and family values play a critical role in hunting and fishing initiation, satisfaction and desertion. To a large extent, hunting and fishing represent the embodiment of family values. Hunting and fishing initiation almost always occurs within the context of family, and some of the greatest satisfactions are derived from the family relationships while participating in these activities. Any promotional or recruitment campaign for hunting and fishing must incorporate "family values" as hunting and fishing's "unique selling point," known to marketers as a product's USP. Fish and wildlife agencies should develop family-type licenses and manage hunters and anglers as social units rather than individual hunters or anglers. Fish and wildlife agencies must manage for family involvement. Agencies must interject the possibility of families hunting and fishing together, including the extended family and close friends, whenever and wherever possible. Often times, hunters hunt and anglers fish to be with friends and family. If this social aspect of hunting and fishing is not fulfilled, there is a likelihood participation will cease. This is an important aspect of hunter and angler management and cannot be stressed enough. Parent/child licenses, family licenses, areas designed for younger hunters and anglers, and special youth hunts and angling experiences are some ways to fulfill this need.

The major factors affecting hunting and fishing participation in the U.S. are broad demographic and social changes, such as urbanization, an aging population and the changing role of women in society.

Use of the terms "legal hunting" and "legal fishing" should be maximized. Many individuals still believe hunting endangers wildlife populations. Also, many people do not seem to differentiate between legal and illegal hunting when expressing opinions on hunting. This is less of an issue with fishing.

Overall, state fish and wildlife agencies are doing an excellent job providing hunting and fishing opportunities to hunters and anglers. U.S. hunters and anglers are very satisfied with their hunting and fishing experiences and very satisfied with state fish and wildlife agencies' efforts to provide hunting and fishing opportunities.

Public attitudes toward and opinions on hunting are being damaged from the "inside out" rather than from the "outside in." The level of antihunting sentiment in the U.S. is minimal and is having little impact on hunter recruitment, satisfaction, retention or desertion. Furthermore, the public supports legal hunting and feels that hunting should remain legal. Damage is being done to hunting as an activity from poor hunter behavior. Efforts to enhance public perceptions and attitudes toward hunting must begin with hunter behavior. Efforts toward improving hunter behavior will go far in increasing positive public attitudes toward hunting. Moreover, improvements in hunter behavior should help to minimize hunters' primary dissatisfaction: not enough access. The main reason landowners limit access is because of poor hunter behavior. Poor and unethical hunter behavior is a principal source of dissatisfaction among hunters. Programs must be developed to curb unethical hunting. From a monetary perspective, every dollar spent on programs to reduce unethical hunting is a dollar spent to increase hunter satisfaction and increase public support of hunting. We strongly suggest that additional hunter education and some type of mandatory refresher courses be looked at.

Fish and wildlife agencies must manage for multiple satisfactions. Multiple satisfactions are a very real and important aspect of managing for hunter satisfaction. Although harvest is important, it is not the only aspect of hunting that is important. Agencies must manage for all aspects of the hunt to enhance hunter satisfaction—from keeping wildlife management areas as aesthetically appealing as possible, to considering family issues whenever decisions are made that affect hunters, to publicizing game recipes.

Managing for multiple satisfactions not only enhances hunter satisfaction but appears to lessen the likelihood of hunter desertion. If a hunter derives multiple satisfactions from hunting, and one element of the hunt is dissatisfactory, other elements may help to maintain the hunter's interest and satisfaction with the total hunting experience.

Efforts to maintain hunting participation among U.S. hunters should focus on hunter retention, not hunter recruitment. Retaining hunters is more cost-effective than attempting to recruit new hunters. Based on their extensive research, Applegate et al. (1984: 67) recommend that "Efforts to reduce juvenile mortality; that is, the number of newly recruited hunters who drop out, would be more profitable than efforts to recruit new hunters to sustain a state's hunter population. As hunter retention increases, the number of new recruits should show a corresponding increase, since recruitment is a relatively constant percentage of the active hunter population."

Efforts to recruit new hunters outside of the traditional hunting community will be difficult, if not impossible. A long-term commitment to hunting is the result of the presence of and frequent exposure to hunting as a child. It takes a hunter to make a hunter. Most hunter recruitment only takes place in this environment and any effort to recruit new hunters must aim to duplicate these conditions. There is little evidence that hunter recruitment outside of the white rural community will be successful. Certainly, fish and wildlife agencies should meet the demand for the increased number of female hunters and small increases in minority interest in hunting. However, there is an important difference between meeting this demand and attempting to create a new demand. The success of women's hunting programs nationwide is meeting a demand, not creating a demand. Additionally, hunter recruitment efforts must be weighed in light of four of the top five dissatisfactions among active hunters—not enough access, not enough places to hunt, poor behavior of other hunters and too many hunters in the field. More hunters undoubtedly would exacerbate these problems.

Fish and wildlife agencies should develop hunter education programs targeted to different groups, taking into account each group's specific needs. Extensive research on hunter education at Cornell University suggests that, at a minimum, students should be separated into two groups—those initiated at a young age by parents or close relatives and those initiated at an older age by peers.

Fish and wildlife agencies should manage for a range of hunting opportunities. Some wildlife management areas or seasons should be managed exclusively for trophy hunting. Other areas should be managed primarily for the largest possible herd, while other areas or seasons can be managed primarily for the naturalistic/wilderness qualities. There are markets for each of these hunting experiences. Matching target groups to preferred hunting opportunities will enhance hunter satisfaction among hunters. The challenge this will create will be an increase in the complexity of regulations. Enhanced communications will be vital to communicate to hunters: 1) why this strategy was initiated; 2) the featured hunting opportunity of each site or season; and 3) the specific regulations for each site or season in a clear and concise manner. A perceived increase in complexity of regulations can be actively countered with effective communications programs to hunters.

Hunting regulations should be developed to maximize the possibility for hunters to see game, not to maximize harvest.

Fish and wildlife agencies must manage for multiple satisfactions for fishing. Catching fish is important, however, being with friends and family, relaxing, and experiencing the natural environment also are critical aspects of the angling experience.

As with managing for multiple satisfactions with hunting, a clearly defined spectrum of angling experiences needs to be offered and communicated to anglers. By offering a variety of angling experiences, some anglers may complain that regulations are too complicated. However, we believe this can be overcome by enhancing and increasing communications with anglers. A toll-free telephone number could be used to help explain regulations by knowledgeable individuals to reduce angler anxiety about not understanding regulations. Another solution would be to have certain "classes" of waters, each with similar regulations. For example, a class A water may be managed for trophy angling with a set of rules, while a class B water may be managed for maximum harvest and would have another set of regulations.

Programs designed to interest children in fishing should include catching fish or at least offer a high chance of catching fish. Children need to catch fish at first to get them "hooked." Once the interest is there, interest in other aspects of the fishing experience develop and should be encouraged to ensure continuation.

The aesthetics of angling sites and fishing in nonpolluted waters are important to anglers. Any attempt to make fishing areas more attractive through active litter pickup and garbage removal will enhance overall satisfaction levels. Water-quality management and improvement should be considered another fisheries management technique that increases angler satisfaction. As important is the perception of the cleanliness of the water. Continued efforts at communicating to the angling public about the cleanliness of certain bodies of waters, the pollution of others, as well as the health risks of eating fish from certain bodies of water, is essential.

It is clear that individuals who have fished for a long time and those that belong to sportsmen's clubs have different preferences than less avid anglers. Advanced anglers and members of sportsmen's clubs tend to be more involved in setting fisheries policy and voicing their opinions. It is important for fish and wildlife agencies to keep guard of only hearing advanced, avid anglers' opinions on regulations and angling preferences. For example, fishing tournaments and derbies are important to only a small segment of the angling population. These individuals tend to focus on the catch, especially large fish. However, catching large fish is not the most important reason for fishing for the majority of anglers.

Lack of time is an important reason people do not fish as much as they would like to or as much as they used to.

There are few negatives associated with fishing. Advertising campaigns on the familial rewards of fishing, and how fishing is exciting and fun may be necessary to keep angling in front of the public's eye.

The social aspects of fishing, especially the bonding of children with parents or grandparents, are important to angling satisfaction. This satisfaction should be promoted in all literature regarding fishing.

The social aspects of fishing also are important when developing programs to bring exanglers back into the fishing ranks. "No one to go fishing with" was cited frequently by exanglers as a reason why they have stopped fishing. More fish or bigger fish were not frequently cited. Mentor programs, programs to take exanglers fishing by rod and gun clubs and "buddy" programs could help bring back exanglers. Mentor programs should be considered carefully in light of child safety and comfort. For children, mentors need to be someone known and trusted by parents. Mentor programs for children that consist of strangers will not succeed.

Fishery program planning should begin to develop and use a typology of anglers. A typology of anglers, for example, trophy, nature, familial, fresh fish and subsistence, should be used when developing programs. Regulations can be evaluated and programs developed based on their impact on each group. The key to managing for angler satisfaction is to match the desired fishing experience with that particular fishing opportunity. Although it will take extensive planning, this must be done.

The cost of a fishing license is rarely a negative value for active or inactive anglers. There is a general discomfort with the rising costs of fishing, but moderate increases in fishing fees, done with disclosure, information campaigns and equity are acceptable. License fee increases may explain short-term decreases in fishing participation, but do not appear to be impacting long-term trends.

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Desertion in the Ranks: Recruitment and Retention of Sportsmen

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Principles of wildlife ecology hold that a population which exhibits low rates of recruitment from juvenile age classes and substantial mortality or emigration of adults is a population likely to be in decline. Sportsmen participating in traditional consumptive fish and wildlife activities comprise a dynamic population of recreationists whose numbers are influenced by recruitment, retention and rejection of continued involvement. Understanding the circumstances of individual recruitment and subsequent retention or longevity in the sportsman population provides important insights into participation trends in consumptive fish and wildlife activities.

Applegate (1977) first argued this organic analogy when describing the dynamics of a population of New Jersey sport hunters. He equated "birth" with initiation or recruitment into hunting, "life" with years of active participation and "death" with desertion or cessation of hunting participation. A definitive factor related to hunting desertion was found to be age. The percentage of active hunters within the general population was found to decrease as the age of the general population increased. In agreement with the findings of several similar studies (Peterle 1967, Klessig and Hale 1972, O'Leary et al. 1987), the longevity of individual participation was found to be related strongly to early initiation into the sport.

The generalizability of this population ecology model was expanded to the nationwide sport hunting population (Applegate et al. 1984) with analysis of data from the screener questionnaire of the 1980 *National Survey of Fishing, Hunting, and Wildlife-Associated Recreation* (FHWAR). Analysis of data from the follow-up hunting and fishing questionnaire of the same 1980 FHWAR National Survey demonstrated that age at initial sport fishing experience provided a reasonable predictor of continued fishing participation later in life (Behrens-Tepper 1985).

The dynamics of the sport fishing population also has been monitored with national survey data. Data from the Summary Reports of the 1955 to 1991 FHWAR national surveys were used to track the rise and fall of hunting and fishing participant numbers and their percentage of the entire U.S. population (O'Leary et al. in press). The observation was made that, since hunting has been on the decline since 1975, and since hunters represent a relatively small proportion of the total number of consumptive activity participants, the charted increase or decrease in the total number of U.S. sportsmen actually tracks the number of anglers. The number of anglers was shown to have increased from 1955 through 1975, leveled off for a decade, and declined from 1985 to 1991. Data from the Summary Reports of the three most-recent and relatively comparable 1980, 1985 and 1991 national survey screener questionnaires also showed that the number of first-time sportsmen has declined across the period (O'Leary et al. in press).

Although there has been considerable discussion elsewhere (O'Leary et al. in press) concerning changes in FHWAR survey methodology and reporting contributing to the changes noted here, the overall population dynamics of U.S. sportsmen deserves careful examination. License sales to hunters and anglers remain the primary source of revenue for most fish and wildlife management agencies (Anderson et al. 1985). As such, national trends in consumptive fish and wildlife activity participation can impact considerably on the revenue structure of an agency. Information that allows managers to anticipate those trends is, therefore, useful. For example, "juvenile mortality," or early decision to drop out, has been demonstrated (Applegate 1977, Applegate et al. 1984) to be related to cohort and age of initiation. In addition, sportsmen initiated later in life are more likely to exhibit dropout or discontinuous participation. Within the small cohort of 1990 first-time sportsmen, approximately 37.8 percent of first-time hunters and 45.6 percent of first-time anglers were older than 20 years of age, indicating a pool of potential sportsmen recruits that likely will exhibit considerable early attrition.

The 1991 FHWAR national survey (U.S. Fish and Wildlife Service [USFWS] 1993) screener questionnaire provides a unique national sample of nonparticipants, active sportsmen and those who have discontinued participation in consumptive fish and wildlife activities. Although only 8.6 percent of the entire screener sample reported hunting in 1990, 22 percent reported hunting at least once in their lifetime. Likewise, although 28 percent of the entire screener sample reported fishing in 1990, 52 percent reported fishing at least once in their lifetime. Are there discernible sociodemographic differences between those who elect to continue and those who choose to drop out? When desertion occurred, was it a wholesale abandonment of consumptive activities in general, or a selective desertion of either hunting or fishing?

The present study examines aspects of longevity or retention in the population of fish and wildlife consumptive activity participants as addressed by the screener questionnaire of the 1991 FHWAR national survey (USFWS 1993). A structural approach will be taken in which the distribution of age and other sociodemographic variables is determined across subgroups of the U.S. population based on active participation, inactivity and nonparticipation. Hunting and fishing are examined simultaneously by assigning sportsmen to categories based on whether an individual is active or inactive in either or both activities. The percentage of active, inactive and non-sporting groups who participated in nonconsumptive wildlife activities in 1990 also will be examined to determine if nonparticipants and inactive sportsmen are engaging in these activities or if they have foregone wildlife-associated recreation altogether.

Methods

Survey Design and Sample Selection

The 1991 FHWAR was conducted in two phases. The first phase (screener questionnaire or File FH-2), which was used in this analysis, contacted about 129,500 households (mostly by phone) to identify individuals who had fished, hunted or participated in nonconsumptive wildlife activities in 1990, and planned to do so in 1991 (USFWS 1993). The screening phase also collected sociodemographic information about household members. The FH-2 screening survey, administered in January and February 1991, had a 95-percent household response rate with an overall sample size of about 264,000 individuals.

Use of data collected in the screening phase eliminated the need to address the Bureau of Census weighting factors applied to the sample in the detailed follow-up phase. However, in most cases, screening information was provided by one adult household member for all household members and not by each individual. The net result was that the screening survey, while not as accurate, was deemed more reliable than the detailed follow-up (W. Fisher personal communication: 1988). As the screener questionnaire contained instructions to interviewers to limit activity questioning to household members six years of age and older, the present analysis generally selected only those cases.

Variable Selection

Related sets of categorical variables were selected or constructed for this analysis. Variables selected from the FH-2 file included participation in consumptive and nonconsumptive wildlife activities, last year of participation, and sociodemographics (age, sex, education, employment, household income, childhood residence, present residence). An ordinal classification based on number of years elapsed since last consumptive participation was constructed from responses dealing with participation in 1990, 1991, and most recent year if inactive. A nominal classification of consumptive activity involvement was constructed by recombining responses concerning whether an individual was at present or had ever participated in hunting or fishing or both. The continuous age variable was reclassified into equal five-year intervals.

Data Analysis

Data were analyzed via the Statistical Package for the Social Sciences, Release 6.1 for MS Windows. Cross-classification analysis of categorical involvement and participant characteristic variables was conducted using Pearson's Chi-square with an alpha coefficient level of 0.05 necessary in order to reject the null hypothesis of independence. Measures of association chosen to indicate the strength of correlation between two categorical variables were Cramer's V and Kendall's tau, appropriate to the level of measurement. A one-way analysis of variance, with the conservative Scheffé's multiple comparison procedure, was used to test whether the mean age of consumptive activity involvement categories differed significantly.

Results

Age Structure of the Active Sportsman Population

The 1991 FHWAR screener questionnaire identified 239,063 individuals, six years of age and older, who were members of the 129,500 randomly selected households. The sample of individuals was categorized into subgroups of participation/activity involvement based on their last reported year of hunting or fishing: (1) active participation (active: 1990 or 1991); (2) short-term, discontinued participation (last year: 1985 through 1989); (3) long-term, discontinued participation (last year: 1984 and before); and (4) nonparticipation. The distribution of the estimated sportsman population according to hunting and fishing participation/activity involvement, respectively, indicated that the ratio of active-to-inactive hunters was 1.00:1.45, while the ratio of active-to-inactive anglers was 1.25:1.00 (Table 1). Recruitment class figures estimated by those reporting 1990 as their first year of participation put first-time hunters at 0.6 percent and first-time anglers at 1.5 percent of the entire U.S. population (including those younger than six years old).

Table 1. Distribution of 1990 U.S. sportsman population by years elapsed since involved in hunting and fishing.

	Hunters		Anglers	
Involvement	n[a]	Percentage of population[b]	n[a]	Percentage of population[b]
Nonparticipant	178,127	76.2	99,369	43.1
Long-term inactive (last time 1984 or before)	21,244	9.1	28,701	12.4
Short-term inactive (last time 1985 through 1989)	11,769	5.0	29,859	12.9
Active (participated in 1990 or 1991)	22,611	9.7	72,757	31.5

[a]Sample of respondents age 6 years and older.
[b]Valid percent adjusted for missing cases.

When the hunting and fishing participation/activity involvement variables were cross-classified with age (categorized in equal five-year intervals), significant correlations were found. Hunting participation/activity involvement was found to be positively related to age class (Kendall's tau = 0.0678). The percentage of inactive hunters in any age class clearly increased with age of the general population, while the percentage of active hunters in the population declined rapidly after 50 years of age. The age class with the largest percentage of active hunters within one age class (13.5 percent) was 16 to 20 years old. Fishing participation/activity involvement was found to be negatively related to age class (Kendall's tau = -0.1079). The percentage of active anglers in any age class stayed relatively constant at 30 to 40 percent until declining in age classes of 50 years of age and older. The number of inactive anglers increased in small increments from 10 percent of 6- to 10-year-olds to more than 30 percent of those over 65 years old. The age class with the largest percentage of active anglers (43.6 percent) was 11 to 15 years old.

The mean age of each hunting and fishing participation/activity involvement category was determined and subjected to a one-way analysis of variance. A significant F statistic and a multiple comparison procedure indicated that significant differences existed between all possible pairs of mean age for each hunting and fishing participation level.

Consumptive Activity Involvement

With the two levels of discontinued participation combined into one "inactive" category, both hunting and fishing were examined simultaneously in terms of whether an individual was at present or had ever participated in either or both activities. With nonparticipants designated as the first level, nine mutually exclusive categories of combined "consumptive activity involvement" were identified (Table 2). The mean age of each consumptive activity involvement category again was determined and subjected to a one-way analysis of variance. A significant F statistic and a multiple comparison procedure indicated that significant differences existed between several pairs of group means (five pairs did not differ significantly, see Table 2). Of particular interest was the fact that the mean age of those who are and have been active only in fishing was significantly lower than the mean age of every other activity involvement group. Likewise, the mean age of those presently active in both fishing and hunting differed significantly from the mean age of all other groups.

Table 2. Distribution of 1990 U.S. sportsman population by consumptive activity involvement and mean group age.

Consumptive activity involvement	Percentage of population[a]	Mean group age[b]
Nonparticipant[c]	40.6	39.197
Inactive: fishing only[d]	18.0	40.616
Inactive: hunting only[e]	1.8	51.049
Inactive: fishing and hunting	6.2	50.269
Active: fishing only	17.3	28.656
Active: hunting only	0.8	37.872
Active: fishing/Inactive: hunting	6.4	42.707
Active: hunting/Inactive: fishing[f]	1.3	39.277
Active: fishing and hunting	7.7	35.077

[a]Sample of respondents age 6 years and older.

[b]Significant differences found between pairs of group means, with noted exceptions.

[c]Mean age not significantly different from mean age of Active: hunting only.

[d]Mean age not significantly different from mean age of Inactive: fishing/Active: hunting.

[e]Mean age not significantly different from mean age of Inactive: fishing and hunting.

[f]Mean age not significantly different from mean age of Nonparticipant and Active: hunting only.

When the consumptive activity involvement variable was cross-classified with selected sociodemographic variables (i.e., sex, education, employment, household income, childhood residence, present residence), significant yet weak relationships were found with all variables except sex. In that case, a strong, positive correlation ($p < 0.00001$; Cramer's $V = 0.4094$) was found between consumptive activity involvement and sex (Table 3). As expected, females constitute the largest percentage of nonparticipants (67.6 percent), while males represent the majority of individuals in any category that includes hunting participation, past or present. However, females made up the majority of individuals who either were currently active in fishing only (51.5 percent) or who had dropped out after being active in fishing only (61.6 percent). The percentage of all U.S. females, six years of age and older, who were active in fishing only in 1990 to 1991 (17.2 percent), was the same as the percentage of U.S. males, six years of age and older, similarly engaged in fishing only (17.3 percent).

Table 3. Cross-classification of consumptive activity involvement of 1990 U.S. sportsman population by sex.

Consumptive activity involvement	Percentage of activity level[a] Male	Female
Nonparticipant	32.4	67.6
Inactive: fishing only	38.4	61.6
Inactive: hunting only	78.4	21.6
Inactive: fishing and hunting	77.6	22.4
Active: fishing only	48.5	51.5
Active: hunting only	84.6	15.4
Active: fishing/Inactive: hunting	81.3	18.7
Active: hunting/Inactive: fishing	86.5	13.5
Active: fishing and hunting	89.5	10.5
Chi-square (Pearson) = 38,058	Cramer's V = 0.4094	
p < 0.00001	sig. < 0.0001	

[a]Sample of respondents aged six years and older.

Relationship to Nonconsumptive Activity

The analysis was extended to how the above-mentioned categories of consumptive activity involvement were related to aspects of nonconsumptive fish- and wildlife-associated activity. Only 17.5 percent of nonparticipants, those who had never engaged in consumptive fish and wildlife sports, were identified as having observed or identified wildlife in 1990; they represented 23.5 percent of nonconsumptive users. Only 9.1 percent were identified as having taken a trip for primary nonconsumptive purposes in 1990.

There was no indication that those who had discontinued a consumptive activity were more apt to participate in a nonconsumptive activity than active sportsmen. The largest percentage of dual participants was comprised of those presently active in fishing only; anglers represented 22.2 percent of those who had observed and identified wildlife. Active anglers also represented the largest percentage (25.7 percent) of those who had taken a primary nonconsumptive wildlife trip. Whether or not an individual had ever fished appeared more indicative of whether they would participate in nonconsumptive activities than whether they had discontinued or never attempted participation in consumptive activities.

Discussion

The simple definition of desertion as the cessation of participation in a particular activity is not inaccurate, but it does fail to convey the complexity of the subject matter. Discontinuity of sportsman "lifespan," or period of active participation, presents a problem not encountered in normal life-table or population ecology models (Applegate 1977: 110). Decker et al. (1987) describe wildlife recreation involvement as a temporal process in which sociopsychological and situational factors influence whether an individual opts to initiate, continue or discontinue activity involvement. Applegate (1977) further states that we have no reliable way to predict whether the inactive sportsman will return or the nonparticipant will be recruited. The unavailability of any psychographic measures that would address reasons for the discontinuation of perennial participation, therefore, make usage of the term "desertion" speculative.

Sportsman population dynamics can be described only incompletely by the data at hand. Natural resource social scientists have lamented the lack of a question addressing age at initial experience in the 1991 FHWAR. However, although the data set does make life-table or cohort analysis difficult, it still allows for a wide range of demographic characterization of active sportsmen, inactive sportsmen and nonparticipants. Researchers must adopt a structural approach that emphasizes identity and dimension of group size and participation, rather than addressing sociopsychological motivations if they are to use the FHWAR data set to its best advantage.

The ratios of active to inactive hunters and anglers in the U.S. population are extraordinary. If inactive individuals could be persuaded to resume participation, the number of sportsmen would virtually double. Intervening influences, such as changes in interest level, social support, ability or opportunity, must be modified or removed before reinvolvement is likely to occur (Siemer et al. 1989).

Significant differences in age and gender are found to exist among the different categories of consumptive activity involvement. Despite the admonition of Applegate et al. (1984: 48), concerning uneven age classes in the national survey report giving the misleading impression that hunters in their 30s outnumbered any younger age class, the data still are reported in that fashion. The findings of the present study indicate that there are more hunters in their late teens than in any other age class. In addition, not only do the data further support Applegate's (1977) earlier contention that younger hunters (35 years old and younger) are more numerous than older hunters, but demonstrate that this also is the case for anglers in an even more dramatic fashion.

The results of the present study, by extending the sample to include those juvenile sportsmen aged 6 to 15, have uncovered ample evidence to argue that the demographics of hunting and fishing are in a transitional period. The activity of fishing has been able to attract large numbers of youngsters, many of them girls. With what already is known about socialization into consumptive activity participation across the lifespan (O'Leary et al. 1987), the future of fishing in America appears secure. Every effort should be made to recruit and retain those young anglers into the adult angler population. However, as reported in 1991, females make up an even larger percentage of those who are inactive (61.6 percent), as opposed to active (51.5 percent), in fishing alone. We must identify what factors cause female anglers to discontinue fishing involvement in such large numbers.

Hunting remains an activity whose outcome makes many women uncomfortable, but definitely not all; 15.4 percent of those whose only consumptive activity is hunting are female. When age is considered, the hunter population also exhibits large juvenile age classes. The very small percentage of the U.S. population who are first-time hunters in any given year, however, does not augur well for the future of hunting. Every effort must be made to retain potential dropouts and reduce "juvenile mortality" within this traditional wildlife activity.

The clear advantage in using the FH-2 screener questionnaire in studies that address aspects of sportsman recruitment and retention is that information is available about those individuals younger than 16 years old. No other data base contains such extensive information on such a large number of cases of sportsmen from all age classes. This study further extends analyses that suggest that the FHWAR national survey remains the effective standard for natural resource and recreation managers to chart demographic trends among traditional consumptive fish and wildlife resource users.

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Status of Hunter Education in the United States and Canada

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While formal hunter education (HE) in the United states was conceived by the National Rifle Association (NRA) as early as 1938, most state programs did not become organized until the late 1940s and 1950s. Most initial programs were voluntary; the first mandatory program was created in New York in 1949. By 1979, 29 states had mandatory programs (International Association of Fish and Wildlife Agencies [IAFWA] 1981). The number of mandatory state programs grew to 47 in 1996.

Much of this growth can be attributed to two amendments to the Federal Aid in Wildlife Restoration Act of 1937 (Pittman-Robertson Act) which provided a funding base for hunter education and shooting range development by adding a 10 percent excise tax on handguns and an 11 percent excise tax on archery equipment. The amendments provided for up to fifty percent of the new funds *may* be available for hunter education and shooting range development.

As HE programs grew, leadership within the IAFWA recognized a need for greater cooperation and coordination among the states. In 1978, IAFWA (1981) adopted a resolution requesting U.S. Fish and Wildlife Service's (USF&WS) assistance in "instituting an analysis and evaluation of existing state and provincial hunter education/safety programs and preparing a model program designed to strengthen State and Provincial efforts." The result of that effort was a report entitled "Hunter Education in the United States and Canada with Recommendations for Improvement" (1981 Study), which was issued in August 1981. Contained within that report was a list of 33 nonbinding recommendations for program improvement.

A partial review of the 1981 Study was conducted by a subcommittee of the IAFWA in 1990. A major conclusion of the subcommittee was that the recommendations set forth in the 1981 Study still were valid (IAFWA 1981, 1990).

No comprehensive review has ever been conducted of the status of HE to determine how well the various recommendations have been implemented and/or what programmatic needs may have arisen. In 1994, at the recommendation of the Hunter Education Council (HEC), the Wildlife Management Institute (WMI) received from the U.S. Fish and Wildlife Service an administrative grant to examine the current status of HE in the U.S. and Canada.

This paper is a preliminary report on *a portion* of the results of that review. It is important to note that the goal of this review was not to *evaluate* the various programs nor to *compare* one program with another. The goals of the project were to determine the overall status of HE programs within each state and province and to make recommendations for programmatic improvements.

Methods

The review was conducted by directly interviewing people knowledgeable HE. Three target audiences were selected: directors of the agencies in charge of implementing HE programs; administrators directly in charge of the day-to-day implementation and operation of the programs; and "nonagency stakeholders," i.e., organizations, industry and/or outside agencies that have had a historic and active interest in developing and supporting HE programs. Interview questionnaires were developed for each of the targeted audiences.

The consulting firms of D. J. Case and Associates and Responsive Management were subcontracted by WMI to develop the questionnaires, collect the information and assist in the analysis. Responsive Management also was contracted to conduct a literature search on both modern educational theory and the factors related to hunting participation.

A Review Team was assembled to assist in the development of the interview questionnaires. The team consisted of HE administrators, researchers from University of Wisconsin at Stevens Point, Cornell and Michigan State University, and representatives from the International Hunter Education Association (IHEA), IAFWA, NRA, Izaak Walton League of America, National Wildlife Federation, 4-H, National Bowhunters Education Foundation, The Wildlife Society, Archery Manufacturers and Merchants Association and WMI. In addition, the project officer with USF&WS provided input and guidance.

A somewhat unique one-on-one approach was developed to collect the information. In-person interviews were the primary and preferred data collection mechanism. This format allowed for probing for additional information as topics arose. In-person interviews were conducted with 30 directors, 42 HE Administrators and 29 nonagency stakeholders. However, phone interviews were conducted when scheduling difficulties prevented in-person interviews. Phone interviews were conducted with 28 directors, 19 HE Administrators and 19 nonagency stakeholders.

In order to preserve a sense of question/answer spontaneity, interviewees were only advised of the general nature of the information that would be asked before the actual interview. However, program administrators also were sent specific questions on budgets, staffing, enrollment, etc., before the interviews. Some of this specific information was mailed to the investigators after the interviews were completed.

The interviews and preliminary analysis of them identified a number of recurrent themes. A brainstorming session was held with the Review Team to solicit the members' input on preliminary recommendations after the interviews were conducted, and the information was compiled and initial analysis had been completed.

Prior to the meeting, all of the information, including the literature review, was shared with the Review Team. Five bound documents were produced: *Hunter Education in the United States: A Review of the Literature and Research* (Duda et al. 1995); *Hunter Education Assessment Data Analysis: Volume I—Directors* (Young and Duda 1995a); *Hunter Education Assessment Data Analysis: Volume II.a—Hunter Education Coordinators* (Young and Duda 1995b); *Hunter Education Assessment Data Analysis: Volume II.b—Hunter Education Coordinators Course Summaries* (Young and Duda 1995c); *and Hunter Education Assessment Data Analysis: Volume III—Non-Agency Stakeholders* (Young and Duda 1995d). In addition, three summaries of Volumes I, II.a and III were produced and shared. The Review Team focused on the recurrent themes during its deliberations, and the preliminary recommendations were targeted to resolve them.

This paper only reports on these preliminary findings. A final report on the complete project will be available in summer, and will contain a more complete analysis of the findings *and likely some additional recommendations.*

Results

Significant progress has been made in the development of HE programs throughout the continent (Benson and White 1995). During the review, progress was identified for each of the 33 recommendations identified in the 1981 Study. However, no evidence discovered indicated that any of the 1981 recommendations either were invalid or fully implemented. Therefore, as indicated in the 1990 partial review of the 1981 Study, those recommendations are considered valid, although of less importance than those identified as a result of this review.

Recurring Themes

Twenty-two "recurrent themes" were identified in this study, and they relate directly or indirectly to 24 of the recommendations made in the 1981 Study. Six additional broad programmatic areas not identified in the 1981 Study were identified as needing attention.

The recurring themes identified, including the six new areas of concern, were: program evaluation; instructor training and retraining; course standards; minimum hourly requirements; reciprocity; course accreditation; course delivery vs. course content; experiential learning; shooting ranges; ethics/hunter responsibility instruction; new technologies; home study; advanced courses; remedial courses for violators; retraining current license holders (refresher courses); funding; customer service; marketing/promotion; public outreach; non-traditional audiences; integrating hunter education into other agency programs; and the role of the IHEA and other organizations.

Specific recommendations were made for each of these 22 recurring themes.

Programmatic evaluations and the monitoring of HE classes are frequently identified needs. While virtually every state and province reported in the questionnaire that some level of programmatic evaluation was occurring, these efforts generally are not part of a systematic plan for program enhancement (Bromley et al. 1981, Benson and White 1995).

Recommendations:

1. *Agencies are encouraged to conduct programmatic-level evaluation regularly.* Evaluations should be conducted by an outside entity familiar with HE. In the United States, a good time to conduct this review is during or just prior to development of the five-year plan currently required by the Federal Aid Program. The Federal Aid Office is the entity best suited to *coordinate* these reviews, but it should use a team approach with the assistance of and involvement from IHEA, IAFWA and state level HE coordinators/ administrators.
2. *Agencies should make internal program evaluation a continuous, regular, and integral part of every HE program.* The USF&WS's (1989) *Self-evaluation and Planning Guide for Hunter Education Programs* should be utilized as a basic program evaluation tool and upgraded to maintain its usefulness. The internal evaluation should include customer service, and program availability, content and delivery (training methods, etc.).
3. *Actual courses should be monitored in a systematic and rigorous fashion to assess content and delivery.*
4. *Agencies should measure overall HE program success against the conduct of hunters in the field.* Each agency should strive to identify specific problems, negative behaviors and public perceptions of hunter behaviors, and then develop educational/training modules to address the identified behaviors (Rohlfing 1978, Smith 1984, Bromley et al. 1988: 585-589, Benson and White 1995, Bissell and Duda 1993). Current research on the

human dimensions aspects of hunting, effective educational techniques and human motivations should be incorporated in both the problem-identification process and program development (Kellert 1976: 533-546, Applegate et al. 1984, Decker and Canaille 1990). Evaluation techniques to measure the effects of training on negative behaviors need to be incorporated in program design (Hendee and Potter 1971). Training modules should be incorporated in the most appropriate level of HE courses, i.e., basic, advanced, remedial, etc. (Ellis and Fouts 1993).

5. *Agencies should pool resources and coordinate research on the effectiveness of program content and delivery methods.*

Having skilled, effective instructors is vital to the success of HE programs. Even a program with outstanding course content and state-of-the-art equipment is rendered ineffective if the instructors are not properly trained and supported (Benson and White 1995, Jackson 1992).

Recommendations:

1. *Agencies should make training and retraining opportunities readily available to all instructors.* These opportunities should include (but not be limited to) effective educational techniques and methodologies, techniques for leading group discussions, safety procedures for live-firing experiences, program administration, and other program elements. Special emphasis should be placed on the use of home study and new technologies such as interactive video, audio tapes, computers using CD-ROM, television, etc.
2. *Agencies should enhance the training provided to prospective instructors before certifying those individuals as instructors.*
3. *Agencies should make periodic continuing education or retraining a prerequisite for maintaining instructor certification.*
4. *Agency staff should be familiar with the basic HE programs and its enrollment procedures, and made aware of the importance of having well-trained, effective HE volunteers in the program.*

The contents of the HE course as outlined in the 1981 Study remain valid. The 1996 review did not reveal any reason to believe that it is *not* still valid.

Recommendations:

1. *Hands-on live firing experience should be required in each course, and facilities should be made available to do so.* This is Recommendation 11 from the 1981 Study; it was reaffirmed in the 1990 partial review and is, by the findings of the current review. Jackson (1992) reported that this was the single most important element needed to improve HE classes. (Note: while this recommendation refers to "each course," this recommendation actually refers to each student in the course.)
2. *Agencies should supplement the current curriculum with experiential learning opportunities, such as field courses, dilemma discussion, and interactive video programs.*

A minimum hourly standard is a convenient and easily recognized mechanism to measure the overall emphasis each program places on specific topics. The number of hours of instruction contained in a course is generally acknowledged as a weak measure of the educational experience provided by the course. A more appropriate measure is the ability of the student to perform desired tasks and exhibit desired behaviors both in the classroom and in the field (Davis and McCallon 1974, Slavin 1985, Beyer 1988, Jackson 1992, Ellis and Fouts 1993, Wentz 1994). However, the 1981 Study recommended that total course length, based on the time needed to cover each topic, should be at least 9 to 11 hours. The current review concurs with that recommendation.

Recommendations:

1. *Agencies are strongly encouraged to maintain the minimum hourly standard recommended in the 1981 Study (9-11 hours).*
2. *The minimum hourly requirement should not be viewed as an obstacle to developing effective, innovative approaches to deliver the learning objectives of the program more effectively.*
3. *Agencies should recognize that the nature of student/instructor contact time may change as new technologies, experiential learning and alternate delivery methods are incorporated into existing programs.* Programs should be designed to maximize the efficiency of the 9 to 11 hours of student/instructor and student/student contact time, and emphasize those course content areas that, by their nature require, student/instructor and student/student contact, such as live-fire, field courses and dilemma discussion (Jackson 1992, Ruh 1994). Home study, using a variety of mechanisms, could be used to deliver the "factual" course content that currently is being taught in classrooms (Benson and White 1995, Wentz 1994).

Interstate certification and reciprocity continues to be an important issue among state and provincial agencies. It may become a larger issue in the future if the trend toward mandatory advanced courses continues.

Recommendation:

1. *Agencies are encouraged to adopt course standards for the basic HE courses.* This alone will alleviate many of the current difficulties. Course standards should be set by an outside organization, such as the IHEA or the Federal Aid Division of the USF&WS. The course outline found in 1981 Study should be used as the foundation.

Development of a widely accepted course-accreditation process is an emerging issue. Such a process may have potential for enhancing recruitment, program credibility and public perceptions of hunters. It also may help resolve reciprocity issues and maintain program quality. However, to focus too much effort on this issue at this time is premature. Greater program benefits would be achieved by implementing a universal course standard (as opposed to standardized courses).

Recommendation:

1. *Agencies are encouraged to begin directing resources and working with the IHEA and Hunter Education Council to determine the desirability and feasibility of developing an accreditation process.*

The current review did not ***reveal a need for abandoning or significantly changing the content or methodologies that agencies presently are using to deliver components of a HE course.*** However, it did reveal an expectation of and a desire for some adjustments and improvements in delivering the course to the students. HE programs have three separate but interrelated components—information, information transfer and information receipt. All are critical for a program to be effective (East 1970, McCarthy 1987, Beyer 1988, Ellis and Fouts 1993).

Recommendations:

1. *Agencies should incorporate new technologies and teaching methodologies into HE courses to supplement traditional methods and broaden the effective range of educational experiences.*
2. *Agencies should utilize "hands-on" experiential learning opportunities whenever and wherever possible in all courses* (East 1970, McCarthy 1987, Beyer 1988, Jackson 1992, Ellis and Fouts 1993).

"Hands-on" experiential exercises provide substantial educational benefits and are more effective than lecture-based learning for most people (East 1970).

Recommendations:

1. *Agencies should provide opportunities to involve students in experiential learning by having them involved actively rather than listening passively whenever and wherever possible.*
2. *Agencies should involve staff as well as volunteer instructors when developing experiential learning programs.*
3. *Agencies should provide volunteer instructors with adequate training in leading discussions, field course operations, live-firing procedures and other experiential learning programs .*
4. *Agencies should take advantage of the natural appeal of experiential learning opportunities and use them as tools for recruiting students to the course.*

The lack of public shooting ranges was clearly identified as a program shortcoming. Ranges play an important role for HE programs as well a potentially important tool for recruitment and retention of hunters (McConnell 1987, Dabb 1987).

Recommendations:

1. *Agencies are strongly encouraged to direct more resources toward meeting the need for public shooting ranges.* This includes utilization of existing ranges (cooperative agreements with private clubs, upgrading/enhancing existing facilities, etc.), as well as constructing new facilities as appropriate.
2. *Agencies should consider the use of portable/mobile ranges as an effective way to provide a live-firing experience in certain situations.* The use of portable/mobile ranges that can be transported to the people, rather than having fixed ranges that require people to travel, can alleviate those situations where no ranges are conveniently located (Hall personal communication: 1995). In addition, some of these types of ranges can be setup in such places as parking lots, athletic fields, local fairs and outdoor shows, to provide public exposure for the HE programs.
3. *Agencies and HE coordinators/administrators should recognize that the need for shooting ranges will become more acute as programs emphasize experiential learning opportunities.*

Next to safety, hunter ethics/responsibility is the most important aspect of HE. Ethics/ responsibility considerations are potentially incorporated in virtually every component of HE, including safety. Many instructors nationwide use trigger films, dilemma and open discussions, and/or brainstorming processes to "teach" hunter ethics/responsibility. New, innovative, long-term approaches for promoting ethical behavior are needed to enhance this area of instruction (Beyer 1976, Jackson et al. 1987, Matthews and Riley 1994: 594-595).

Recommendations:

1. *Although ethics/responsibility should permeate every HE course, specific time still should be allocated for class discussions of carefully designed dilemmas that address real-world situations.* The goal of dilemma discussions should be to give students the skills necessary to identify and understand the consequences of their actions before they make decisions (Lemming 1993, Matthews and Riley 1994: 594-595).
2. *Agencies should provide appropriate instructor training in the skilled use of dilemma discussions, etc.* (Beyer 197).
3. *Agencies should identify current hunter behaviors that are acceptable/unacceptable, and develop educational packages that will help emphasize the positive and resolve the negative* (Rohlfing 1978, Smith 1984, Bromley et al. 1988: 585-58, Benson and White 1995, Bissell and Duda 1993).
4. *All HE programs should incorporate into all aspects of all courses the core message that a responsible hunter is safe, legal, skilled, and ethical.* The topic of hunter ethics/ re-

sponsibility should not be limited to a single, separate section within the overall course (Wentz 1994).

5. *Agencies are encouraged to consider the effects that their regulations may have in causing ethical dilemmas for hunters in the field.* For example, a hunter may be discouraged from checking a game animal at a check station if agency does not adequately publicize the location of those stations or ensure that they are situated in reasonably convenient locations.

New technologies and delivery methods such as public television, video instruction, interactive video, CD-ROM, Internet, etc., are becoming increasingly prevalent and continuing trend (Wentz 1994). The new technologies are not direct substitutions for traditional teaching methods; their effectiveness is directly dependent on the skills of the instructors using them and the role they play within the context of the overall program (Beyer 1976, Wentz 1994).

Recommendations:

1. *Agencies are encouraged to investigate new technologies and delivery methods and, wherever they are shown to be effective, embrace them as complements to traditional teaching methods.*
2. *Agencies should apply new technologies so as to maximize the effectiveness of instructor/student and student/student contact.* Many of the new technologies can be used to minimize the instructor contact time needed to convey less intensive aspects of the HE course (e.g., parts of a firearm) (Wentz 1994). By encouraging more efficient use of instructor time, instructors will be able to devote more contact time to such subjects as dilemma discussions, firearm handling, etc.
3. *Whenever new technologies are implemented, HE coordinators and administrators should be sensitive to traditional instructors and the contributions that they can make to the program--especially if the new tools replace the traditional instructors' portions of the program.* Enhancing program areas such as live-firing, field courses and dilemma discussions, can effectively redirect the instructors' traditional involvement.
4. *Agencies must train their instructors to implement any new technologies that are adopted.* New technologies may not change the course *content* at all, but *delivery* of this information may be completely different.

Home study courses offer an important alternative method of delivering HE course material to students (Wentz 1994, Benson and White 1995). This method is particularly well suited for introductory material and/or supplemental material. Providing an array of options, including home study, to deliver HE is another way agencies can strive for better constituent service. Home study programs also may have public relations and outreach benefits, as well as the potential to enhance social and cultural values of hunting by encouraging family participation.

Recommendations:

1. *Agencies should support the development and evaluation of home study courses and implement those shown to be effective as optional means to deliver some of the course material.*
2. *If used, home study for the basic course should be paired with field days and compressed classroom sessions so that students can demonstrate knowledge and understanding of the material before they are certified.* A suggested structure and sequence for this pairing would be: (1) a student is sent home study material that they complete at their own pace; (2) once home study is completed, the student contacts the agency and schedules a "field day"; (3) the field day consists of a brief review of the home study material, a test on this material, a guided discussion on ethics and responsibilities, a "field" experience, and live-firing; and (4) a final exam.

Advanced courses offer the opportunity to provide hunters with continuing education, and allow for additional contact between the agency and experienced hunters who may never have attended a HE course.

Recommendations:

1. *Agencies should offer a variety of advanced and speciality courses that feature specific equipment, challenges, or opportunities.* Examples include archery, muzzle loader, spring turkey and waterfowl hunting, etc.
2. *Whenever possible, agencies should develop and provide advanced courses in partnership with other agencies and organizations to maximize efficiency and effectiveness.*
3. *There is no apparent need to make advanced courses mandatory unless there are compelling circumstances.* Instead, agencies should develop incentive systems for encouraging hunters to attend advanced courses, such as being eligible for special drawings, getting "bonus points" for limited entry permits, etc. (Benson and White 1995).
4. *If an agency makes an advanced course mandatory, the infrastructure needed for delivering the course must be in place before the mandate goes into effect, or the courses should be phased-in over time.* This will ensure that the courses are fully available to everyone who needs them. Agencies also should consider coordinating these course curricula with other states and provinces (perhaps though IHEA) to address reciprocity issues.

Developing specific courses for convicted wildlife law violators may provide public relations benefits as well as focusing additional attention on specific violations. A specific course may be more desirable than relying on the general course because it would target specific problem areas.

Recommendation:

1. *Agencies should consider the development of remedial courses for game law violators.* Many courts, with the agencies' support, currently require remedial courses in certain circumstances. Instituting this as a mandatory requirement for certain situations before hunting privileges are restored could have a significant impact on specific violations as well as public perception of hunting and hunters (P. Carr personal communication: 1994).

Periodic retraining of current hunters is an emerging issue. A portion of the public, based on public opinion polls (see Duda et al. 1995b) desires current hunters to undergo retraining. This perception may be changed by increased outreach and publicity efforts regarding existing programs. However, increased public scrutiny of hunting programs may lead to increased pressure for hunter retraining. Additional research may be useful in clarifying safety needs and public expectations.

Recommendations:

1. *Agencies are encouraged to conduct research to determine the expectations of the public concerning hunter retraining, as well as to ascertain the degree to which the public understands current HE requirements.*
2. *Agencies should encourage current license holders to participate in the basic HE course, and should emphasize advanced HE courses or consider remedial courses as opportunities to attract and retrain graduates of the basic course.*

To maintain effective HE programs, staffing needs, as well as operational funds, must increase proportional to program expansion.

Recommendations:

1. *Agencies are strongly encouraged to utilize their potential HE program funding to the fullest extent possible.* In the United States, this means utilizing the full Federal Aid HE apportionment (or equivalent state funds). As programs are expanded to meet demands, the funding should be expanded accordingly (Smith 1984).

2. *Agencies are encouraged to fund HE programs adequately to meet demands.*
3. *HE coordinator and administrators are encouraged to become actively involved in the budgeting process in their agencies and more effective at acquiring and using existing Federal Aid (and other) funds.*
4. *Agencies that are adequately addressing basic HE needs without using their full Federal Aid apportionment should consider using more of the apportionment to initiate or enhance advanced HE opportunities and other program/outreach efforts.*

Agencies should carefully examine the process,* from the customer's point of view, *that people experience when attempting to find out when, where and how to obtain HE training courses, to ensure that the process is convenient, timely, and positive. HE students *and potential students* are some of the most important and valuable constituents an agency has, and should be treated as *life-long customers.* An agency's ability to develop and maintain positive relationships with its constituents is directly related to its customer service capabilities.

Recommendations:

1. *Agencies are strongly encouraged to investigate the use of technology--from 800 numbers to the Internet--to provide access to HE program information.*
2. *Agencies are encouraged to train their staffs, including volunteer instructors, in customer-service techniques, to ensure that every public contact results in a positive experience.*
3. *Agencies should ensure that HE courses are available in a timely manner, in sufficient quantity and at the appropriate locations to meet the needs of their constituents.* This will be an ongoing challenge, and agencies need to be diligent about finding creative ways that are sensitive to special needs of these customers.
4. *Agencies and instructors should think of HE courses in terms of mechanisms to transfer information and an opportunity for students to attain and demonstrate a high level of competency.* A "class" should not be thought of as strictly a classroom with four walls and an instructor but rather, as a broad educational *experience* (McCarthy 1987, Ellis and Fouts 1993, Wentz 1994).

Agencies need to engage in marketing and promotion to find out what their constituents want and need in the way of HE programs. Stated simply, *marketing* is the process of identifying what people want or need and then providing appropriate products or services to meet those wants or needs. *Promotion* is just one aspect of marketing, and is concerned with informing the target audience that the product or service exists and how they can get it. This *does not* mean that public opinion should dictate program content. However, agencies that are able to deliver the established course content in creative or alternative ways that meet their constituents' needs and desires will be more effective than those that do not. Discovering what constituents need and providing HE courses to meet those needs still are not enough if no one knows about the courses. Agencies must also *promote* the program availability. (Note: While this is an ongoing need, it may not come under the auspices of the HE program and may not be fundable with federal funds.)

Recommendations:

1. *Information about HE courses (when, where, etc.) needs to be available to the public on a continuous basis and through a variety of different outlets so that constituents have adequate opportunity to enroll and take part.*
2. *Agencies are encouraged to investigate constituents needs and desires concerning HE programs, particularly concerning home study and new technologies.*
3. *Agencies should publicize successes achieved by HE program and students, and take advantage of these opportunities to promote HE programs.*

HE programs currently are not getting full credit for what they have accomplished in the past and what they currently are accomplishing. In the United States, certain outreach efforts may or may not qualify as Federal Aid HE expenditures. Previously, this may have limited states' abilities or motivations to promote their programs. In recent years, Federal Aid administrative staffs have promoted and, in some cases, staffed more effective outreach efforts at regional levels.

Recommendations:

1. *Agencies and HE coordinators and administrators should promote the positive aspects of the HE program.* Several ways of doing this include developing a stronger relationship with agency Information and Education staff and other media representatives, and developing special events that center around HE program and the shooting sports. (Special events that emphasize HE often generate a considerable amount of positive media coverage (S. Hall personal communication: 1995).
2. *Each agency should define what its HE public outreach objectives, and communicate those objectives to agency staff and volunteer instructors.*
3. *Agencies should develop core messages such as: "Hunting is a safe, family-oriented and enjoyable activity. We (the agency) want to make sure you get started correctly so we have developed a course that shows you how to do it safely, responsibly and enjoyably." These messages should be incorporated into agency HE and public outreach efforts at every opportunity.*
4. *Agencies should focus immediate efforts on meeting all existing unmet demands for courses and hunting opportunities.* Agencies should clearly understand that there is a difference between meeting existing, unmet demand and creating new demand (Applegate et al. 1984, Duda 1995b).

Agencies should continue to work to meet the needs/desires of women and other "nontraditional" constituents. News releases, special hunts, courses and programs such as "Becoming an Outdoors-Woman" should continue to be developed to meet demand for HE presented by nontraditional constituents.

Recommendations:

1. *Agencies should acknowledge and identify the barriers to hunting participation that currently exist, and develop programs and opportunities to reduce these barriers* (Thomas and Peterson 1993).
2. *To accommodate nontraditional constituents, agencies should consider taking additional steps such as: (a) solicit input from nontraditional audiences to determine actual barriers to participation;(b) actively recruit instructors from among nontraditional audiences, to achieve greater participation and gender/cultural balance among instructors; and (c) develop specialized courses for specific ages, skill levels, gender/ culture, and other variables as demand necessitates.*

HE has untapped potential to be a positive image-building program for the agency. As such, the HE program may provide the basis for the strongest *proactive* strategy that an agency can develop. Using HE to draw attention to and build positive image for the agency also will likely increase the efficiency of the HE program.

Recommendations:

1. *Agencies are encouraged to integrate HE into other agency programs.* Examples include "Becoming an Outdoors-Woman," 4-H shooting programs, Boy Scouts, youth conservation camps, etc.
2. *HE coordinators and administrators should look for opportunities where HE can help achieve agency goals and solve problems.* Examples include preventing specific hunting accidents, developing stronger understanding of the role of hunting and modern management programs, encouraging hunter compliance with wildlife laws and regulations (Decker

and Connelly 1990, Hammit et al. 1990, Enck and Decker 1991), and creating awareness of other conservation programs such as "Turn In a Poacher," "Conservation Reserve Program," public hunting opportunities, nongame programs, etc.

IHEA can best serve both IAFWA and the larger goals of HE by: (1) acting as a clearinghouse of information on accidents, policies and program status; (2) facilitating task forces assembled to identify emerging issues and opportunities (e.g., accreditation, reciprocity, etc.); (3) coordinating professional development training programs for instructors; and (4) identifying research areas that will lead to enhancing the effectiveness of HE programs. Other organizations that have an interest in HE should stand willing to assist the IHEA and the agencies in these activities.

Recommendations:

1. *The IHEA should develop a stronger communication network within IHEA so that it can fulfill its role as advocate for strong, effective and professionally developed HE programs.*
2. *The HEC should be revitalized and its role in identifying and resolving emerging issues in HE be defined through a cooperative effort among IAFWA, IHEA, organizations and the hunting/shooting sports industry.*

Discussion

The current review was designed to "pick the brains" of people familiar with HE programs. The results, therefore, were not particularly surprising. Nothing was uncovered that more than one interviewer did not address. Consequently, no suggestions were advanced for *revolutionary* shifts in the program content or delivery systems.

Significant progress has been made in implementing the recommendations put forth in the 1981 Study. Virtually every HE program has grown. However, much refinement is possible and desirable.

The proposed recommendations of this review represents, in many ways, a call for the maturation of HE programs. They also present a challenge to agencies to do some soul-searching to determine how serious they are about *educating hunters* to meet resource objectives, needs of participants and societal expectations.

Society has changed significantly since the programs were first implemented. Demographic changes are well documented. While the core information that a hunter needs to be safe and responsible has not changed radically, the delivery systems for transferring information have. HE programs need to adapt to changes in society and technology in order to continue to deliver quality, effective programs.

While not radical, the changes recommended may be more difficult to implement than those of the 1981 Study. The current recommendations are largely directed at enabling programs deliver their products in a more effective, efficient, consistent, targeted and user friendly manner. To be successful, agencies (with few exceptions) will be required to dedicate more funds, staffing and energy than currently are provided. Special focus will be needed for program evaluation, service, training of the instructors and provision of experiential learning experiences for students. However, significant program and resource benefits can be expected if these recommendations are implemented with ingenuity timeliness and priority.

Conclusion

While current HE programs have made great progress, this review identified 22 "recurring themes" that require attention. Recurrent themes relate to 24 of the 33 recommendations put forth in 1981. Six additional themes relate to areas not covered by the 1981 Study.

HE has been and will continue to be one of the most powerful proactive tools an agency has at its disposal. However, it has not reached its full potential to produce safe, responsible and ethical hunters or to solve specific problems identified within the hunting community. To do so will require increased and continued investments in program design, development and delivery.

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Retaining Likely Dropouts from Hunting: New York's Apprentice Hunter Program

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Declining participation in hunting has been a concern of state wildlife management agencies for several years. During the 1980s and early 1990s, both the number of hunters and the proportion of hunters in the general population have declined nationally (Heberlein and Thomson 1991, U.S. Fish and Wildlife Service [USFWS] 1991, Decker et al. 1993). These declines were predicted as early as the 1960s (Outdoor Recreation Resources Review Commission 1962). They occurred and persist despite numerous agency-sponsored efforts aimed at reversing them (International Association of Fish and Wildlife Agencies unpublished data). Besides loss of wildlife-related benefits for citizens, these trends indicate erosion of financial and political support for some wildlife management activities.

In New York, the number of hunting licenses sold (an index of hunting retention) has declined about 30 percent since 1980 (New York State Department of Environmental Conservation [DEC] unpublished data). Further, the number of persons attending hunter education courses annually (an index to hunting recruitment) has declined more than 50 percent over the same period (DEC unpublished data). Brown et al. (1987) suggested that declining trends in hunting participation were likely to continue without programmatic intervention.

The New York State Department of Environmental Conservation and the Human Dimensions Research Unit (HDRU) at Cornell University collaborated in the late 1980s to develop and evaluate an intervention called the Apprentice Hunter Program. This program was aimed at youths ages 12 to 17 who had expressed an interest in hunting by attending a mandatory hunter education course, but who were unlikely to purchase a hunting license or continue hunting after a few years. The program sought to help youths who had expressed an interest in hunting gain positive hunting experiences that we hypothesized would increase hunting retention and maintain the range of wildlife-related benefits experienced.

Cornerstones of the Apprentice Hunter Program

The program was built on a conceptual model developed by HDRU from a combination of moral and cognitive development theories (e.g., Pomerantz and Decker 1986), innovation-adoption theories (e.g., Purdy et al. 1985) and empirical evidence from previous research (e.g., Applegate and Otto 1982, Decker et al. 1984, McCarty 1985, Purdy et al. 1985). The model describes changes in an individual's involvement in hunting (Figure 1). It suggests that an individual passes through stages of involvement from general awareness of the activity, to developing an interest in it, trying it, and continuing and enriching involvement over time. Alternatively, an individual may stop involvement and begin again later, or may stop altogether (Decker and Purdy 1986). A longitudinal study that followed a cohort of new hunters in the 1980s verified the model (Purdy et al. 1989). With this research-based knowledge as background, we knew that a key to a successful Apprentice Hunter Program would be to bridge youth from "interest" or "trial" stages into a "continuation stage," keeping them from becoming sporadic hunters or dropouts.

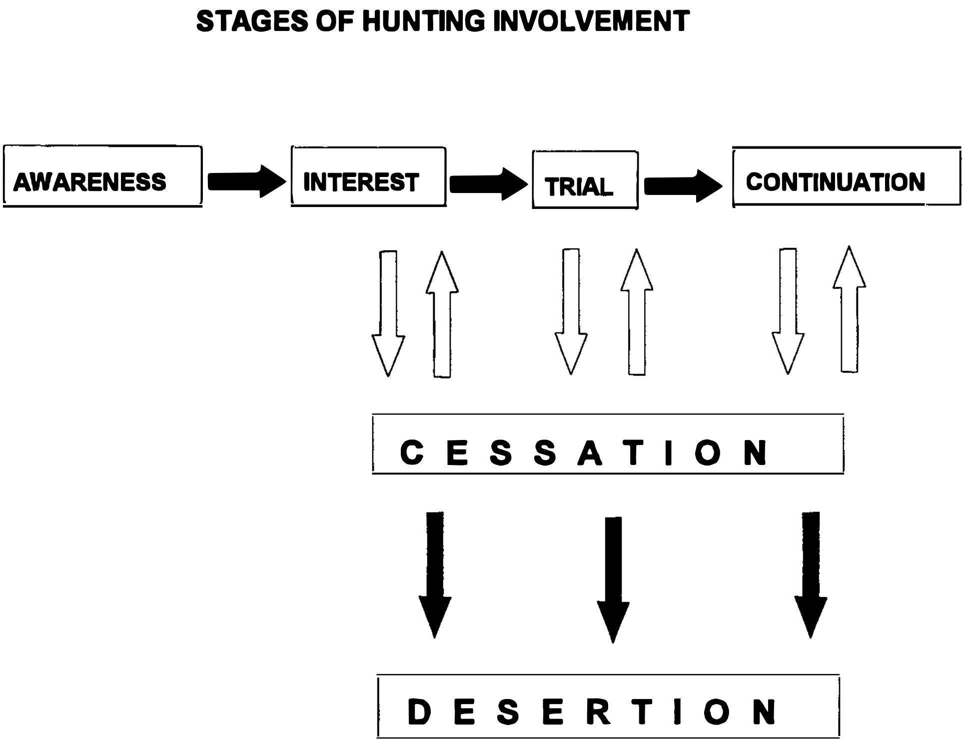

Figure 1. Conceptual model of the process of adopting hunting as a long-term activity (from Decker and Purdy 1986).

Long-term research identified lack of hunting apprenticeship experiences and lack of social support for hunting, especially by family members, as two critical barriers to participation in hunting for both youths and adults interested in hunting (Brown et al. 1981, Decker et al. 1984, Purdy et al. 1985, Purdy and Decker 1986, Purdy et al. 1989). Lack of apprenticeship experiences and lack of social support were found to be more important in preventing persons from moving into the continuation stage of hunting than other barriers, such as low game abundance, lack of access to hunting areas, cost of licenses and hunting equipment, and complex hunting regulations. Thus, the concepts of apprenticeship and social support were cornerstones for program development.

Apprenticeship was defined as a set of pre-hunting or early hunting experiences occurring with someone who is a role model or mentor for hunting.

Apprenticeship involves providing youth with a way to learn hunting skills and knowledge from someone they respect. The concept of apprenticeship as applied in the program has four parts:

1. Multiple experiences are required for knowledge and skill development. One-time field events are not sufficient.
2. Youths unfamiliar with hunting should be introduced to it carefully. They should be allowed to assume firearms handling and shooting responsibilities when they are mature enough to do so.
3. Small group sizes are optimal. Youths with limited hunting knowledge and skills can benefit most from personal attention.
4. The total hunting experience should be emphasized, from planning and preparation, through field activity, to reminiscing about the hunt. New hunters should be exposed to the broad range of satisfactions that are associated with hunting.

The concept of social support is more difficult to put into action. Based on previous research and social science theory (e.g., Bandura 1977, Bronfenbrenner 1979), we defined social support as linkages between youths who are interested in hunting and other persons who: (1) help further develop that interest; (2) initiate the youths into hunting; (3) accompany the youths afield; and (4) reinforce the experience through post-hunt interaction. Social support has these important parts:

1. Linkages work best if they involve persons who are meaningful in the lives of the youths, especially family members and same-age friends, or those who become meaningful through mentoring relationships.
2. Youths should feel that participation in a hunting-related program is a sign of strength, not a weakness. The Apprentice Hunter Program is not a "remedial program." Rather, it is designed to help develop tools necessary for youths to enjoy hunting and become long-time participants.
3. Social support involves developing positive linkages between a "hunting setting" established by a hunting mentor and other important settings for the youths, including their home, school, work and peer-group settings. As important individuals in each of these settings demonstrate support of the youths' interest in hunting, the youths will feel more secure about hunting.

Although some program designers recognized that both short- and long-term benefits could be obtained by including in a retention program those adult hunter education graduates who were likely to drop out or never start hunting, youths were the initial target audience for the Apprentice Hunter Program. Youths were thought to represent the future of hunting in New York and account for about 50 percent of graduates from hunter education courses (Pomerantz and Decker 1986). The program specifically targeted youths who had an interest in hunting, but who did not have apprenticeship experiences or positive social support. Those youths were least likely to fulfill their interest in hunting.

Evaluation of the Apprentice Hunter Program

This innovative program was initiated by DEC as a pilot program in two regions. Southeastern New York was chosen as a pilot area because its urban and suburban character was expected to provide a large number of youths who had an expressed interest in hunting (i.e., attended a hunter education course), but who did not have hunting apprenticeship experiences or positive social support for hunting. A pilot area was selected later in westcentral New York to replicate trial of the program in an area with greater *a priori* support from sportsmen's groups and agency staff, and to reveal potential differences that might occur in an area staff characterized as being more rural.

We used a formative evaluation strategy that provided constant review and assessment of effectiveness during all stages of the pilot program from development through implementation (Kraus and Allen 1987). This strategy provided opportunities to modify or strengthen the program as it was being developed and implemented. It also provided opportunities for understanding why various aspects of the program succeeded or failed. The evaluation played an important role in DEC's decisions about ways to enhance the program and whether to expand the program statewide.

Our application of this evaluation strategy had four stages. First, we examined whether the program was based on an appropriate model developed from theories and empirical evidence for the specific context in which the program was to be conducted (Enck et al. 1988). Second, we examined the proposed program design prior to implementation to determine if the design adhered to the conceptual model, complied with DEC policies, was logistically feasible and had adequate decision criteria to determine success or failure (Enck and Decker 1990). Third, we systematically monitored the program as it was being put into effect (Enck and Brown 1992, Enck 1993). Finally, we determined impacts of the program on participants and reasons for success or failure. This paper focusses on a subset of those impacts.

Description of the Program

A full description of the program plan can be found in New York State Department of Environmental Conservation (1989) and Enck and Decker (1990). The Apprentice Hunter Program was designed by a team of DEC staff which included persons who: (1) had a vested interest in the outcome and could benefit from having ownership in the program; (2) could make program-level decisions; (3) would be involved in implementing the program; and (4) had experience recruiting and working with volunteers. The program was designed to be a one-year experience that matched adult mentors having at least seven years of hunting experience with youths aged 12 to 17 who were interested in hunting but were unlikely to initiate or continue hunting. During the year-long program, these mentor/apprentice pairs were to meet a minimum of 15 times, and the mentors were to help the apprentices learn hunting skills and knowledge. Mentors also were to help build a positive social support network for their apprentice.

The program design document (DEC 1989) outlined all major steps for implementing the program. These included: (1) locating and inviting candidate youth to participate; (2) locating and screening mentors; (3) overcoming expected logistical and practical barriers to the pairing process; (4) training mentors to help them understand their roles in this "pilot" program and to ensure that youths received the intended elements of apprenticeship and social support; and (5) officially ending the program to complete apprentices' sense of fulfillment. Detailed descriptions of actions taken during implementation, and evaluation of those actions have been reported elsewhere (Enck and Brown 1992, Enck 1993, Enck 1994). The remainder of this paper reports findings associated with the impact of the program on youths who participated in it.

Program Outcome

From 1990 through 1993, 3,192 youths were screened at hunter education courses in the two pilot areas. Youths were eligible for participating in the pilot if they met *any* of the following criteria: (1) answered "no" to the question "have you ever been hunting? (the term 'hunting' means that you went afield with others who were hunting even though you may not have carried a firearm)"; (2) checked any of the statements "I tried hunting, but did not like it, so now I feel I will not develop into a hunter," "I tried hunting, but now I cannot decide if I will develop into a hunter," "I previously thought of myself as a hunter, but now I feel I will not continue to hunt" or "I previously thought of myself as a hunter, but now I cannot decide whether I will continue to hunt"; (3) answered "no" to either question "do any of your family members currently hunt?" or "do any of your friends currently hunt?"; or (4) selected response category "never" for either question "if you get a hunting license, how often do you think your family will go hunting with you?" or "if you get a hunting license, how often do you think your friends will go hunting with you?"

Of the youths screened, 1,482 (46 percent) lacked apprenticeship experiences and/or social support for hunting and, thus, met criteria for being invited to participate in the program. Numerous problems were encountered by staff attempting to invite candidate youths to participate, including processing delays, geographic inconsistencies between mentors and apprentices, and general mismanagement. The formative evaluation helped to overcome many of those problems (Enck 1993). About 500 youths were invited by mail and/or telephone to participate in the program within a year after they were screened. More than half of those did not respond in a timely manner. About 90 youths expressly declined the invitation or their parents refused to allow them to participate. During the 1992 to 1994 evaluation period, 119 youths agreed to participate in the program. Forty-seven of these were matched with a mentor and comprised a treatment group. A random sample of youths not matched with a mentor (n = 54) comprised a control group.

Program impacts were evaluated by examining criteria DEC intended to use to decide whether to expand the program statewide, and a variety of other behavioral and attitudinal variables. Only three of DEC's decision criteria are discussed here. Insights about other behavioral and attitudinal variables are incorporated into the conclusions and implications.

We compared the youths' stage of hunting involvement (Decker and Purdy 1986) at the time they completed the hunter education course with their stage of involvement at the end of the evaluation period (Table 1). Youths in the treatment group progressed further in their stage of hunting involvement than youths in the control group (Mann-Whitney test, $z = 1.58$, $P = 0.05$). We also examined the percentage of years each youth purchased a license after attending a hunter education course (Table 2). No differences were found between treatment and control groups (Mood median test, $X^2 = 2.599$, $P = 0.11$) with respect to consistency of license purchase. Finally, we examined the mean number of days hunted by youths in the treatment and control groups using

Table 1. Change in stage of hunting involvement for youths who were matched with mentors in New York's Apprentice Hunter Program (treatment) and youths who were not matched (control).

Change in stage	Treatment		Control	
of involvement[a]	n	Percentage	n	Percentage
Regressed two stages	0	0.0	5	10.4
Regressed one stage	0	0.0	1	2.1
No change	3	16.7	11	22.9
Progressed one stage	8	44.4	21	43.8
Progressed two stages	7	38.9	6	12.5
Progressed three stages	0	0.0	4	8.3
Total	18	100.0	48	100.0

[a]Stages of hunting involvement considered here are 1 = cessation, 2 = interest, 3 = trial and 4 = continuation.

Table 2. Consistency of license purchases for youths who were matched with adult mentors in New York's Apprentice Hunter Program (treatment) and youths who were not matched (control).

Consistency of license purchase	Treatment		Control	
	n	Percentage	n	Percentage
Never hunted	7	16.3	5	9.6
Hunted <50 percent of possible years	7	16.3	10	19.2
Hunted 50 percent of possible years	8	18.6	2	3.8
Hunted >50 percent of possible years	3	6.9	11	21.2
Hunted every year	18	41.9	24	46.2
Total	43	100.0	52	100.0

Student's t-test. Licensed youths in both groups hunted a similar number of days in 1992 ($\bar{x}$ treatment = 9.2, $\bar{x}$ control = 7.0, P = 0.45) and in 1993 ($\bar{x}$ treatment = 10.9, $\bar{x}$ control = 6.6, P = 0.15). However, licensed youths in the treatment group ($\bar{x}$ = 14.3) hunted more days than the control group ($\bar{x}$ = 6.2) in 1994 (P = 0.01).

Conclusions and Implications

The Apprentice Hunter Program has the potential to benefit hundreds of youths who otherwise would not act on their interest in hunting. Each year in New York, about 30,000 persons attend a mandatory hunter education course, and about half of those are youths. Given that 46 percent of youths who attended a hunter education course in the two pilot areas met criteria for participating in the Apprentice Hunter Program, about 7,000 youths potentially could benefit from the program annually. If only about a quarter of those were invited and agreed to participate, as in the pilot program, up to 1,700 youths could be involved in the program each year. This number could be doubled based on our experience with youths who became aware of the program without taking the hunter education course and requested information about it.

This magnitude of impact will not reverse the declining trend in license sales in New York (DEC unpublished data). Declining trends in license sales are a result of patterns of participation behavior occurring over the last two decades. Changes in the retention of graduates from hunter education courses will not influence very quickly either total number of licenses sold or trends in sales.

One reason for this is the dynamic nature of hunting participation. In New York, about half of the persons who complete a hunter education course consistently purchase a hunting license year-to-year, about a third purchase hunting licenses only sporadically and the remainder either drop out after a short time or never start hunting (Purdy et al. 1985, 1989). The Apprentice Hunter Program was aimed at potential dropouts and those who never start. It is not likely to reduce sporadic behavior.

Another reason that agency-sponsored retention programs like the Apprentice Hunter Program may have difficulty increasing license sales is that programs implemented todate have not been able to replicate easily the range of conditions that produce the family-initiated, experience-rich "traditional hunters" (Decker and Mattfeld 1988) who are most likely to be long-term participants. "Traditional hunters" are initiated into hunting through many local hunting cultures that both produce and are held together by shared beliefs about appropriate reasons for hunting, kinds of satisfactions sought from hunting and, in general, what it means to be a hunter. Each local hunting culture likely succeeds in developing hunting interest in youths and helping the youths act on that interest because youths develop their beliefs about hunting largely through interaction with adults who reinforce hunting interest in the community's youths. The system is self-perpetuating.

Through qualitative aspects of our evaluation, we observed that apprentices and mentors had various notions about motivations for hunting, what satisfactions they sought and what they thought hunting was about. In those cases in which apprentices were matched with mentors who seemed to share those notions about hunting, the apprentices responded positively to the mentors' efforts and the interaction succeeded. When apprentices were matched with mentors who did not seem to share their ideas about some of the important elements of hunting, the interaction failed. We also found that agency-sponsored training of mentors was most effective when it provided mentors with support that was consistent with their notion of what a hunter is, rather than trying to train mentors to be something they are not.

Further, the kinds of programmatic assistance that may be appropriate for state wildlife management agencies to provide to youths differ from those that may be appropriate for other groups or individuals to provide. For example, some youths seem to have difficulty developing a mentoring relationship with nonfamily hunters, but others seem to respond quickly to efforts of trained strangers to provide social support and apprenticeship experiences.

Our experience with the Apprentice Hunter Program suggests there is no "one-size-fits-all" solution to the challenge of increasing hunting retention. We believe agency-sponsored programs can work for some but not all youths who have unmet interests in hunting. The various ways that persons are recruited into hunting and the conditions that influence whether they are retained are very difficult to recreate programmatically. Nonetheless, efforts like the Apprentice Hunter Program can provide opportunities for youths to enrich their hunting involvement by developing additional skills and experiencing social settings that are supportive of their hunting interest.

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Adoption of Home Study Hunter Education to Enhance Learning

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Home study gets hunters personally and actively learning about hunting, safety, wildlife identification, wildlife management, game care, survival and first aid, laws and regulations, ethics and responsibility, and how to use hunting tools properly. This paper reviews implications of research about home study hunter education and its early adoption in hunter education programs, placed within a context of recruitment and retention of hunters.

Recruitment, Training and Retention

Recruitment, training and retention of hunters are good for society, landscapes, wildlife and our natural resources professions. Society values open spaces and abundant wildlife. Hunting requires that wildness and diversity are part of landscape management objectives, whether in the forest, rangeland or on agricultural lands. Wildlife management needs hunters. And, hunters need education to improve knowledge, skills and attitudes.

Without changes in current hunting opportunities and management, hunters may decrease on a per-capita basis as humans urbanize, but it likely will remain as part of our cultural heritage and a desired recreation by more hunters than the supply of harvestable surpluses will provide. Hunters will insist that wild places and wildlife remain for enjoyment and use, now and for future generations. Recruitment, retention and training of hunters will continue to be a need. Reaching out to hunters with education and diversified hunting offerings is no different than promotion and education practiced by other interest groups or businesses. Training is easiest when recruitment and retention are high.

Young and old hunters are likely to enjoy their activities more and stay involved with hunting when they are more knowledgeable, skillful and have attitudes that were developed over time. Active learning is better than passive learning and active, dedicated hunters want to learn in active ways. Home study puts action and personal involvement into the students' study programs, covers the same materials that wildlife agency hunter education administrators and volunteer instructors want to be taught, simulates real world situations, provides a way for students and instructors to evaluate learning, and uses the written format that still is a universally accessible and acceptable form of communication.

Obstacles and Opportunities for Hunting and Hunters

Hunting is not easy! Hunting faces three obstacles that provide opportunities for educational intervention:

1. hunting *opportunities* which provide access, enjoyment, success and dedication are restricted;
2. *rewards* and reinforcement for hunting are lacking from peers, family, friends and society; and
3. *training* that gets hunters involved needs to be improved.

Opportunities decrease as society urbanizes, and opportunities are confounded by competing activities from school and sports, friends and phones, work and worrying, television and latest trends, computers and cars. Opportunities are decreased by longer distances to hunting areas, less private access, and more hunters and other users on public lands. Hunter training courses are more difficult to schedule, since schools and clubs offer fewer opportunities, nights and weekends are filled, and rural or urban travel to classes can be time consuming. Opportunities for success are hampered by decreased populations of farm game and waterfowl and the need to allocate big game opportunities via drawings to distribute a large demand over a smaller supply. Opportunities are restricted by states which only allow one license per species per year even though hunters are willing to use archery, rifles, muzzleloaders and handguns in different seasons. Some opportunities are denied because wildlife professionals are concerned with the time and administrative costs to work more seasons or they cannot work more according to labor laws.

Rewards and reinforcement for the cultural contributions of hunting and the heritage of hunters need to be positive. Friends, family, peers, wildlife and land agencies, conservation organizations, the media, and citizens need to understand and represent hunting as a positive contributor to conservation. Hunters should be viewed as honorable, ethical and respectful; but, they must earn their image, and education helps! Agencies and organizations must promote good images and appreciate hunters and hunting traditions. Non-hunted species management and more holistic approaches to land stewardship are appropriate, but should not be implemented at the expense of the traditional heritage provided by hunting and hunters without compelling reasons. Hunting always will be questioned because it takes life. It is reassuring to understand, however, that managed hunting and hunters are components of traditional and less intrusive ecological and anthropological systems compared with other human activities that exploit and change nature. In modern cultures, where recreational hunting is practiced, society provides sound hunting management systems and programs for protection of wildlife and landscapes compared with cultures where wildlife are diminished and even excluded through subsistence use or where agriculture and industry predominate. Modern hunting and related management is good for society, and that story needs to be told with more vigor and commitment. Hunters need their historical and current efforts to be noticed and rewarded. Recruitment and retention of hunters should follow.

Training of hunters through the basic government-based hunter education programs has reached a crossroad where it could expand or retrench. Basic hunter education has trained more than 20 million hunters in North America, met several goals for safety and increased the scope of educational topics to include many aspects of hunting and outdoor behavior; however, the primary delivery system of lecture-based education by volunteer instructors has changed very little (Benson 1992, Hilaire 1994). Expanded "advanced hunter education" evolves slowly, either through the basic programs or as unique offerings in North America (Benson and White 1995). Home study is part of that evolution process with training for instructors (Benson 1980) and now for students in the basic course (Benson and Hilaire 1995). Critics believe that wildlife agencies should not have mandatory training and should offer shorter classes. The logic is that freedoms are restricted with mandatory programs, entrance requirements may reduce hunter recruitment and few other recreational programs require that participants learn from government about how to participate. Proponents of hunter education believe that hunters benefit greatly from the learning: safety is increased and accidents are reduced; hunters learn about hunting, perhaps their first and only formal or informal contacts; and hunters discuss proper ethics and responsibility. Hunter education helps hunters to become motivated and it starts a learning process for them to be more dedicated. We know, however, that students are not necessarily retained as hunters after they take the basic classes (Enck et al. 1996). Basic hunter education courses are highly instructor-centered and do not provide enough student-centered training about knowledge, skills and attitudes in the short duration of classes. Even if hunters were well trained and motivated by educational activities, other obstacles to hunting initiation, satisfaction and continuation must be overcome.

The Role of Home Study to Address Obstacles to Education

The goal of this paper is to explain the merits and document the adoption of home study where hunters learn at home (in addition to field and classroom) by using our new *Hunter Education Home Study Workbook* (Benson and Hilaire 1995) to accompany the standard *Hunter Education Manual* published by Outdoor Empire Publishing, Inc. (OEPI). The manual is used in 44 states. The premises are that learning is better when it is active (doing), student-based (involvement), spread over time (long-term learning), and complementary to apprenticeship systems where hunters learn from families, friends, peers and instructors.

Apprenticeship examples include the intensive training systems of Europe, opportunities in North America, such as "Becoming an Outdoors-Woman" and "Wisconsin's Student-Hunter Project" (Thomas and Lueck 1996, Craven et al. 1996), club and community programs, instructor-based hunter education classes, 4-H, Scouts, or other programs which provide hunters with participant-oriented, activity-based learning opportunities. Home study prepares students for those experiences, gives them concrete exercises to develop knowledge, skills and attitudes, and it is in a written format that can be made available to nearly everyone with basic reading skills.

Research Results about use of the Hunter Education Home Study Workbook

Home study for hunter education was developed and evaluated at Colorado State University (Hilaire 1994) as an educational tool designed to provide broad-based and systematic content to courses, which would open classroom time for hands-on activities, discussions and opportunities to cover a greater depth of subject matter. Test performance with home study was compared to teacher-taught classes in Colorado, Texas and New Jersey which were chosen to represent varied hunter education programs in North America. More than 200 learning objectives were compiled, reviewed and approved by the hunter education administrators from participating states. Questions and activities were created from these objectives and assembled into a home study hunter education workbook. The workbook was produced and used in conjunction with OEPI's seventh-grade reading level hunter education manual because 44 of 50 state hunter education programs use some form of OEPI's manual. Missing information that was needed to achieve the learning objectives was added to the workbook. A 125-question written evaluation instrument was compiled from examination questions used in Colorado, Texas, New Jersey and Virginia based on learning objectives and the amount of time spent in classes on the following topics: ethics, safety, wildlife identification, game care, wildlife management, survival, specialty hunting and laws. True/false questions were changed to a multiple choice format to decrease the chance of a correct guess. A limitation of this study was that treatment and control subjects were only compared regarding learning within the cognitive domain using the 125-item test of knowledge. Changes in skills and attitudes also may have occurred.

Seven-hundred and ten students from Colorado, Texas and New Jersey were randomly divided and assigned into three test groups: home study (n = 279), teacher-taught (n = 205) and pretest/control (n = 226). More students were assigned to home study to assure an adequate sample of the various age groups taking hunter education. Contrasts using analysis of variance revealed no statistical difference in exam scores between the home study (Mean = 85.44, SD = 11.30) and the teacher-taught groups (Mean = 87.25, SD = 8.71) but did reveal a significant difference between both these groups and the control group (Mean = 73.46, SD = 13.45). Scores evaluated based on four age groups (10-14, 15-20, 21-30 and 31+ years) revealed progressively better scores on the written exam for all topics as age progressed until age 20 years or more, when scores were less variable. A follow-up survey was given by state facilitators to home study students and a few instructors who participated with home study to get their inputs about the program.

Students (n = 217) reported that completion of the home study workbook averaged 10.8 hours. The overall program was rated 3.6 by students from a range on 1 being "terrible" and 5 being "great." When given an array of choices about why home study might be chosen for learning, students responded as follows: they preferred to study on their own (28 percent); lived far away from classes (24 percent); were involved with school activities (23 percent); they could learn more on their own (16 percent); and 9 percent responded that they would never consider a home study course again. Some participants (57 percent) received help with the home study workbook from: a father (35 percent), friend (25 percent), mother (15 percent), other (14 percent, usually a spouse), brother (8 percent) or sister (4 percent). Forty-three percent had no help and 16 percent had more than one helper.

Instructors (n = 30) scored home study a 3.2 from a range on 1 being "terrible" and 5 being "great." When instructors were given an array of choices about how home study might fit into their state's hunter education program, responses were as follows: it could be an option for students in rural (distant) areas (67 percent); students could progress at their own rates (63 percent); it could help educate more than one learner at once, and the workbook could be used as a class workbook (53 percent); home study would allow for more class discussion time (50 percent); it could allow for greater subject depth to be covered and could be used as an option for students involved with extra-curricular activities (47 percent); it could be an option for adult learners reluctant to attend a class, and could increase hands-on time in class (40 percent); it could be an option for out-of-state hunters requiring certification in another state but not in their own (37 percent); it could be an option for bilingual education (30 percent); home study had no place in hunter education (20 percent); and 17 percent thought that home study made a student's learning more consistent and could be used to balance periods of high and low enrollments.

Adoption of home study on a formal basis was initiated by sharing results with hunter educators at the Hunter Education Association annual meeting in 1994, by publishing a summary of results in the *Hunter Education Instructor* (Benson 1994) and via letter to hunter education administrators. A full report of the study was submitted for publication in The Wildlife Society Bulletin in late 1995 and was published as part of advanced hunter education opportunities (Benson and White 1995).

Adoption Theory for Home Study Hunter Education

The next step for home study hunter education—as an aid for recruitment, training and retention—is widespread adoption of educational offerings within the hunter education community. It is an innovation, however, which may be viewed negatively as a change to the status quo and a threat to some instructors. New programs and innovations often receive concerns, pessimism and even rejection because of misinformation, misconceptions, misunderstandings, fear of personal rejection and loss of job or status. In reality, home study merely uses existing materials and structures the students' and instructors' time to result in more productive outcomes.

Innovations typically are communicated through certain channels, over time, among the members of a social system. Individuals progress through five stages: awareness, interest, evaluation, trial and adoption or rejection of the innovation (Rogers and Shoemaker 1971). Awareness and interest in hunting can be created by wildlife agencies, persons responsible for hunter education, the hunting industries, hunting clubs and organizations, and outdoor media. Individual instructors and hunters can evaluate their interest in home study with the benefits of our evaluation from three states as a foundation.

The evaluation stage is key to whether the innovation is adopted or rejected. There are five characteristics of an innovation which help to determine the outcome of this stage: (1) relative advantage: degree to which an innovation is perceived as better than the previous idea; (2) compatibility: consistency with the values, past experiences and needs of the receivers; (3) complexity: difficulty of use and understanding; (4) use: can be experimented with on a limited basis; and (5) observableness: the results are visible to others (Rogers and Shoemaker 1971). Instructors should be trained to use home study properly and students should be informed of its availability through active promotion. Home courses will be tried and their results will be shared formally and informally in an evolutionary process toward acceptance or rejection. The study which follows was undertaken to determine the status of adoption early in the evaluation and implementation stages approximately one year after comparative research was finished and results were disseminated to hunter education administrators.

Methods

A 10-question survey was mailed in November 1995 to hunter education administrators from the 13 states where copies of the *Hunter Education Home Study Workbook* (Benson and Hilaire 1995) were purchased during 1995. A telephone follow-up survey was conducted of nonrespondents.

Results

Adoption of home study for hunter education began with 10,028 workbooks purchased by hunter education administrators from 13 states which shall remain anonymous. Administrators from 12 states (92 percent) responded to the survey and 5 reported that the program was not yet in place and, therefore, they had no data about implementation. Seven states adopted home study in some form with six states reporting a total of 1,056 student participants. No state advertised the availability of home study, although one state administrator said that individual instructors advertised it. Results of the study evaluating home study versus teacher-taught classes for hunter education (Benson 1994, Hilaire 1994) were read by seven respondents and not read by two. Respondents from four of seven states reported that hands-on activities were conducted in classes before home study was used and no state added more hands-on activities now that some of the required information could be learned via home study.

The *Hunter Education Home Study Workbook* (Benson and Hilaire 1995) was used by seven states in the following ways:

1. As a supplement to the regular course and optional for each instructor to use.
2. As an alternative to those who cannot attend a traditional course.
3. On a trial basis by 12 instructors who used it as an option.
4. To meet needs of outlying communities where students complete the workbook then get together for a test, and to catch up on "into season" panic education during September.
5. As an experiment conducted in one region of the state only.
6. Currently developing criteria for use of home study.
7. By providing workbooks along with student manuals to anyone who wants home study rather than attending a class.

The workbook was considered effective for teaching students by six state administrators with no respondents indicating otherwise. Comments from four states are paraphrased as follows:

1. It was an excellent alternative course offering and had its place.
2. Students are going to have to look through the manual; they may know more about the manual than instructors; it will benefit people who work odd hours; students can work at their own pace.
3. Very good material; only just a few things aren't applicable to our state; instructors want to hold off on wildlife identification materials.
4. I like the comments, interaction between student and instructor; well written.

Testing procedures were reported by six states and included:

1. Exactly the same procedures as for a regular course (written and range).
2. Test in district offices, turn in workbook, and shoot; hope to expand to 4-H offices.

3. Students get together for hands-on portion; use visual aids, etc., may have video program, too.
4. Exactly the same as regular test, about four-hour test; students get together for practical test, see film and take written test.
5. Workbook is checked for completion; regular examination is administered and live firing is required.
6. Two instructors developed an "entrance exam" and we use the standard state exam at the end of the course.

Discussion

Incorporation into Existing Delivery Systems

Adoption began in a short period of time without much promotion. Administrators used varied approaches for implementation, but each reported success. For change to occur, innovators need support, creativity, the willingness to take calculated risks and hear continued success stories of how home study is working to bolster their efforts toward adoption. If one compares home study hunter education with a similar and well-known delivery system (i.e., drivers licensing programs), one realizes that home study not only is appropriate for the basic hunter education course, exam and field test, but also could be considered as a delivery system for remedial programs.

Home study hunter education could easily adapt to and become part of other delivery systems currently being evaluated, including "satellite" programs and interactive video. In a satellite program, the first half of the course focuses on the basics of hunter education and the second half is more specialized, covering a specific area such as turkey hunting, deer hunting or small game hunting— the student's choice (J. Wentz personal communication: 1994). Home study could be used for both parts of the course where knowledge is the key factor for learning. Skills training and testing could require face-to-face contact. The use of interactive video, such as the FATS (Firearms Training Systems, Swanee, GA) or DART systems (DART Int. Inc., Englewood, CO), or interactive computer screen technology (Greenhouse Interactive Systems Inc., Provo, UT; OQUIRRH Productions, Salt Lake City, UT) combined with the home study hunter education workbook offer other options for combined delivery systems in hunter education. Use of technology such as audio and videotapes and cable television also could add additional information and varied stimuli to learners, thus enhancing the printed word.

Summary and Recommendations for the Future

Home study provides more involvement by students in the learning process before class, prepares students for classes, and allows class time to be used for subjects where teacher and student should interact: firearms handling and shooting, discussions about ethics and responsibilities, and advanced topics. It adds consistency of learning for all students and better access to education. Performance of students on a 125-question test of knowledge—more than is now required to get a hunter education card—was compared between home study and teacher-taught classes in Texas, Colorado and New Jersey and no significant differences were found. Home study students used the standard hunter education manual from Outdoor Empire Publishing Inc. and a new workbook (Benson and Hilaire 1995) evaluated through Colorado State University, while teacher-taught students used the standard manual and had the benefit of a teacher in the standard hunter education classes taught within each experimental state. It was not surprising that home study worked because the National Home Study Council (Valore and Diehl 1987) reported that "...all of the research studies published since 1920 indicate that correspondence students perform just as well as, and in most cases better than their classroom counterparts." Home study is used throughout the world for military, K-12, university, trade, vocational and avocational training. Not surprisingly, some hunter education instructors and state administrators have questions about whether home study could replace traditional classes and weaken hunter education. The opposite should happen if home study is administered properly.

Persons with state wildlife agencies, clubs, organizations, volunteers and even businesses could provide materials for students to study at home. Participants would fill in the workbooks, present them for review and/or pass the written test required by state wildlife agencies. Then, they become eligible to take classroom instruction. During classes, instructors and students build on existing knowledge—and other learning that likely was gained, but untested at this point in the educational process—from home study and learn new information , practice new skills and develop new philosophies. Instructors can use simulated situations and handle firearms, rather than repeat—through lectures—what students already learned from the manual and workbook.

Drivers are tested after they studied at home, then they drive to demonstrate proper skills and attitudes: hunter education can be handled in a similar manner. Home study is recommended as a learning supplement for hunter education as part of a program that includes hands-on training and/or evaluation associated with firearms and discussions about hunter ethics and responsibility. Student-centered learning should increase with home study and class time can be used more efficiently and effectively when students have attained a consistent and greater knowledge level prior to and during classroom activities.

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Training and Retaining Women in Traditional Fish and Wildlife-based Recreation

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Background

The "Becoming an Outdoors-Woman" (BOW) program was started in 1991 to address the fact that women have not had the opportunity to learn outdoor skills in the traditional ways that men have (Thomas and Peterson 1990). The program was designed to teach fishing, hunting, shooting and non-harvest outdoor skills in a non-threatening atmosphere (Thomas et al. 1995). That first workshop was well-received (Thomas and Peterson 1993, 1994) and the program spread to 34 states and 2 Canadian provinces by 1995. While the program definitely provided an opportunity for women to learn outdoor skills and women took advantage of the opportunity as quickly as workshops became available, questions remained regarding the effect that workshop participation had on the behavior and attitudes of participants. Did workshop participants continue their activities beyond the clinics? Did the workshops change participant attitudes? Did attendees participate in the outdoor recreation economy? To answer those questions, BOW national sponsors funded a graduate research project. Those sponsors included the Archery Manufacturer's Organization, National Shooting Sports Foundation, National Rifle Association, Safari Club International, Rocky Mountain Elk Foundation, North American Hunting and Fishing Clubs, Wildlife Forever, Cabela's, and Gander Mountain, Inc.

Methods

It was the hypothesis of this research (Lueck 1995) that attending a "Becoming an Outdoors-Woman" workshop would encourage participants to continue with outdoor activities at a level that they would not have attempted without the clinic.

In order to determine whether this hypothesis was valid, a survey was developed and mailed to all persons who had participated in a BOW workshop in 1991, 1992 and 1993 in Wisconsin, Nebraska, Arkansas, Texas, Oregon and Washington.

There was a possibility that women who had an interest in outdoor activities would respond in the same way as BOW workshop participants. To give a basis for comparison, and to determine whether attendance at a workshop made a difference, a control survey was developed.

Survey Objectives

The survey was intended to answer three questions: (1) had BOW workshop participants increased or decreased their use of learned outdoor skills during the year after they attended the clinic? (2) did workshop participants' attitudes toward shooting sports, angling and other outdoor activities become more positive or negative since attending the workshops? and (3) did participants purchase or receive outdoor equipment and clothing for themselves since attending the workshops?

Survey Dissemination

The total number of participant surveys sent was 761. Four hundred and forty-nine (59 percent) usable surveys were returned. Four hundred control surveys were sent to individuals who had expressed an interest in the program, so were on the mailing lists, but had not attended a workshop. Two hundred and four (53 percent) usable surveys were returned.

Results

Demographics

There was no significant demographic difference between the two populations of respondents. Virtually the only difference was attendance at a BOW workshop.

A couple of notable demographics surfaced. More than 65 percent of the survey respondents in both groups were childless or had adult children. This may mean that these women are more likely to have time to be involved with outdoor activities. In addition, more than 90 percent of the two groups of respondents were Caucasian. This does not reflect the ethnicity of women in the country overall; perhaps an effort needs to be made to target minority populations for attendance at BOW workshops.

Activities

Both workshop participants and the control group were asked to indicate changes in participation level in outdoor activities. Significant difference between groups was shown in all but one activity associated with classes taught at BOW workshops. Hunting with dogs was the only activity where a difference was not shown. Overall, participants showed an average increase of 18 percent in these activities. Participant respondents showed an average decrease of less than 2 percent. The control group showed an overall increase average of 12 percent and a decrease of 8 percent.

The percentage of increase in some activities almost certainly was attributable to the workshops. For example, fly fishing by participants increased 14 percent as opposed to a 4-percent increase by the control group. Shotgun target shooting and hunting, rifle hunting, and bow target shooting and hunting all showed strong increases by participants. Turkey hunting is another example of a specialized class that had an effect on participant respondents. While only 2 percent of the control group showed an increase, 9 percent of the participants increased in this activity. Perhaps the most notable increase came in orienteering, a growing sport that may be unfamiliar to novice outdoor enthusiasts. While 8 percent of the control group increased this activity, a sizable 27 percent of participants reported an increase in orienteering.

An important point to consider in interpreting these data is that each participant only attended four sessions at a workshop, not all 20 activities listed. Therefore, those 30 women who reported an increase in muzzleloader activities, for example, may represent a low percentage of respondents, but include a high percentage of the women who actually enrolled in muzzleloading.

Workshop participants reported a lower decrease in participation—less than 4 percent in any listed activity. The control group, on the other hand, showed decreases of 17 percent and 15 percent even in camping and hiking, indicating that BOW workshops also prevent women from dropping out of non-harvest activities.

Sixty-one percent of participant respondents said the workshop was important or essential in increasing outdoor activities.

Marketing

Sponsors and sporting goods retailers were very interested in the marketing component of the surveys. Eighty-seven percent of the participant respondents and 83 percent of the control group said they bought outdoor equipment or clothing. Items bought and percentages of each group were very similar. The only item with a significant difference, probably directly attributable to workshops, was Dutch ovens—a class taught at the workshops. Fishing gear, shooting/hunting gear and camping equipment were about equally represented in purchases.

It is notable that "fit my size and ability" was a highly cited factor in purchases, and a factor that probably affects many women. Ill-fitting equipment and clothing were cited as barriers to participation by women in hunting and angling (Thomas and Peterson 1990).

Demonstration at a workshop did appear to affect purchases. Sixty-four percent of participants said that some or all of the equipment and clothing they bought was the same brand as demonstrated at a workshop, and 72 percent said that demonstration influenced the purchase. Fifty-six percent of participant respondents said they did acquire clothing or equipment from a BOW sponsor or contributor, and an impressive 82 percent said they would make an attempt to buy from a sponsor or contributor.

Attitudes

Both groups surveyed were asked about their changes in attitudes toward various outdoor activities. The participants were, on average, significantly more positive than the control group. An especially notable effect of the workshops was in the area of the shooting sports. Sixty-four percent of participant respondents said they now feel more positive toward the shooting sports, whereas only 47 percent of the control group responded positively. In addition, only 5 percent of the participants responded that they felt more negative toward shooting sports, while an appreciable 21 percent of the control group responded negatively. In a related question, 86 percent of participants said they were likely to hunt or fish in the future, with 76 percent of the control group giving a positive response.

It was believed that exposure to outdoor skills would awaken an appreciation of nature and conservation in participants. It was encouraging to note that 76 percent of participants responded that they now were more interested in environmental protection. Only 51 percent of the control group gave a positive response.

For most survey statements, the attitudes of the participant and control respondents were significantly different. However, both groups were adamant about one thing: they would use their outdoors skills more in the future!

Discussion

Attendance at a "Becoming an Outdoors-Woman" workshop had a positive influence on the factors surveyed. In many cases, participants discovered an interest and ability in an activity they might otherwise never have considered. In addition, they tended to continue with these activities, with almost no dropout rate.

There is the possibility that more-experienced women attended the first BOW workshops in any state, intrigued by the opportunity to meet other women with the same interests and the chance to be in on the ground floor of something new. More true novices may attend the clinics in subsequent years. Women who are repeat attendees often bring a friend or two with them. These friends, or participants who have heard about the BOW workshop from a previous participant, may have less experience in outdoor skills.

In addition, the first workshops were advertised in more male-traditional avenues, such as flyers in sport shops, the sports sections of newspapers and hunting magazines. These articles may have reached women who already were somewhat experienced in outdoor activities. In recent years, however, the nontraditional press has included articles in the "Living" section of newspapers and in health and fitness or travel venues (Brotman 1994, Hanson 1995) that have reached more urban, less-skilled audiences.

If this less-experienced audience is indeed the group that is being reached by subsequent workshops, changes in activities, attitudes and purchases may be even greater than those of the first group of participants surveyed.

Future Directions

State fish and wildlife agencies, conservation groups, and industries have demonstrated through their cooperation in the "Becoming an Outdoors-Woman" program that women are interested in participating in wildlife-based recreations. We do not need to "recruit" women in the military sense of the word. There are women out there who want to join the ranks of outdoor enthusiasts, if they only knew how to get started. This research also has shown that workshops of this nature can act as a retention tool, by rekindling and maintaining an interest that might otherwise wane. We would offer that retention is at least as important as recruitment.

There is much more that needs to be done. This year, the BOW program will directly touch the lives of 6,000 participants. Many more women will try to enroll, but will be turned away for lack of space. We need to find ways to provide more opportunities. Agencies will be tempted to move to one-day workshops as a way of stretching resources. We are cautious about the potential success of that as a tool for recruitment and retention. As Matthews (1995) points out, one-day type clinics may not produce the social and emotional changes that transform the participant into a member of the outdoor community. As an alternative to the "one-day" solution, we suggest that agencies try to foster partnerships that allow them to offer multiple three-day workshops. Minnesota, Wisconsin and Michigan all have committees that are experimenting with these partnerships.

Programs need to be developed that take women from the BOW setting and ease them toward independence in the field. These programs will move us toward the Matthews model of multiple efforts and an infrastructure that fosters long-term participation. Some states have experimented with this, including New Mexico where women were offered a free cow elk hunt; and Texas Parks and Wildlife, where bird hunts and backpacking trips have been organized for BOW graduates. Other states have worked to develop organizations that foster outdoor activities for women. South Dakota, as an example, has started Outdoor Women of South Dakota. It would be a great idea if existing conservation groups would take the initiative to move women from these workshops into their ranks. Still other states are experimenting with one-day or weekend follow-up courses to BOW. Wisconsin is offering a "Women's Whitetail Weekend," and Iowa has developed "Iowa Women's Outdoor Adventures."

Many of the barriers that have existed for women could be removed at the youth level. Iowa's Outdoor Journey for Girls is a good example of one such program. Girls who complete that four-day program are both hunter-education and aquatic-education certified. The program is fully enrolled each time it is offered. This program should tell us that more girls and women would take hunter education if they could take it in a less-threatening setting. We also need to recruit more women into the ranks of hunter education instructors.

In conclusion, the "Becoming an Outdoors-Woman" program is one model that shows that programs can be developed that successfully train and retain wildlife-based recreationists. The job that lies ahead is labor-, money- and equipment-intensive. Models that are not labor-, money- and equipment-intensive will not work. Recruitment, training and retention of wildlife-based recreationists must be a full partnership between agencies, industry and conservation organizations.

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Overcoming Constraints to Women's Participation in Consumptive Uses of Fish and Wildlife

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A variety of factors have converged over the last few years to increase agencies' interest in supporting women's participation in consumptive uses of fish and wildlife. Addressing the interests and needs of women participants in activities such as fishing and hunting raises some questions and presents some challenges. Will agency programs and educational communications that have worked for men be effective for most women? A large body of research-generated knowledge suggests not. In general, women differ from men in their acculturation, communication preferences and learning styles (Philbin et al. 1995), making tenuous any assumption that programs effective in meeting the needs of or satisfying one gender will do so for the other.

Our purpose is to discuss a theoretical framework that can be used to examine motivations and constraints influencing women's participation in consumptive uses of fish and wildlife. The framework can guide research to aid management agencies in the design of educational communication programs that enhance women's participation in consumptive uses of fish and wildlife.

We focus on "consumptive uses" of fish and wildlife because a considerable knowledge base has been generated on motivations of hunters and anglers (who are predominately male) upon which we encourage building further with a focus on women. We hope that, with little modification, the theoretical framework can be applied to women's participation in other natural resource-based activities, such as wildlife viewing or camping.

Motivations and Constraints of Women Who Want to Participate in Consumptive Uses of Fish and Wildlife—A Review

Leisure Constraints Faced by Women

Jackson (1988) defined a leisure constraint (sometimes called "barrier") as anything that inhibits a person's ability to participate in leisure activities. Researchers have identified three general types of constraints to leisure participation: (1) external constraints, such as physical or economic impediments; (2) internal constraints, such as psychological barriers; and (3) social and relational constraints (Goodale and Witt 1989). These constraints are not "insurmountable," but rather are obstacles through which one can "negotiate" (Jackson et al. 1993).

Gender long has been recognized as a significant variable affecting leisure behavior. We use the term "gender" because it refers not just to whether one is biologically male or female; the term "encompasses the social expectations and cultural definitions associated with one's biological sex" (Jackson and Henderson 1995: 33). Thus, it is not one's biological sex, but the way in which one's gender is defined and experienced in society that creates circumstances that may be perceived as constraints to leisure participation (Shaw et al. 1991). Evidence exists that women have less time for leisure than men do. Women are differentially constrained by household obligations and family commitments (Witt and Goodale 1981). The "ethic of care" (Gilligan 1982), a theory of moral development that generally applies to women, explains women's role as the primary caregiver in the family, revealing how family commitments and family structure can constrain women's leisure. Characteristics such as age and income also interact with family structure to alter constraints perceived by women (Jackson and Henderson 1995).

Motivations and Constraints of Consumptive Users

Motivations of consumptive users of fish and wildlife (not women specifically) have been examined in several studies (e.g., for hunters [Decker et al. 1984, Decker and Connelly 1989] and anglers [Siemer and Brown 1994]). Decker et al. (1987) proposed a theoretical framework for wildlife recreation involvement in which motivations of consumptive users were described as fitting one of three motivational orientations: (1) *achievement*, where hunters or anglers primarily want to meet some standard of performance, such as bagging a deer of a certain size or sex or catching a fish of a certain species and size; (2) *affiliative*, where participants primarily seek camaraderie with others and the opportunity to strengthen personal relationships through involvement in hunting or fishing; or (3) *appreciative*, where participants want to relax, enjoy nature and escape from everyday problems by engaging in hunting or fishing. It was found that a person may hold any combination of these motivational orientations, but usually one orientation dominates for the activity of concern (Decker and Connelly 1989).

Constraints on participation for consumptive users of fish and wildlife include those identified in the general leisure constraints literature, such as lack of leisure time, costs, etc. Constraints more specific to hunters and anglers include regulations placed on them by the management agency as to where, when and how they can hunt or fish. However, recent research on duck hunters in New York indicates that regulations may not always be the most limiting constraint; other factors, such as cost and competing demands on time, may be more important in some situations (Enck et al. 1993).

Theoretical frameworks developed to explain the motivations and constraints experienced by general populations of hunters and anglers have been based on samples composed largely of men because of the relative number of men versus women in populations of these users. (Eight percent of hunters and 28 percent of anglers were women according to the 1991 National Survey of Fishing, Hunting and Wildlife-associated Recreation [U.S. Fish and Wildlife Service 1993].) How applicable are these models to the experiences of women? Research on leisure constraints faced by women would indicate that differences in available free time, the importance of family responsibilities and the sociocultural role of women all should contribute to explaining the constraints perceived by women who want to participate in consumptive uses of fish and wildlife. These factors are largely absent in the models developed thus far for hunters and anglers.

A theoretical framework that describes why women come to participate in consumptive uses of fish and wildlife requires research focused on women. Such research is limited, but some evidence exists of differences in antecedents to hunting involvement experienced by women compared with men (McCarty and Kelley 1985), and some support exists for the hypothesis that women more frequently go afield for affiliative reasons (Decker et al. 1984, Jackson et al. 1989). A recent study of women hunters in Texas supports the hypothesis that more women depend on spousal hunting participation (83 percent) compared with men (15 percent) (Steen 1995). Women viewed hunting as "an opportunity to bond with family in an outdoor setting" (Steen 1995: 43).

In 1990, many barriers faced by women who wanted to participate in hunting and fishing were identified during a conference on the topic; these included lack of suitable equipment, insufficient time, paucity of female role models and sociocultural pressures against participation (Thomas and Peterson 1993). Subsequently, a program was designed to reduce some of the barriers faced by women and encourage their participation in consumptive uses of fish and wildlife. This program, Becoming an Outdoors-Woman (BAOW), has been implemented in a number of states since 1991. Attendees at the first BAOW workshop held in New York provided us with an opportunity to learn more about the motivations and constraints felt by women with an interest in outdoor recreation activities.

Women's Views of Motivations and Constraints to Hunting and Fishing Participation

Interviews were conducted with three members of New York's BAOW workshop steering committee (as a pretest) and with 19 of the 88 women who attended the first workshop in 1994. Because of the limited time available for interviewing during the weekend workshop, we conducted the interviews with small groups of women rather than one-to-one. All interviews were taped with the consent of participants and later transcribed for analysis. These interviews were useful in developing a theoretical framework, our primary objective at this time, but the self-selection of women attending the workshop and the number of interviews obviates generalizability of results. Research with more representative samples from populations of women interested in consumptive uses of fish and wildlife will be needed to test hypotheses suggested below.

Motivations

Primary motivations expressed by the women interviewed included their desire to be outdoors, close to nature and enjoy the peace and quiet found outdoors. They wished to escape from the everyday stresses of work and household chores by being outdoors; they wanted an opportunity to relax. Interviewees often mentioned that the outdoor activity itself was less important than having a change of pace. "Sometimes I don't go fishing to catch a fish. Sometimes I just go to get some peace and quiet."

An important aspect of the outdoor experience for these women was learning new skills. Proficiency in these skills provided senses of accomplishment, security and independence (i.e., confidence that one can take care of oneself in the outdoors and be comfortable doing it). Some women also said they received satisfaction from showing men that they could be accomplished in outdoor skills.

Women interviewees also identified the importance of having a challenge. The challenge was not always about shooting something big or catching a big fish, but rather about executing a skill well and deriving a sense of accomplishment in doing so.

Constraints

The most commonly mentioned constraint to participation in outdoor activities was lack of leisure time. Many women reported that both paid work and household responsibilities left little time for outdoor activities.

When leisure time was available, the next most commonly mentioned barrier was lack of knowledge and skills to be able to feel *comfortable* and *safe* outdoors. Some women did not know anyone with the skills, ability, time or desire to teach them. Some also were unaware of where they might be able to find information. More often they knew someone with knowledge and skills (e.g., boyfriends, husbands) but did not want to learn from them because they were poor teachers and had a "know-it-all" attitude; the women said they felt intimidated and were unwilling to ask questions.

The women we interviewed expressed a desire to be physically "comfortable" in the outdoors. They often referred to wanting to be warm. Many women observed that lack of clothing and equipment that fit appropriately or kept them warm prevented them from enjoying the outdoors.

Barriers, especially to hunting, often were expressed in a sociocultural context. Comments such as "women aren't supposed to be in the outdoors" and hunting is "a man's sport" reflect an image of men and women in traditional roles. Women said that often their husbands would go hunting or fishing, leaving them at home to take care of the children. It was their "job." Women also reported that the need to complete household chores after hunting or fishing decreased their desire to participate.

Safety was an issue mentioned in some form by all women. Four categories of safety issues emerged. The first, mentioned by very few women, was concern about encountering dangerous animals, such as bears, poisonous snakes, etc. The second safety issue related to becoming lost in the woods and obtaining help in an emergency. Many women at the workshop signed up for classes to learn how to use a map and compass to help them address this safety issue. On the evaluation forms, women also suggested having courses in first aid and survival skills, reiterating their concerns about this issue. The third safety issue was encountering other hunters exhibiting dangerous behaviors. Women expressed reservations about hunting on public land because of hunter safety; they had heard too many stories of "near misses" while hunting on public land. The last safety issue, the possibility of being sexually assaulted when afield, was mentioned in some way by most women. For example, one woman said she felt fearful when she went fly fishing by herself and ended up on a stretch of river with four men (strangers). This reflects a general social barrier for women, as expressed by Henderson (1991: 372), "over a period of time, women accept the fact that they cannot do certain activities alone or at certain times of the night or day."

Physical strength also was a perceived barrier to participation. As an example, one woman had the impression that an individual had to be "superhuman" to do anything outdoors.

The workshop also seemed to attract women who expressed a "latent demand" for hunting or fishing. Because of cultural constraints (e.g., only men hunt) or their traditional role in the family (e.g., men go out while women stay home with the children), they had not previously had the opportunity to hunt or fish. They had developed interest and acquired knowledge, but had not had the opportunity to learn or practice the necessary skills. They now were at a different stage of their lives, however, where either through death of a spouse or divorce, the cultural constraints or family obligations were diminished so they were able to explore these interests. They wanted to learn the skills to be independent and self-sufficient. Being comfortable and feeling safe were important issues. Some say "a companion would be nice, but I don't need that." The existence of this group of women shows the circumstantial nature of leisure constraints.

Motivations and Constraints Framework

Shaw (1994) notes the androcentric nature of early leisure theories and the resultant need to develop new theoretical frameworks which take into account both women's and men's experiences. The framework we propose below is only a beginning, a starting point. The ideas are based on previous literature and findings from the limited qualitative research we conducted with women in New York.

The overall framework has seven parts that contribute to a series of decisions leading to increasing levels of involvement in a leisure activity (Figure 1), similar to the Decker et al. (1987) adaptation of the classical innovation-adoption model of Rogers (1995). The model begins with a person's leisure interests, which are shaped by antecedent motivations and constraints. If interest in an activity exists, then whether a person tries the activity is determined by circumstantial facilitators and constraints. If the trial experience is positive, the person moves to the continued involvement stage. How long a person continues with an activity and her level of involvement depend on circumstantial constraints and facilitators similar to those affecting the trial stage. How-

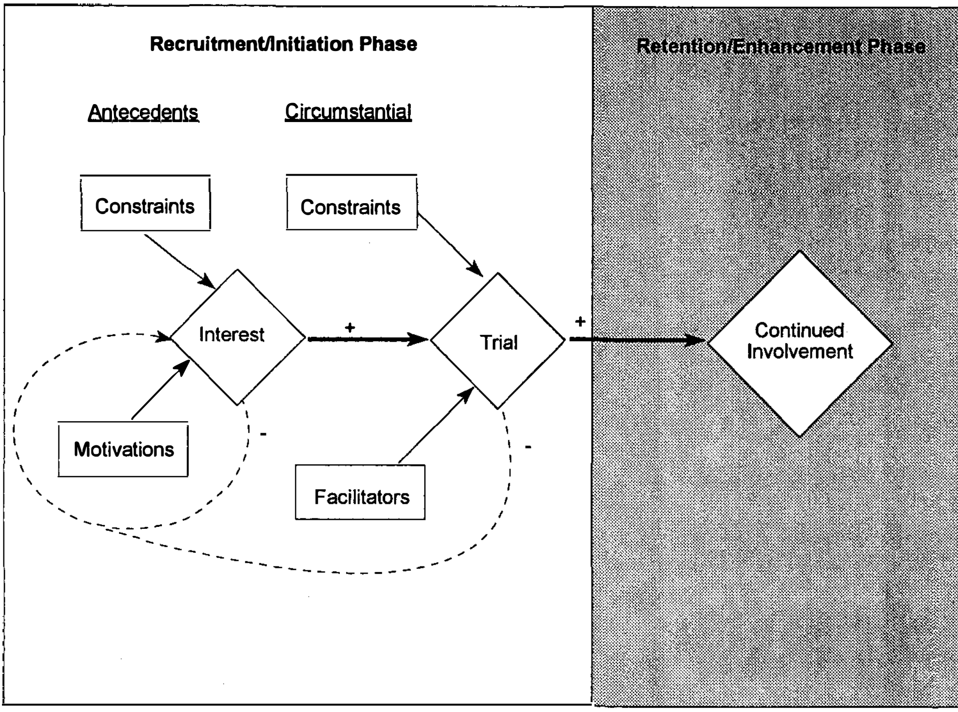

Figure 1. Proposed theoretical framework for examining motivations and constraints to participation in leisure activities (adapted from Rogers 1995 and Jackson et al. 1993).

ever, for the purposes of this paper, we will concentrate on the initial stages of involvement up to trial of an activity (unshaded portion). We have named this part of the model the "recruitment/initiation" phase and named the second part of the model, which refers to continuing involvement, the "retention/enhancement" phase. As the labels imply, both phases can be affected by agency programs, but further discussion here will focus only on the recruitment/initiation phase.

Interest Development

Interest is considered a psychological state. Research has indicated that leisure interests are a product of a balance between antecedent constraints and motivations (Jackson et al. 1993). We suggest in Figure 1 that, if motivations are greater than constraints, sufficient interest will be present and the individual will move toward the trial stage.

Antecedent Constraints

Crawford and Godbey (1987: 122) discuss intrapersonal barriers as being antecedent constraints on leisure preferences. "Examples of intrapersonal barriers include stress, depression, anxiety, religiosity, kin and non-kin reference group attitudes, prior socialization into specific leisure activities, perceived self-skill, and subjective evaluations of the appropriateness and availability of various leisure activities." Gender roles for women can be an antecedent constraint to their participation in hunting or fishing. Women we interviewed at the BAOW workshop in New York had experienced some of these antecedent constraints, such as lack of skills, concerns about physical strength and sociocultural norms of "women aren't supposed to be in the outdoors."

Antecedent Motivations

The general description of motivations proposed by Decker et al. (1987) and discussed previously in this paper, seems to fit women well for two of the three motivational orientations—appreciative and affiliative. The women we interviewed want to spend time outdoors enjoying the natural world (appreciative motivation) and some of them go outdoors to spend time with their spouse or friends (affiliative motivation). The third orientation described by Decker et al. (1987) was achievement. While the women we interviewed expressed a desire to be proficient at certain outdoor skills, they did not view the process as being a competitive one. Success in the sense of bagging game was rarely mentioned. Rather, these women wanted to learn and practice skills in a supportive environment and wanted to be proficient at them so they could be independent. Our interviews support the idea of achievement as proficiency, but not as competition with others. So the idea of three major types of motivations seems appropriate for women, but further research is needed on a broader spectrum of women to ensure that their motivations fit this framework as well.

Trial

If interest in the activity is positive, the person moves to the trial stage. Whether a person actually tries an activity also depends on the result of the balance between circumstantial constraints and facilitators.

Circumstantial Constraints

Circumstantial constraints may include some of the same antecedent constraints, such as lack of skills or adherence to social norms against participation. However, additional constraints also may affect the level of participation. These include leisure time, resources, finances, facilities, personal safety, obligations and control. The women we interviewed mentioned all of these constraints to some extent, but higher-priority competitors for time was most prevalent. Many women reported that both paid work and household responsibilities left little time for outdoor activities.

Safety is a constraint we also want to highlight because it is particularly relevant to women. Previous androcentric models have not emphasized safety, but it was a concern of all women we interviewed and should be examined in future research and carefully considered in programs developed to reduce constraints faced by women.

Circumstantial Facilitators

Facilitators to trying an activity include money, leisure time, facilities, opportunity for social interaction, etc. These also are many of the same things that can be viewed as constraints. Knowledge of the availability of a program such as BAOW may be enough of a facilitator to make the balance go in favor of participating in a trial experience (i.e., attend the program).

Facilitators and constraints change as situations change. As children become adults, possibly have families and become senior citizens, their motivations change, and the number and intensity of constraints they feel change. The importance of changing circumstances led us to identify women with a "latent demand" for hunting. This latent demand transforms to expressed demand upon entering a stage in their lives when social norms or family obligations no longer constrain their motivation to participate.

Serving the Needs of Women: Research Summary and Recommendations

Accurate understanding of the motivations and constraints important to women who want to participate in consumptive uses of fish and wildlife may be a vital missing element for agencies' strategies to increase participation. To gain such an understanding, a conceptual framework that integrates existing knowledge of factors influencing women's leisure choices and participation should be helpful. Some knowledge exists that aids identification of women's needs (e.g., Thomas and Peterson 1993). Our interviews identified additional constraints for a selected audience, but verification of the comprehensiveness of the constraints identified to date needs to be pursued with a broad array of women.

The motivations research conducted by Decker et al. (1984, 1987) identified different motivational types. Quantification of the extent to which different motivational types occur among women and the number of women who face different constraints would help define the potential audiences for programs such as BAOW. It is likely that a comprehensive strategy to address the needs of women will employ a set of programs aimed at diminishing constraints and enhancing facilitative factors among various types of women. Studies using the model we propose can help agency program planners: (1) target segments of women with "latent demand"; and (2) uncover the important constraints and necessary facilitative factors that a program can address. This knowledge can be put to use in program design. For example, BAOW attracts one type of participant that we identified in our interviews, i.e., those with a "latent demand" for hunting and fishing. Research on participants at eight BAOW workshops (who responded to a mail questionnaire after the workshop) found that more than 60 percent were childless or had adult children (Lueck 1995). Seventy-four percent of attendees at the most recent New York BAOW workshop were childless or had adult children (K. Stang personal communication: 1996).

We believe that priority areas to investigate include: (1) assessing the size of this group with "latent demand" in the general population; (2) determining whether the number of BAOW workshops being offered is meeting the demand that could be produced by this group (apparently not, because most BAOW workshops are full and some have waiting lists [Lueck 1995]); and (3) determining if other types of programs are needed to reach women in families, with small children or single mothers. The primary leisure constraint faced by these women presumably is family responsibilities. If programs were developed that reduced this constraint, possibly by accommodating children, what might the level of demand be for such programs? One obvious benefit of programs that include children might be the development of fish and wildlife recreation and conservation interests in children as well as women.

Management agency goals might include increasing numbers of license buyers, providing participants with more days afield or providing a broader range of constituents with benefits from wildlife resources. Realistic goals can be set by developing estimates of the number of people who would have interest in a certain program and identifying what constraints agency programs could reasonably be expected to reduce. Past research has identified a "social world of hunting" (this concept also could be applied to fishing), where those who do not go afield in pursuit of game animals receive benefits from their association with hunters and hunting (Stedman et al. 1993). To be considered a core member of the hunting social world, an individual who does not hunt has to participate in hunting-related behaviors, have social contact with hunters, share key beliefs with hunters and perceive personal benefits related to hunting. Stedman et al. (1993) found that 5 percent of New Yorkers fit this definition of core nonhunting members of the hunting social world. It is this small group, we believe, that is the most likely to be reached and to be open to programs by management agencies. They have some barriers to participation, but overcoming those barriers seems possible.

After identifying motivations and constraints of women with consumptive-use preferences, strategies to overcome the constraints can be identified. Some areas that should be explored include: (1) educational communication programs targeting women; (2) hands-on skills workshops; (3) building networks for social support; and (4) long-term apprenticeship experiences. For example, the New York Department of Environmental Conservation paired youths who showed an interest in hunting but lacked social support with "master hunters" for a year-long apprenticeship experience. The program successfully increased youths' days afield in succeeding years after the appenticeship experience (Enck et al. 1996). One needs to evaluate whether such an intensive effort is necessary and appropriate for certain groups of women. Any program developed for women should have an evaluation element built in that can serve program improvement purposes *and* contribute to refining the model proposed.

Management agencies intending to modify or develop policies and educational communication programs that support women (and men) who want to participate in consumptive uses of fish and wildlife will find it challenging to set realistic goals for those policies or programs. The research community can contribute by helping agencies identify the constraints faced by women and the likely numbers of women experiencing those constraints. Program development then can focus on reducing critical constraints and encouraging women's participation to the degree they desire.

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Systematic Strategies for Recruiting, Training and Retaining Hunters and Anglers

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Increasing emphasis on recruiting, training and retaining hunters and anglers can have positive effects on society and wildlife conservation. Recruitment issues can be controversial, but in my experience, the controversy surrounds personal definitions of what recruitment means, rather than actions taken to enhance it.

Recruitment, in its simplest biological definition, refers to "movement into a population" (Davis et al. 1980). Hunter and angler recruitment, in my opinion, means using a marketing approach to make hunting and fishing more accessible and more enjoyable for those people who want to participate.

Declining participation in hunting, for example, may not mean there has been a decline in interest. In Ohio, studies reveal that 15 percent of youths ages 12 to 17 have some type of hunting experience, but 34.3 percent of nonhunting youths said they would like to try it (Miller 1993). Nearly all of the teenagers, 97 percent, support firearm safety training for hunters, while 50 percent said they did not have time to take a mandatory course. Additionally, 63 percent knew someone who would take them hunting, while 53 percent needed more information on how to get started or find hunter education courses.

The good news is that we, as government agencies, have created many of our worst problems, so we also have the power to overcome them. Fish and wildlife agencies can do a better job of recruiting, training and retaining hunters and anglers by applying systematic strategies to agency operations. People who are interested in hunting and fishing may not start due to real or perceived barriers and the existence of other recreational options that compete for people's time. Recruitment issues for an agency involve measuring demand, understanding potential customers, providing opportunities that the customer values and removing real or perceived barriers to participation.

Training and retention needs often are discussed separately from recruitment, but systematically applied strategies generally apply to all three as components of hunting and fishing participation. It would be difficult, for instance, to do a good job of recruiting new hunters if agency programs ignored training and retention needs.

Agencies must involve all personnel in efforts to improve hunting and fishing participation. The Ohio Division of Wildlife (ODOW), through comprehensive planning processes and research, has been successful implementing new programs that facilitate participation. In this paper, I am proposing general guidelines, programmatic principles and specific recommendations for organizational units within fish and wildlife agencies that are based on Ohio's approach to recruitment, training and retention. Then, I describe examples of systematically developed efforts to improve hunting and fishing participation in Ohio.

General Guidelines

- Involve the entire agency in plans that address participation.
- Reduce barriers to participation.
- Program the agency to create recreational opportunities.
- Increase use of human-dimensions research.

- Focus on behaviors of people as related to hunting and fishing motivation.[1]
- Instill a customer service attitude throughout the agency.

Programmatic Principles Related to Training Strategies

- Strategies must be capable of serving large numbers of people.
- Use multiple delivery systems.
- Develop partnerships that can deliver mutually beneficial programs.
- Use marketing tools to target audiences and change behavior.
- Create long-term opportunities and mentorships.

Recommendations for Agency Directors and Administration

- Communicate participation concerns to all employees as part of mission and goals.
- Allocate more resources for plans that respond to those goals.
- Insist on a customer service attitude throughout the agency.
- Evaluate current programs and drop or change those that are not needed.
- Train employees to create and nurture partnerships.

Recommendations for Fish and Wildlife Managers/Biologists

- Share research and survey findings with Information and Education (I&E) personnel.
- Consider I&E as a management tool—identify problem behaviors to change.
- Assist I&E with training for volunteers, partners and internal staff.
- Consider effects of management on quantity and quality of opportunities provided.
- Consider effects of management on participation and behavior.
- Listen to all current and potential participants, not a vocal special interest.
- Study human-dimensions research and do more of it.
- Gather information for I&E through existing research and surveys.
- Think in terms of managing populations of hunters and anglers.
- Help design evaluations for I&E programs.

Recommendations for Law Enforcement

- Make regulations clear and easy to understand.
- Consider dropping unnecessary or outdated regulations, but....
- Pay attention to traditions for opening days, etc.
- Assist I&E with student and instructor training programs.
- Identify problem behaviors and target audiences for I&E objectives.
- Promote positive attitudes of officers when checking hunters and anglers.

Recommendations for Information and Education

- Use agency plans and directives as a basis for I&E plans.
- Develop plans that solve problems instead of plans that provide for general education.
- Study curriculum development and training principles, then apply that knowledge.
- Make evaluation a consistent and meaningful part of your operations.
- Study human-dimensions research, marketing, psychology and education.
- Target specific audiences and behavioral objectives.
- Empower others through partnerships, grants and training; give them credit.
- Have the strongest customer service attitude within the agency.

Case Studies of Hunter Recruitment, Training and Retention Programs in Ohio

Mourning dove. Legislative approval listing mourning doves as game birds gave Ohio hunters a new opportunity in 1995. Prior to the season, ODOW offered dove hunting clinics taught by

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[1]Agencies should use the models identified by Kellert (1980), Brown et al. (1987) and Decker et al. (1984, 1986). Additional insights are available from hunter-responsibility training materials developed by Robert M. Jackson that discuss five phases of hunter motivation. Kellert's study was duplicated by Responsive Management (1995), and this study reveals some significant shifts in hunter motivation, primarily declines in meat hunting and increases in nature appreciation motivations.

wildlife biologists and wildlife officers throughout the state to introduce people to effective, safe and responsible hunting methods. A new publication was developed on dove hunting and distributed through hunter education courses, sporting goods stores and division offices. Special dove fields for youths were set aside during the entire season at 26 wildlife areas for use by hunting parties that included young hunters. Additional dove fields were available for other hunters to use. Wildlife officers were given training on making positive contacts with dove hunters to promote effective, legal, safe and responsible hunting. Outdoor writers were invited to clinics and given information and news releases, while similar information was sent to the state's 800 conservation organizations.

This example illustrates several of the general recommendations and programmatic principles discussed earlier. The agency created new opportunities by opening dove seasons. Barriers were reduced by using multiple delivery systems to provide information and training about where to go and how to hunt. Long-term participation and mentorships were encouraged by creating dove fields for parties that included youths. Finally, a customer service attitude was created throughout the agency and customers heard a consistent message that the agency and its employees valued their participation. By all accounts, it appears that the season was safe and enjoyable, and accepted by the majority of the people in Ohio. Animal rights groups attempted to gain enough signatures to put a dove hunting ban on the ballot for this fall's election, but they reportedly fell short of the signatures needed. I mention this here because public opinions about hunting appear to be a factor in hunter recruitment. In Ohio, 37 percent of hunter education graduates agreed or strongly agreed that they should take antihunters seriously, and 42 percent agreed or strongly agreed that they should be concerned about what nonhunters thought about their hunting methods (Peyton et al. 1995).

Youth hunts. Quality hunting opportunities provide strong incentives for youths to choose hunting over competing recreational choices. A variety of youth hunts, special areas and special seasons have been created to enhance opportunities for families and mentors to have enjoyable hunts with youths. Nearly 200 youth hunts were scheduled for the 1995-96 season. All wildlife areas were open for mentored youth hunts the last two Saturdays in October, before the regular small-game season. These hunts create new opportunities (see Guidelines) and serve large numbers of people (see Principles), because they do not require any registration and little personnel time other than spot checks by wildlife officers. Twenty-five controlled hunts were scheduled for waterfowl, deer and turkey. Twelve Young Trappers Workshops were set for refuges where instructors took youths out and set traps that were checked the next day. Many of the controlled hunts and the trappers workshops offered training programs as part of the day's activities. Members of Pheasants Forever provided guides and dogs at several other areas, and the Ohio State Trappers Association provided instructors for all of the trapper workshops.

This year, a seven-day primitive deer-hunting season is proposed for Christmas break when kids are out of school and able to participate, and ODOW personnel hope to add even more hunts. Pat Ruble, group administrator for Wildlife Management and Research in Ohio states "We have only scratched the surface of things we can do to improve the number and quality of opportunities for youth to hunt."

Turkey hunter training. In terms of numbers of people reached and positive effects on behavior, the strategies used to make turkey hunting safer have been effective. In 1984, there were 8,849 turkey hunters in Ohio and they harvested 1,583 turkeys. One fatal and three nonfatal hunter injuries were recorded for an accident rate of 4.52 incidents per 10,000 hunters (Stoll et al. 1993). In 1995, 53,342 hunters harvested 10,892 turkeys, and there was one very minor injury incident for a rate of 0.19 accidents per 10,000 hunters.

Achievement-oriented, experienced, adult turkey hunters were responsible for most of the turkey hunting accidents, more than 90 percent of which were classified as "mistaken for game."

Starting in the mid-80s, brochures describing effective and safe turkey hunting methods were distributed with all permits. "Be Safe" stickers for shotguns were given out for voluntary use. Many of the materials and strategies from the National Wild Turkey Federation's National Turkey Hunting Safety Task Force were adopted as materials became available.

Several strategies in the ODOW's *Strategic Plan 1990-1995* identified the need for turkey hunter training classes and some specific training objectives (Budzik et al. 1989). In 1991, the ODOW started offering turkey hunting classes that targeted achievement-oriented hunters by stressing effective hunting techniques in the curriculum and the advertising. Safety was mentioned only briefly in news releases and descriptive materials. Thousands of hunters voluntarily attended these courses. The average participant had 23 years of hunting experience and 2 years of turkey hunting experience, and most of the older hunters had never taken a hunter education course. Participants received free turkey hunting manuals, a calling instruction tape, maps and other publications. Hunters were very satisfied that they learned about effective hunting techniques according to post-course and post-season surveys. Hunters rated the course on eight qualities, including how much the course helped them with scouting, calling, gear selection, hunting techniques, regulations, safety, appreciation for the wild turkey and overall hunting satisfaction. Appreciating the wild turkey was ranked first, followed by safety, overall satisfaction and then regulations. Ninety-five percent of the respondents said they would recommend the course to other hunters.

Turkey hunting courses alone did not reduce accident rates, but the evidence does show that it is possible to target populations of experienced adult hunters and market voluntary training programs to them. Agency training objectives can be effectively packaged with benefits desired by the hunter.

Hunting simulators. Hunting simulators are being used to help recruit and train hunters more effectively in Ohio and we project more use in the future as software improves and systems become more available. Combining home-study options for hunter education with simulator sessions offers promise for increasing the quality of hunter education training, reducing the barriers to course enrollment and promoting family involvement in hunting initiation (Wentz 1994). Simulated experiences are encouraging people to go target shooting and hunting. Changes in behavior can be observed during training programs, and this happens because people can practice using their knowledge, skills and attitudes to make judgements. The instructor then can provide feedback on those judgements to help improve student understanding which is a factor in the student's confidence level and desire to participate. Simulators provide a rich field for applied research and training evaluation.

Case Studies of Angler Recruitment, Training and Retention Programs in Ohio

Generally, programs for angler recruitment, training and retention target urban youths in Ohio. There appear to be few barriers for initial fishing experiences among the general population, where 87 percent of Ohio's teenagers ages 12 to 17 have had the opportunity to try it (Miller 1993). Urban teens fish at a slightly lower rate, but there is a great disparity between the general population and urban blacks, where available data suggests participation is much lower. Ohio's 1993 Public Attitude Survey reported 50 percent of urban black teenagers ages 12 to 17 had fished sometime during their life. *The 1991 National Survey of Fishing, Hunting, and Wildlife Associated Recreation* (Ohio) reported that only 10 percent of black youths ages 6 to 15 reported fishing within the last 12 months, while 44 percent of white youths participated (U.S. Fish and Wildlife Service 1993). ODOW fishing programs are offered statewide, but special emphasis has been placed on creating programs that provide instruction, equipment, fishing opportunities, mentoring relationships and social support for fishing in the state's largest urban areas where the majority of the black population resides.

ODOW has found that there is no shortage of opportunity to create partnerships that help children learn to enjoy fishing. Politicians, city recreation departments, schools, zoos, museums, conservation clubs, civic clubs, churches, courts, police departments, drug prevention agencies, universities and other groups have demonstrated eagerness to get involved. A long-term partnership between the agency and the Future Fisherman Foundation's "Hooked On Fishing—Not On Drugs" (HOFNOD) program has created new supporters among many nontraditional groups who now see a valuable connection between ODOW's mission and their own. The connection for nontraditional partners is based on human values rather than ecological ones.

An Urban Example

Columbus, Ohio is, by some measures, the 18th largest urban area in the country. Partnerships have created a community of support and opportunity for young anglers.

City recreation department. The Columbus Recreation and Parks Department was eager to expand its program beyond an annual fishing derby when the ODOW started its HOFNOD and urban angler education project in 1992. Approximately 40 Columbus city recreation employees attended a training program on basic fishing. Eight city pond sites were surveyed by ODOW fisheries biologists and they were stocked with catfish and bluegills. Each of the eight ponds was located at a city park with staff and facilities. ODOW provided several hundred cane poles, rods and reels, and terminal tackle. The parks now offer fishing seven days a week and weekly, two-hour fishing classes during the summer season. Children that attend multiple classes get an extra chance each time to be drawn for fieldtrips to state park lakes, fish hatcheries, Lake Erie and other locations. Recreation personnel often match up senior citizens with children that need a fishing partner outside of class time.

Many of the children who fish at the Columbus ponds have no other safe place to go fishing and no way to get equipment of their own. Recreation leaders say that many of the fishing participants are first-time visitors to their recreation centers. Most of the recreation leaders have grown up in the community and they recognize fishing and HOFNOD as qualitatively different from other recreation programs. Fishing allows the leaders to develop positive, ongoing relationships with children in ways that competitive sports do not provide.

Museum. Ohio's Center of Science and Industry (COSI) is another important partner that provides social support for fishing and exciting educational opportunities. COSI has a large area of interactive exhibits developed around fishing and aquatic resources. Children delight in "catching" artificial fish from a moving boat in COSI's pond. The fish are two-dimensional, but they are the shape and size of typical Ohio game fish and there is a "tackle shop" right there where the fish can be identified and measured. A series of interactive computers allows visitors to manage walleye in Lake Erie, pilot a boat through an Ohio lake, identify fish on a touch screen, examine live aquatic animals with an aquatic scope, participate in environmental game shows, or view maps of Ohio's landscape throughout recorded history and see how native wildlife populations have changed due to land-use changes. An innovative drug awareness program used in combination with the fishing exhibits makes COSI an attractive destination for schools taking fieldtrips as part of the HOFNOD program.

Zoo. The Columbus Zoo, as another important partner, has an outdoor exhibit that shows above and below water views of marshes, kettle lakes, streams and otter pools. The zoo exhibit is one of the first of its kind in the nation, and even adult anglers spend extra time there observing natural fish behavior in various habitats.

Schools. Many central Ohio schools use HOFNOD and the program is popular with teachers, parents, administrators and board members, such as Dr. Robert Teater of the Columbus Public Schools, who frequently has promoted it. Approximately 15 community service organizations use HOFNOD and provide year-round opportunities for fishing activities in the Columbus area alone. Several outlying metroparks and suburban recreation agencies also have adopted HOFNOD programs.

Statewide, hundreds of trained educators and recreation leaders are using HOFNOD in innovative school and community programs. Fish and wildlife agencies that use the HOFNOD program will find that new partnerships are possible because of it. HOFNOD makes fishing activities attractive to organizations that have missions related to improving the quality of children's lives. HOFNOD is profoundly different from other programs that *seem* to emphasize the quality of life for fish and wild animals, the agency or special interest groups. As the natural resources community enters the 21st century, I believe that we must use programs such as HOFNOD that define our missions in terms of human benefits if we are going to maintain significant places for fish and wildlife populations in our world.

State park fishing programs. ODOW plans to expand angler education efforts and HOFNOD into state parks during 1996. The value of associating fishing with a family-based activity such as camping to encourage retention in fishing has been documented by Dann (1993) and others. Many youth camps already offer fishing, but ODOW will target camps that serve urban youth and minorities for increased angler education activity in an effort to further the social support for fishing that these audiences need.

Fishing simulators. Although there is interest in the development of fishing simulators, I personally think aquatic education technology should be directed at management simulations and aquatic conservation. Hunting simulations offer advantages over actual field training due to the ability to create hundreds of scenarios that would be dangerous, illegal or impossible to create in the field. With fishing, suitable areas are within reach of everyone, and it is one place where actual reality will top virtual reality nearly every time.

Conclusion

Hunter education courses, shooting range operations, legalization of new hunting devices, license pricing and distribution, and public information efforts are but a few of the many other areas where agencies can make improvements that will have positive effects on participation. Agencies can begin systematically improving hunter and angler recruitment, training and retention efforts by making them a part of the agency's mission, educating agency personnel about the issues and involving all personnel and potential partners in planning efforts. Once agency employees fully comprehend their mission in terms of improving the quality of human life through effective fish and wildlife management, better efforts at recruiting, training and retaining hunters, anglers and other wildlife enthusiasts will follow.

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Wisconsin Student Hunter Project

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The Need

Hunting is an important form of outdoor recreation in Wisconsin, the United States, Canada and many other countries. In the U.S., hunting provides the financial base for conservation of all wildlife and their habitats, as it has in the past and probably will continue to do (Wildlife Management Institute 1992). However, hunters comprise a declining proportion of the U.S. population (U.S. Fish and Wildlife Service 1993), and we suspect the proportion of hunters among wildlife biologists employed by management agencies and among university departments educating wildlife biologists also has declined. Given more humans, urbanization and other social changes, we are not surprised by the declining recruitment rate of new hunters. However, numbers alone may not be as important as the characteristics of future hunters.

We strongly suspected that the number of hunters and knowledge/awareness of hunting among the undergraduate and graduate students in the Department of Wildlife Ecology at the University of Wisconsin-Madison (Department) had declined. Student enrollment (declared majors) in the Department in 1995 was at an all time high (>200 undergraduates and >30 graduate students); however, we noticed dramatic demographic shifts. In the 1970s, the student body was primarily male with a rural heritage. By the early 1990s, the student body was primarily female (>60 percent) with urban/suburban origins. Informal conversations about hunting became less frequent, classroom examples of hunting-related data and concepts prompted many questions, and the curriculum evolved more toward contemporary concepts and issues (biodiversity, conservation biology, sustainable development, etc.) and away from harvest strategies, game management and other aspects of "traditional" wildlife management.

These changes may be temporary or permanent and we assign no value judgements. However, we strongly believe that hunting will remain an important component of wildlife management well into the future. Sustained use is an integral part of wildlife population management, and hunting cannot be ignored in any program that educates and trains future wildlife professionals. We believe most wildlife professionals will interact with hunters and hunting during their careers. Some students agree with our basic premise. As Ledford (1995) recently noted, "Recent surveys show that about half of the students in wildlife management have never hunted. The problem with this is that at some time, almost all wildlifers will deal with hunters or game species management. If, as a biologist, you know nothing about hunting or hunters, you will be at a huge disadvantage when it comes to establishing credibility and carrying out your duties in a professional manner." While we agree with Ledford, we strongly believe that contemporary wildlife programs produce high-quality future professionals. There is, however, always room for improvement.

The Response

The primary goal of the Wisconsin Student Hunter Project (WSHP) was to strengthen the training and preparation of future wildlifers by exposing them to the history, ethics, motivation and methods of participation, and role of hunting. If some of the participants went on to become hunters, so much the better, but hunter recruitment was a secondary objective.

As these thoughts evolved on the University of Wisconsin (University) campus, the Wisconsin Department of Natural Resources (WDNR) initiated a statewide Outdoor Skills Program designed to improve skills and increase participation in outdoor recreation, including hunting. The WSHP emerged from several meetings between University faculty and WDNR biologists and managers as a plan to meet the objectives of both the University and the WDNR.

Informal discussions in the Wildlife Ecology Club (made up of undergraduate and graduate students) and several University classes during the winter of 1994-95 suggested that a substantial number of students wanted to learn more about hunting and perhaps participate in a hunt. We were encouraged by this and developed a one-page announcement of a voluntary evening and weekend program to learn more about hunting during the spring semester of 1995. Only students with no prior hunting experience were eligible. Following this publicity, we developed and distributed a brief application form through two introductory-level classes and the Club to reach undergraduate students. Graduate students were approached individually. On the application, we asked the students two open-ended questions: 1) "Why have you never hunted in the past?" and 2) "Why are you interested in this opportunity?"; as well as name, address and other baseline data.

The information derived from the applications was enlightening and surprisingly similar among students. A well-documented barrier to hunting participation—lack of family involvement and a mentor (Decker et al. 1993)—was cited by 22 of the 25 students who responded. Childhood spent in an urban environment (eight students) and opposition to hunting (six students) frequently were cited as reasons for not hunting. Several students also mentioned a fear of firearms, reluctance of male family members to involve females and vegetarian lifestyle. The stated barriers did little to dampen a broad range of interests in learning more about hunting. Most of the students (18) were interested in the role of hunting in wildlife management. Learning about hunting methods, firearms and firearms safety, making an informed choice, and providing food were other common reasons for seeking admission to the WSHP. The desired class size of 25 was selected based on academic major (preference to wildlifers), application responses and diversity (gender, student status). The final group consisted of 4 graduate students and 21 undergraduates (12 females and 13 males).

The Program

The WSHP was constructed around four objectives: 1) provide information on the role of hunting in modern wildlife management, the enlightened self-interest of hunters and financial contribution of hunting to wildlife and habitat conservation, and the evolution of traditions, ethics and hunter attitudes, from subsistence to recreational hunting; 2) provide information on the history and use of hunting firearms, safe gun handling, and ethical hunting practices; 3) develop shooting skills; and 4) provide high-quality, mentored hunting experiences.

The program was conceived in three modules: hunter education leading to a Wisconsin Hunter Education Certificate (objectives 1 and 2), shooting skills (objective 3) and mentored hunting experiences (objective 4). Under Wisconsin law, new hunters must complete a hunter education course. Thus, the first module was structured around a standard adult hunter education class.

During the first class, the students and faculty and WDNR volunteers were introduced. The session was informal and began with wild game snacks provided by WDNR instructors. The subject matter concentrated on objectives and logistics; the role of hunting in wildlife management; the evolution of modern hunting; a discussion of why people hunt, with four guest hunters of diverse age, gender and motivation; hunting opportunities; and a discussion on the place of the hunter in modern society. Classes two through five (two hours or more each) were devoted to the formal WDNR adult hunter education course. The focus for the hunter education class was more on firearms (history, use, handling and mechanics) and firearms safety than on hunting methods, ethics and wildlife management. The students did receive the Wisconsin Hunter Education Manual for self-study which included the latter information. During the final class, the students took the written portion of the Hunter Education Examination. The field examination was held at a local Sportsmen's Club.

Following completion of Hunter Education, we scheduled three opportunities for the students to develop their shooting skills (module two). The first opportunity was informal and conducted on the property of one of the mentors. The second and third shooting sessions were more formal and held at established ranges. At the first shoot, we provided a shotgun firing line and a separate .22 rifle and pistol range. The students were allowed to move freely between shooting stations. A variety of firearms was available, and ammunition was provided for as much shooting as the students chose to do. Instructors at each station taught range safety and skill development. At this point, we began to match students with a mentor of similar interests and personality.

The initial announcement of the program indicated that only 15 of the 25 participants would be selected for module three (actual hunting opportunities) because of the limited number of mentors available. At the conclusion of the shooting skills module, we had identified the 15 students who wished to hunt. All students from the original group of 25 who wished to hunt were accommodated. These students were matched with University and WDNR mentors. Telephone numbers and addresses were exchanged, the type of hunting students were interested in was established (i.e., upland game, waterfowl, deer, etc.), and it was left to the mentor and student to arrange a hunting trip.

To ensure that the 15 students had at least one opportunity to hunt in a high-quality situation with a high probability of success, we also arranged a shooting preserve hunt for ring-necked pheasants. We provided transportation and all equipment for a half-day hunt with professional guides and dogs at the Max McGraw Wildlife Foundation in Dundee, Illinois. The Foundation provided all the facilities and staff at no charge and the WSHP paid for the released birds (30) and lunch for the students. The day-long event included a three-hour hunt, a tour of the game farm operation and habitat projects, a discussion of the McGraw research program, and lunch. This event culminated the WSHP for the students and the mentors.

Program Evaluation

Was the program successful? The instructors rated it as a success beyond any expectations. Attendance was excellent at all classes and all students passed the Hunter Education Exam with scores above 90 percent. We also asked the students to complete a detailed written evaluation as a measure of their satisfaction and any effect on their attitudes and actions. We received 22 completed evaluations.

We first asked them to describe their expectations, which ranged from firearms safety to learning about hunting. We met their expectations "very well" (11) or "perfectly" (11), and accomplished what we "promised" them in the first class session "mostly" or "completely" (18). No student selected "not at all" or "somewhat" for either question. As a better measure of satisfaction and assessment of value we asked them if they would recommend this program to their peers. They were almost unanimous with 18 responses of "absolutely" and prose comments like "definitely worthwhile," "great opportunity" and "it is an opportunity for which many people have been waiting to come along."

With regard to future programs, we asked for an assessment of the number of other students who might participate. We were very encouraged by the distribution of responses among "a few" (1), "quite a few" (15) and "a lot" (3). The students also suggested several improvements, including more material on wildlife and hunting (techniques, types, etc.), more female instructors, more time on the firing range, and more discussion of game management and outdoor ethics. Some of these comments suggest opportunities/needs for our classroom curriculum, as well as the WSHP.

Of most interest to educators was the open-ended question, "Do you think any of your opinions or attitudes toward firearms or hunting have changed as a result of this program?" Of 21 respondents to this question, 17 said yes. Some of the comments included "I am more at ease with firearms" (4), "the hunter educators were good role models of responsible hunters," "I no longer see hunting as a negative," "my view of hunters and why they hunt has changed," and "I have more respect for traditional hunters and further respect for the WDNR and their level of professionalism." These comments strongly suggest that the WSHP made a difference and was well worth the time and resources invested.

Discussion

We prepared a news release with the help of the College News Service and it led to feature stories in several state outdoor publications, interviews and a detailed story in the College quarterly newsletter. Once the story was told, there were many positive comments and inquiries about future programs on the University campus or in other locations.

Support for the WSHP was readily available and generous. Besides the core group of two University faculty and three WDNR instructors, numerous WDNR employees volunteered their time and equipment. For the third hunter education class, during which the students handled, loaded and unloaded, and examined different firearms, 12 WDNR employees brought more than 80 personal firearms of all types.

Instructor time and facilities were donated, but costs of ammunition (25 cases), targets (10,000), travel expenses, refreshments and other costs added up quickly. We did not anticipate a large formal fund-raising effort for the pilot project because we initially viewed it as inexpensive. Informal personal contacts generated financial support from the Ruffed Grouse Society (John Keener Chapter), AWARE (A Wisconsin Alliance for Resources and the Environment), the Wisconsin Wildlife Federation and the Waterloo Sportsmen's Club. Financial contributions and disbursements were administered by the Wildlife Management Institute. The Federal Cartridge Corporation donated ten cases of ammunition. The Max McGraw Wildlife Foundation, Dundee, Illinois provided the group's pheasant hunt. Firearms used all were the personal property of the instructors. Liability was covered by the WDNR Hunter Education Program. When the students actually began hunting and wanted additional shooting practice, availability of firearms became a minor but manageable problem. If firearms (20 to 25 shotguns, 5 to 10 .22 cal. rifles) were added to program costs, the budget would increase dramatically. Our experience suggests that a similar program would cost at least $3,000, although costs could exceed $15,000 if firearms, all legitimate travel and other personal expenses are included. The enthusiasm we encountered suggests that grant support for similar programs would be available.

Several things happened accidentally but proved important. For example, provision of wild game snacks by the University and WDNR instructors seemed trivial, but it was not. At several classes, volunteers set up grills outside and cooked venison steak sandwiches and other foods as a simple gesture of camaraderie. That had a marked and dramatic impact on the students. First, it conveyed the depth of commitment on the part of the volunteers. More important, it conveyed a deep sense of the importance of game utilization to a hunter and the quality of the product. This seemed very important in affecting the students' attitudes toward hunting. In fact, one student, a life-long vegetarian, observed the attitudes of the mentors toward game consumption, saw the enthusiasm of the other students and decided to try the meats offered. That student is no longer a vegetarian. That was not our intent, but that event illustrates the powerful dynamics that developed between the volunteers and the students, something that could not have been planned.

The only two problems we encountered involved modules two and three. The importance of hands-on shooting opportunity cannot be overemphasized. Several students expressed an initial fear of firearms and most had never fired a gun. The firearms handling, dummy ammunition and instruction in the hunter safety class helped, but the students were keenly interested in enough shooting to feel comfortable with the firearm and develop a level of competency that would lead to confidence in the field. Despite three extensive shooting opportunities at private facilities and ranges where students shot about 500 rounds each, this was not enough experience for some of the students. Additional group opportunities should be planned.

The only other problem was related to communication. Both students and mentors have busy schedules. It was difficult for students to contact mentors and vice versa, and hunting trips were difficult to schedule. As a result, not as much student/mentor hunting was done as we had hoped for. More than half of the students did not hunt with their mentors at all. We believe this places added emphasis on a well-planned group hunting experience, such as the shooting preserve trip we conducted. That trip was an unqualified success. In addition to a strong education component (tours, discussions), the 11 students bagged 20 pheasants. They were a very happy group of students at the end of the day.

We do not believe that our students, situation, volunteers or facilities are unique. A similar audience and set of resources should be available at most university campuses with a wildlife curriculum. Thus, we see no barriers to the use of this model program at other institutions and, perhaps, in other settings, e.g., youth groups, public schools, environmental organizations, etc., except the issue of firearms liability. In the case of the WSHP, the WDNR Hunter Education Program assumed liability. Relative to the professional benefits and personal rewards for students and instructors, the costs are low.

In conclusion, student evaluations such as this reaffirm for us why we developed the WSHP and why we would do it again. "I entered this program hoping to get another perspective on hunting and firearms—beyond the stereotypes of Bambi killers and the fears of urban violence. I have been immensely impressed with the instructors involved in this program. Their genuine passion, respect and dedication to the land has given me that different perspective. Their sheer pleasure and sense of well-being due to being able to hunt and experience nature in a hunting relationship has been eye opening and refreshing."

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Recruiting, Training and Retaining Hunters and Anglers: Challenging the Natural Resources Education Community

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Sparked by concerns over declining avidity and participation in traditional outdoor activities, natural resource agencies and other organizations increasingly are engaged in efforts to counter these trends (Decker et al. 1993, Enck et al. 1996, Fund For Animals 1995, Matthews 1993, 1995). Because this decline potentially threatens agency funding, impacts regional economies, reduces the range of wildlife-related benefits available to people and ultimately may diminish public resource advocacy and environmental stewardship, more efforts are being focused on recruitment, training and retention of hunters and anglers. Are these efforts on target? What challenges face the natural resources community in its efforts to address this decline?

Recruitment and training efforts have targeted youth, primarily boys from white, non-urban cultures—the groups that have traditionally comprised the majority of hunters—which also, ironically, are population groups declining both proportionally and actually in size (Matthews 1993). More recently, young women as well as adult women are being included in recruitment and training efforts (Connelly 1996, Lueck 1995, Thomas and Peterson 1993). Today more attention is being focused on urban cultures, including non-Anglo audiences, particularly in some states' aquatic education programs (Matthews 1995, Pajak 1994, Schramm and Edwards 1994). Are these programs likely to achieve their objectives of recruiting, training and retaining more hunters and anglers?

How an individual becomes interested in and ultimately identifies him or herself as a hunter or angler is a complex process, influenced by numerous variables (Purdy et al. 1985). Natural resource agencies and others interested in maintaining and developing strong hunter/angler constituencies may use various intervention strategies in recruitment, training and retention efforts (Enck et al. 1996, Fund For Animals 1995). It may be helpful to examine these strategies using a conceptual programming model as a foundation. Using this model, agencies should be able to develop more-effective strategies targeted at specific stages in the recruitment-training-retention process. They should be able to identify gaps in their efforts to develop comprehensive programs, understand the research basis for building effective strategies and evaluate their success. It should help avoid a lemminglike rush to adopt misdirected strategies ill-suited for often ill-defined purposes. Using this model may enable agencies to overcome the paradigm paralysis that sometimes occurs when what is needed most is a fresh approach.

The Recruitment-Training-Retention Intervention Model

As noted earlier by Enck et al. (1996), the innovation-trial-adoption work done by Purdy et al. (1985) identifies a four-stage process through which an individual may pass in the adoption of hunting. These stages are awareness, interest, trial and adoption/continuation. While this process is widely accepted and used (Enck et al. 1996), it has not been modeled in such as way as to allow natural resource professionals to target appropriate intervention and programming strategies. Natural resource agencies wishing to influence this process often choose (or, in the case of hunter education, are required) to intervene at certain waypoints in this process. Some examples of these interventions include aquatic education programs, organized youth hunting experiences and the Pathway to Fishing program. Failure to understand which intervention strategies are most likely to have the desired outcomes may result in a mismatch, ineffective programming and ultimate failure. Failure to target intervention strategies at *each* of these stages also may subvert the entire recruitment, training and retention process. Use of this model, therefore, may enable agencies and organizations concerned with recruitment, training and retention of hunters and anglers to assess the direction and focus of existing programs, as well as identify where gaps exist, taking steps to intervene where appropriate.

Sociocultural Context of Recruitment, Training and Retention Intervention

It is important to understand that throughout this model the entire process is couched in a supportive sociocultural milieu. Though not always specifically mentioned, this sociocultural context is the glue that holds the entire process together, connecting, communicating and perpetuating itself in a series of feedback loops that continuously serve to reinforce participant attitudes and choices. It is the most critical element in retaining hunters and anglers. The thicker the glue, the more likely the desired outcome. In fact, it will become clear that in those traditional communities and families where hunting and fishing are honored traditions—where youngsters are encouraged and expected to become hunters, anglers and trappers—precious little outside intervention is necessary (Dann 1993, Enck et al. 1996). It is only in today's society in which the vast majority do not live in these communities–do not have a sense of shared values, attitudes and stories revolving around hunting and fishing–that significant barriers exist to the development of hunters and anglers, and interventions may be needed (Matthews 1993).

This is a four-part model, corresponding to each of Purdy et al.'s (1985) stages in the development of hunters. A similar progression probably occurs with anglers (Dann 1993). Again, a socially supportive environment is an antecedent condition for both entry into and progression through this model.

Phase One: Awareness (Figure 1)

PHASE ONE : Awareness

Intervention Focus : Public Relations

Intervention Strategy : Promotional Campaigns

Programs :
- National Fishing Week
- National Hunting and Fishing Day
- Free Fishing Days
- 1-800-ASK-FISH Promotions

leading to

↓

Awareness
Public Acceptance

Figure 1. Recruitment-Training-Retention Intervention Model—Phase One.

Individuals must become aware of the opportunity to participate in hunting and fishing activities. Interventions supporting this phase typically will involve promotional campaigns using mass media strategies. Program examples include National Fishing Week campaigns, National Hunting and Fishing Day, Conservation Field Day programs, bumper stickers, magazine ads, mall displays, etc. This phase also likely is assisted through exposure to television programs.

Phase Two: Interest (Figure 2)

Initial interest is developed through exposure to a threshold experience or series of experiences, an initiatory occasion(s) where the individual directly participates. These occasions need not necessarily mean the actual pursuit of game or catching fish. They may involve participating in a hunting or fishing camp experience, or simply sitting around the dining room table sharing stories and experiences. Interventions are media and event-focused, conducted in an effort to enable potential participants to have access to the threshold with the idea of recruitment as a goal. Program examples include fishing derbies, casting contests, Pathway to Fishing programs, conservation camp activities and shooting sports events.

PHASE TWO : Interest

Intervention Focus : Recruitment

Intervention Strategy : Offer Threshold Experiences

Programs :
- Fishing Derbies
- Casting Contests
- Shooting Events
- Pathway to Fishing

leading to

↓

Initiation of Interest

Figure 2. Recruitment-Training-Retention Intervention Model—Phase Two.

Phase Three: Trial (Figure 3)

The trial stage occurs as an individual participates in the activity to see how well it fits. The individual invests time, energy and resources in efforts to learn the ropes. Intervention strategies involve training, with a focus on eliminating or minimizing barriers to access that include lack of knowledge, skills, equipment or access to the natural resource. Developing an understanding of behavioral expectations also must occur at this stage. Ideally, interventions include multiple opportunities to engage in a sequence of in-depth experiences.

Program strategies focus on eliminating barriers to trial and ultimate adoption. They may include hunter or angler education courses. They may include library loan programs enabling equipment access or efforts to make resources available. Enabling resource access involves understanding what lands and waters are available, how to get there, how to obtain permission to use them (if not public) and the factors associated with social/attitudinal access. This last is an essential element, particularly when the audience is not white adult males.

Program examples may include fishing clinics and courses, hunter or trapper education courses, youth hunts, youth fishing camps and short-term apprentice/mentoring programs.

PHASE THREE : Trial

Intervention Focus : Training

Intervention Strategies : (1) Education Programs
- Knowledge
- Skills
- Behavior

(2) Access
- Equipment
- Resource

Programs :
- Hunter Ed
- Aquatic Ed
- Trapper Ed
- Fishing Clinics
- Youth Hunts
- Camps
- Becoming an Outdoors Woman
- NRA Youth Education Challenge

leading to

↓

Trial

Figure 3. Recruitment-Training-Retention Intervention Model—Phase Three.

Phase Four: Adoption/Continuation (Figure 4)

Adoption/continuation choices are made based on participant satisfactions and benefits, as well as the elimination of barriers. Participants begin to identify themselves as hunters and anglers. Intervention strategies focus on retention.

It is in this phase that social factors most clearly play the ascendant role. Program strategies designed to build and reinforce this social support take time and are difficult to evaluate—and arguably may be outside the scope of public agency efforts. Yet, clearly, if adoption of hunting and fishing is a desirable outcome and the requisite social support is not forthcoming from families, schools or communities, then intervention strategies offering this social support must come from somewhere else.

Examples of programs providing social support, that reinforce the decision to adopt and/or continue with hunting and fishing include supporting the development of long-term apprentice/mentor relationships and building community clubs focused on participation in hunting and fishing activities. One example may be the use of the Winsor Dinner or songfeast celebration, pioneered by the Orion Institute, whereby hunters and anglers are enabled to reconnect with one another and their larger community while telling the stories so important to the perpetuation of a hunting and fishing cultural tradition. Recognizing that a major contributing factor for older anglers dropping out is the loss of their fishing companion(s), another program may intervene through building connections among elders and between elders and youngsters (Harrington Market Research 1992).

As with any attempt at modeling, the lines so conveniently drawn between stages are frequently quite blurred in reality. For example, a hunter education course may serve in an initiatory capacity as well as playing a role in the trial stage. The Becoming an Outdoors-Woman program may act as an initiatory experience or fit the trial stage or both, and connections built as a result of participation may contribute to the adoption/continuation process. Mentoring likely is an extremely important factor during both the trial and adoption phases. Using this model does, however, enable agencies and organizations to understand better the recruitment, training and retention process, thereby developing strategies that target gaps or weaknesses in the process.

PHASE 4 : Adoption and Continuation

Intervention Focus : Retention

Intervention Strategies : Build Social Networks

Programs : • Long Term
• Apprentice - Mentoring Programs
• Community Clubs

leading to

↓

- **Adoption**
- **Continuation**
- **Development of Identity as Hunter/ Angler/Trapper/Outdoors Person**

Figure 4. Recruitment-Training-Retention Intervention Model—Phase Four.

Feedback Loops

It is important, as well, to understand the feedback loops in the model, which keep it dynamic and flowing. As individuals move through the stages and particularly upon entering the adoption/continuation phase, opportunities exist for them to feed back into the process. As an example, where would mentors come from to support the interest and trial phases if not from those in the continuation phase?

Challenges to the Natural Resources Community

If recruitment, training and retention of hunters and anglers are important, individuals must have *full access* to each stage. Whose job is it to provide this access? What is the role of various natural resource agencies in the process? Let's take another look at the model (Figure 5).

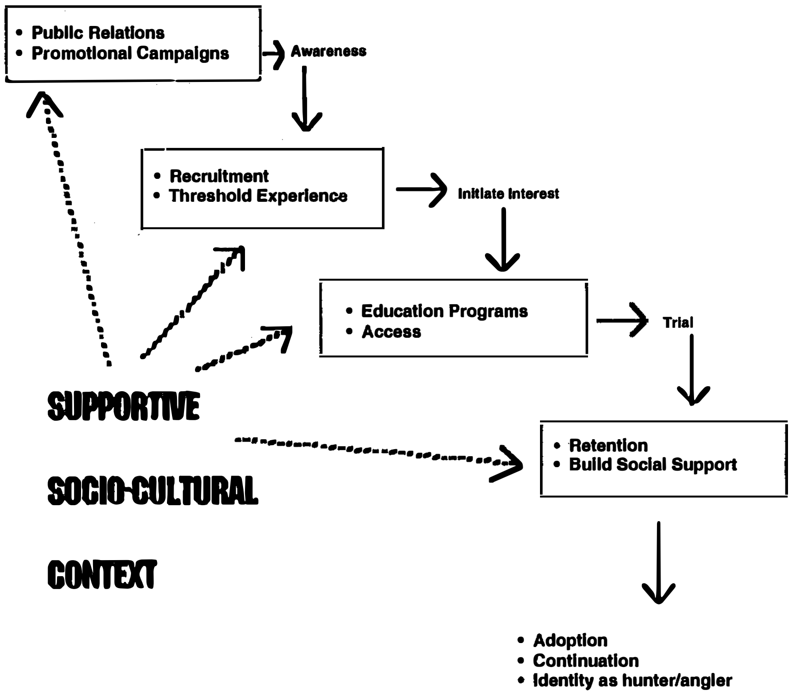

Figure 5. Recruitment-Training-Retention Intervention Model.

The first phase, awareness, relies on public relations interventions through the media. Many natural resources agencies maintain their own information and education sections, and promote programs such as Free Fishing Days. Yet, promoting an awareness of hunting and fishing has value beyond that gained by management agencies. Tourism interests may be served, as well as community and youth development. In some cases, the fishing and hunting industry and advocacy groups support recruitment efforts such as National Hunting and Fishing Day, National Fishing Week, 1-800-ASK-FISH, etc., as well as promotional campaigns advocating involvement in hunting and fishing, good outdoor behavior and so on.

Great care must be used, however, in addressing potentially negative public opinion issues regarding hunting and fishing and those who participate. For example, hunting involves the use of weapons and the intent or willingness to kill. Nonhunters are unlikely to appreciate any message that includes these elements. Promoting hunting may, in fact, backfire on an agency if the message content is inappropriate.

While there likely is plenty of room for additional promotional efforts directed at increasing awareness—particularly those efforts developed cooperatively among industry, advocacy organization and resource agencies—the danger is that efforts will go no further than reliance on marketing and promotion. The model seems pretty clear about why this is not a high-percentage bet.

The second intervention strategy focuses on developing and supporting interest primarily through short-term, one-shot events. Conducted by natural resource agencies, advocacy groups, Cooperative Extension, service organizations and, occasionally, schools, these events enable youth and others to participate in threshold experiences which then may, with proper social support, lead to the trial phase.

Again, the danger lies in assuming that interventions leading to the simple development of interest go far enough. In conducting events such as Conservation Field Days, Free Fishing Days Clinics or Fishing Derbies, great effort often is expended and large numbers are reached in many cases. Short-term evaluations generally reflect positive outcomes and event organizers are proud of their accomplishments. As a result, there is a great temptation to fall into a Field Days Feel-Good trap. A glance at the model shows that, without efforts focused on moving participants further along the continuum toward trial and adoption, simply generating interest may do little more than make event organizers feel good.

Intervention strategies for the trial phase focus on training and education efforts, preferably involving opportunities for repeated participation. Broad-based approaches that address the need for skills and knowledge development, and to enable participants to access the resource, equipment and expertise are needed. These can be provided to some extent by natural resource agencies through camp programs, aquatic education, clinics, hunter education, youth hunts and other efforts. The development of apprentice/mentor programs and school curriculums, as well as other longer-term efforts, clearly indicates opportunities for other partners in the process, which may include cooperative programs with advocacy groups such as state trappers' associations, 4-H and other youth organizations, schools, community service groups, and others. Given the magnitude of need in this area as well as the potential for partnering, it seems clear that a comprehensive cooperative effort on behalf of all interested parties is indicated.

The fourth phase, adoption/continuation, is supported through intervention strategies designed to retain hunters and anglers. The most promising of these programs are those that emphasize building a long-term apprentice/mentor relationship which, as Enck et al. (1996) point out, is not easily achieved unilaterally by natural resource agencies. This does not mean that agencies should not concern themselves in this area; rather, it suggests, perhaps even dictates, that they seek out partnerships enabling them to support retention.

Clearly, the successful use of the Recruitment-Training-Retention Intervention Model requires more than a single agency response. One of the great challenges facing natural resource agencies today is realizing that it is imperative *not* to see themselves as the primary instigator or savior of all hunting and fishing. Partnerships with other agencies, organizations, businesses, universities and community infrastructure are an essential ingredient. This is the first challenge: to avoid the unilateral temptation to try to go it alone. There is absolutely no room for turf battles, departmental infighting or agency provinciality. The ruggedly individualistic approach—the Marlboro Man in the agency uniform riding off into the sunset—can only result in our sending our hunting heritage riding along with him. Getting past these barriers and exploring ways to build partnerships and relationships with organizations best suited to work together to accomplish recruitment, training and retention intervention strategies is an imperative first step in filling the gaps in the process.

Second, the natural resources community needs to develop a much clearer understanding that different audiences require different combinations of recruitment-training-retention programming strategies. Women have different motivations and are constrained differently in their adoption of outdoor activities (Connelly et al. 1996, Henderson et al 1996, Loeffler 1995, Lueck 1995, Thomas and Peterson 1993). As Connelly et al. (1996) have pointed out, current models for hunting adoption may not accurately reflect motivations, intentions, behaviors and barriers to women. Yet, there is a growing body of literature which addresses women in the outdoors. When targeting women—long overdue—agencies must not make assumptions based on traditional white male constituent groups. We are far more aware today of constraints to women's participation in the outdoors than we were even two years ago (Connelly et al. 1996, Henderson et al. 1996, Loeffler

1995). In building social support for more women to participate in fishing and hunting, it is essential for the natural resources community to understand these constraints—many of which involve male culture—and work to reduce them.

A similar rationale needs to be applied when considering the potential that African, Asian and Hispanic Americans have as members of fishing and hunting constituencies (Blahna 1992, Matthews 1995, American Fisheries Society 1996, Roberts and Drogin 1993). By understanding the differences culture makes, different recruitment, training and retention strategies can be developed for the effective inclusion of a more diverse constituency for fishing and hunting.

Older Americans need to be included in recruitment and particularly retention efforts. While, clearly, youth audiences make the most sense for recruitment efforts, the fact that there will be more older Americans in the future would indicate some attention should be directed in this area. As an example, Lueck (1995) documented the effectiveness of Becoming an Outdoors-Woman in reaching an audience of women who no longer are constrained by child care.

Professional natural resource managers rely heavily on a rigorous scientific research basis for guidance with management decisions. "Using good science" is the byword with managers and biologists. We remind each other of this constantly in the literature and at professional meetings. I would suggest that the natural resources management community needs to extend its emphasis on a rigorous, science-based approach to include its efforts in the education arena. The research basis is there. The challenge will be to use it in guiding our decisions regarding efforts to recruit, train and retain a strong resource-based constituency.

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Special Session 6. *The Link Between Long-term Research and Management*

Cosponsored and coordinated by The Wildlife Society

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Linking Long-term Research and Management

Paul R. Krausman and Eric G. Bolen

The profession of wildlife conservation and management was developed from natural history observations resulting in conclusions established between environmental factors (i.e., climate) and wildlife population changes (Ratti and Garton 1994). As a result, the profession has a tradition of wildlife management based on "laws of association" (Ratti and Garton 1994) instead of experimental tests of hypotheses (Romesburg 1981). The descriptive studies over the past 50 years have yielded a huge body of data; most of the management programs in North America are based on these data. However, according to Ratti and Garton (1994), "advances in our ability to manage populations and to predict factors that cause population change have slowed tremendously in recent years. If our profession is to continue to advance with *management based on science*, we must use carefully designed experimental research to examine the many untested hypothesis that have evolved from descriptive studies."

In other sciences, time may not be as critical as it is in studies of wildlife and their habitat. Disciplines like chemistry and physics have the luxury of controlling variables in a timely manner more so than in environments that are large, fluctuating, often without controls and sometimes disappearing (i.e., due to floods). When such controls are not possible, studies need to be long enough to cover the variables that influence the system, which is especially important for management from a scientific basis. Our purpose in this introduction to the link between long-term research and management is to illustrate the natural link between the two, discuss the advantages and disadvantages, and briefly outline mechanisms to strengthen the link.

The Link and Its Advantages

There are numerous paradigms with the potential to replace the "management" in "wildlife management"; e.g., administration, conservation, enhancement, husbandry, investment, maintenance, operation, optimization, protection, support, sustainability and utilitarianism (American

Heritage Electronic Dictionary 1992). Although each would give the name a slightly different slant, the different names all imply the importance of time (e.g., investment, "a commitment, as of time or support;" or maintenance, "to keep in existence; sustain..."). The time that we imply here is that which leads to knowledge, often via long-term research. Short studies can lead to incomplete or short-term insights into ecological processes (Weins 1984) and may preclude witness of stochastic events (i.e., fires). As summarized by Morrison et al. (1996), the tradition of short-term studies that has developed over the past several decades arose from an interrelationship among constraints created by funding duration, needs for rapid answers, turnover of graduate students and the pressure to publish.

Clearly, all studies need not be long-term to address an hypothesis completely. We would argue, however, that all studies need to be long enough to adequately address the questions under consideration. In the laboratory where variables can be controlled, this period can be rather short (i.e., days or months). With many ecological responses, studies will have to be longer (i.e., years) to experience the numerous environmental variables that can influence results. Likens (1983) and Strayer et al. (1986) claim long-term studies are needed to understand slow processes, rare events, subtle processes, processes with high annual variability and complex phenomena. Franklin (1989) provides some examples that fit these categories, including succession, ecosystem changes, controls on productivity patterns of mortality in long-lived species, competitive interactions, geomorphic processes and ecosystem responses to atmospheric inputs, including pollutants. As humans continue to modify habitats of wildlife, the mitigations created for altered habitat also need to be considered. These are not new ideas, as Leopold (1939, 1966) stressed that humans needed to focus on a wide range of biota and the long-term scale at which they operate, including their holistic nature and intrinsic value; he stressed the need to understand the direct application of research to a management goal. Leopold began the odyssey and was followed by his students (Gawlik 1992) and numerous others. Sound management often is facilitated by long-term research because shorter studies do not adequately provide information from which to make informed decisions. That link (i.e., long-term research providing data for sound management) often cannot be provided by short-term studies. Longer-term studies are especially important for effective management, as they allow managers the necessary tools to mimic the full spectrum of natural disturbance in a system that forms the basis of conservative management (Lindenmayer 1995).

Examples of long-term studies (>10 years) in the literature cover a broad array of situations, species and questions that have been useful to managerial decisions. Overall studies have been long-term by necessity to address concepts related to population dynamics (Hindell and Little 1988, Congdon et al. 1994, Drewien et al. 1995, Mladenoff et al. 1995), habitat (Swenson et al. 1987, Gasaway et al. 1992, Green and Griffiths 1994), diet (Mattson et al. 1991), pollution (Fuller et al. 1990), management (Lyon et al. 1985, Nolte 1994), harvesting (Ginsberg and Milner-Gulland 1994) and various impacts related to ecological processes (Barnes et al. 1994, Pence and Windberg 1994, Van Roaz and Stumpel 1995), among others. The quest for knowledge as it relates to management also may be linked to why systems operate as they do. Understanding "why" should lead wildlife biologists into the realm of evolutionary biology and place emphasis on understanding spatial and temporal variability in reproductive success and survival of wildlife species (Gavin 1991). The most useful insights about populations and communities often develop from long-term studies.

That advantage is the link between research and management. Long-term studies that provide controls, account for variables, detect the rare events and accurately provide cause and effect relationships are those that will provide managers with the best data from which to apply to wildlife and their habitats. To do otherwise, managers are only obtaining short views of patterns and processes that *may* or *may not* be correct (Morrison et al. 1996).

Limitations to Conducting Long-term Research

Giles (1978) describes a wildlife triad as people, animals, and habitat and their interactions as the core of wildlife management. Of these, the former is the largest handicap to long-term studies. To obtain data that will span variable conditions is time consuming, expensive, unproductive for young scientists (i.e., no rewards) and more time often is needed for research than managers can afford to expend before making decisions (McAninch and Strayer 1989). The latter concern is important because long-term studies are essential to the health of understanding ecological systems and to society (Franklin 1989). Managers often want answers immediately, but scientists may be unable to provide complete answers without a long study. The problem is one of dealing with scientific uncertainty (McAninch and Strayes 1989). The result can be managers that are skeptical of scientists due to lack of answers as fast as needed, and can result in lack of support (i.e., funding, research sites). McAninch and Strayer (1989) offer three mechanisms to reduce conflicts that serve as obstacles to long-term research.

1. Scientists, managers and policy makers need to be aware and convinced of the essential rate that sustained observations play in understanding and managing key problems in ecology.
2. Communication between scientists and managers needs to improve so that scientists are more sensitive to the needs, interests and constraints of managers (and vice versa).
3. Scientists need to present a united front when approaching policy makers. Internal conflicts within the ecological research community have damaged efforts to improve relationships among scientists, managers and policy makers.

Additional Mechanisms to Strengthen the Bond

Franklin (1989) summarized various approaches to conducting long-term studies over short snapshot studies. He argued for a selection of key hypotheses to be identified, experimentation with contrasting treatments and studies conducted across and within biomes. He also argued for research designs that span organizational levels from populations to landscapes. This is especially important for wildlife studies.

Studies of the natural history of organisms and ecosystems must have a major place in any program of long-term studies; indeed, such investigations need to resume their rightful place in our science. We must admit to the public, resource managers and ourselves that such detailed and specific information is essential to making meaningful decisions about the use of biological resources, as well as to the formulation of ecological hypotheses (Franklin 1989).

Clearly, the management of the world's resources will benefit from long-term research. Sound data will facilitate informed decisions about resources to be made by managers that also are supported by the public. Without sound data, management will not be accurate, which, for some species and their habitat, will be unacceptable.

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Long-term Research on the White-tailed Deer/Conifer Thermal Cover Relationship: Aligning Expectations with Reality

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Background

Minnesota's forests presently comprise 16.7 million acres (6.8 million ha), a third of the state's total area (20.6 million ha), but only half of the forested area prior to European settlement (Jaakko Poyry Consulting, Inc. 1994). Most (88 percent) of the forests are classified as timberland.

Historically, Minnesota forests were dominated by conifers, especially white pine (*Pinus strobus*) and, prior to 1860, white-tailed deer (*Odocoileus virginianus*) were relatively rare (Petraborg and Burcalow 1965). Between 1880 and 1910, nearly all of the white pine was logged out, and early successional regrowth, light hunting pressure, wolf (*Canis lupus*) control and expanding game refuges favored increased numbers of deer in northern and central Minnesota (Petraborg and Burcalow 1965). Since then, variation in annual deer harvests, logging, fire control, human development, winter severity and predation have contributed to fluctuations in deer numbers, but generally, the population has been increasing (Petraborg and Burcalow 1965, Mech 1973, Mech and Karns 1977, Jaakko Poyry Consulting, Inc. 1994, Minnesota Department of Natural Resources [MNDNR] 1994).

In the Forest Zone (contiguous northcentral and northeastern portions of the state), county, state and federal agencies implement practices aimed at sustaining timber productivity, while enhancing wildlife habitat quantity and quality (MNDNR 1985, USDA Forest Service [USFS] 1986). Winter "habitat requirements" of white-tailed deer receive notable consideration in the design of timber harvests. Specifically, current guidelines more strictly limit harvests of conifers compared with hardwoods, because their value as winter thermal cover is viewed as "vital" to deer survival (MNDNR 1985, USFS 1986). Only 28 percent of Minnesota's forest presently are comprised of conifers, most (77 percent) of which occurs as timberland (Jaakko Poyry Consulting, Inc. 1994).

Projections of a Generic Environmental Impact Statement, prompted by citizens' concerns over the environmental impact of increased timber harvesting, indicate that the forest areas in northern Minnesota will continue to decrease (Jaakko Poyry Consulting, Inc. 1994). Furthermore, harvests of balsam fir (*Abies balsamea*), spruce (*Picea* spp.) and pine (*Pinus* spp.) are expected to exceed recommended harvest levels by 1997 (MNDNR 1990). Minnesota's wood industry, employing 55,600 people, is the state's second largest manufacturing industry, and produces forest products valued at $4.98 billion annually (MNDNR 1990). With a steadily increasing demand for wood products, limited hardwoods and actual timber harvests rapidly approaching a maximum allowable harvest of 4.79 million cords per year (Jaakko Poyry Consulting, Inc. 1994), the MNDNR anticipates greater pressure from the logging industry for more liberalized conifer harvests.

Although much has been learned from descriptive studies about the habitat composition of winter ranges of northern deer, and how physical attributes of dense conifer stands afford deer thermal benefits (e.g., Cox 1938, Verme and Ozoga 1971, Ozoga and Gysel 1972, Moen 1973), additional quantitative assessment of the relationship of conifer stands to deer survival is needed. Thomas et al. (1979) discussed the need for information on responses of deer and elk (*Cervus elaphus*) to changing thermal cover:forage area ratios. Recognition of these needs and of consequent challenging, controversial management decisions, prompted the MNDNR to implement a comprehensive, long-term (≥12 years) field study of the relationship of conifer stands to winter movements, distribution and survival of female white-tailed deer.

During the past two decades, increased attention has been focused on the relationship between wildlife research and management, long-term versus short-term research, research design, and the concept of ecological dependency (Romesburg 1981, Peek et al. 1982, Macnab 1983, Ruggiero et al. 1988, Ratti and Garton 1994). The first five years of our long-term (≥12 years) study of white-tailed deer in northcentral Minnesota have provided insight into several of these issues. Herein, we address questions related to design and analysis of long-term, ecological field studies with an emphasis on survival. We will discuss advantages of long-term versus short-term research, the significance of the difference in temporal scales of long-term research and management, and the value of long-term research to management.

Study Design and Associated Statistical Issues

Ultimately, we propose to test the hypotheses that reduced conifer cover alters movements, distribution and survival of female deer on their winter range. Herein, we describe a test of the hypothesis of decreased survival by application of a modified Before-After-Control-Environmental-Impact (BACI) assessment design (Stewart-Oaten et al. 1986). The design involves matching, as closely as possible, a control site to the site of the proposed impact (or manipulation), controlling for any potential confounding factors, while allowing sufficient distance that any impact effects cannot reach the control site. In the traditional BACI, impact effects are evaluated on estimates of species-specific population density obtained from parallel time series of cross-sectional samples, taken at both sites, during the pre- and post-impact periods. The length of the periods is determined by temporal variability at the sites and by the estimated length of the induction period for the impact effects. The null hypothesis of no impact effect is examined by comparison of paired differences (1) between sites, within periods; and (2) between periods, within sites. Under the assumption that there are no time x site interactions, the first test provides an external control and the latter test functions as an internal control (Stewart-Oaten et al. 1986).

For large, long-lived animal species, density estimation by cross-sectional sampling is impractical. Thus, we have made two modifications to the traditional BACI design. First, we have focused on comparison of site-specific survival curves estimated from longitudinal sampling of individual deer. Second, we have employed a replicated BACI with two matched pairs of control/impact sites. These two modifications require a different analysis strategy, but will lead to inferences comparable to those of the traditional BACI.

The two matched control/impact sites (Dirty Nose Lake-Inguadona Lake and Willow Lake-Shingle Mill Lake) are located in the Forest Zone of northcentral Minnesota. All four sites were selected within the same vicinity; thus, they were well matched on such potential confounders as local vegetation, weather, and wolf and hunter densities. Nonetheless, some heterogeneity in survival is to be expected. Thus, we matched pairs so that the subsumed control/impact sites had pre-impact survival curves that were as similar as possible. Similarity was assessed by comparison of survival curves estimated for each site at the end of the five-year pre-impact period (January 1, 1991 through December 31, 1995). The pre-impact period will be followed by a one- to two-year manipulation phase (harvest of moderate [41-69 percent canopy closure] and optimum [≥70 percent canopy closure] thermal cover), and a post-impact period which will extend for at least five additional years.

In this study, survival time has been defined as deer age, using June 6 as the birth date of all deer. The year of birth was estimated (from cementum annuli in the last incisor [Gilbert 1966]) at the time deer (female fawns and adults) were captured and radio-collared. Age was calculated as the total number of days lived since June 6 of the birth year. Since we were not able to recruit deer into our study sample on the day of their birth, survival estimates were conditional on the deer's surviving long enough to be recruited. Thus, our estimates are left-truncated and right-censored; this precluded use of the standard Kaplan-Meier estimator of survival (Tsai et al. 1987, Collett 1994). Instead, we estimated survival curves using the generalized product-limit estimator (Tsai et al. 1987, Tsai 1988). This estimator, similar to that of Pollock et al. (1989), reduces to the Kaplan-Meier estimate when there is no left-truncation. Confidence limits for survival curves were based on the linearized Taylor series estimate of the variance (Greenwood's estimator).

The appropriate statistical model for testing for impact-induced differences in survival time accumulated by individuals in such a staggered entry design is the Andersen-Gill proportional hazards model (AG) (Andersen et al. 1991, Fleming and Harrington 1991). The AG model is a robust extension of Cox's Proportional Hazards model (Riggs and Pollock 1992, Collett 1994), which allows both left-truncation and correlated survival (e.g., survival of siblings or social group members). Like the Cox model, it can be blocked and will lead to interval estimates of the risk of death of individuals at the impact sites relative to those at the control sites. The relative risk is expressed as a risk ratio (RR); an RR whose 1-α percent confidence interval includes 1.0 implies no risk difference, while an RR estimate with a lower bound greater than 1.0 implies greater risk at the impact sites.

The AG model allows for adjustment for covariate effects. Covariates may be constant baseline factors (e.g., sex) or time-varying factors (e.g., ambient temperature, percentage body fat). Baseline covariates are modeled as subject-specific constants and time-dependent covariates as temporal step-functions (Collett 1994). Time-dependent covariates are especially useful for evaluating the effects of climatic factors which may exhibit strong annual variation. Unlike baseline models, time-dependent AG models can accommodate covariate x survival time interactions.

We employed the AG model, with blocks corresponding to the matched pairs, to estimate RR in the pre-impact period. At the conclusion of the post-impact period, the same model will be used to estimate RR for the post-impact period. Both models include baseline covariates for age and weight (kg) at recruitment, and will provide the external controls for the impact effect after adjustment for covariate effects. Finally, we will combine the pre- and post-impact data in the blocked AG model, introduce a dichotomous time-dependent impact variable and time-dependent weather variables, and will again estimate RR, thus providing the internal control.

We also examined three components of the underlying hazard, wolf predation, hunter harvest and residual causes, which we will refer to as "miscellaneous." Such analyses often are called cause-specific or competing risks analyses (Marubini and Grazia 1995). The general approach is to model the specific causes separately and then compare them with the all-causes model with likelihood ratio tests (LRTs). This approach is possible because the cause-specific models form a subset derived from the all-causes model. The LRTs were used to test the null hypothesis that the RRs of the submodels did not differ from those of the all-causes model. We also have compared separate cause-specific survival curves pooled over sites.

Baseline (Pre-impact) Summary Statistics

Sufficient data were collected to permit rigorous survival analyses on 112 of 139 deer recruited to the study during the pre-impact winters 1991 to 1995 (Table 1). Deer with incomplete data (e.g., missing age, weight) and deer that died of capture-related causes within seven days post-recruitment were excluded from the analyses. Small sample size dictated that car-killed deer and deer dying of capture-related or other causes be collapsed into a single "miscellaneous" death stratum for cause-specific mortality analyses.

Table 1. Status of free-ranging white-tailed deer used in survival analysis, northcentral Minnesota, January 1, 1991 through December 31, 1995.

Status	*n*	Percentage
Still alive	25	22.3
Lost-to-follow-up	16	14.3
Car-killed	4	3.6
Hunter-killed	25	22.3
Wolf-killed	31	27.7
Capture-related death	4	3.6
Miscellaneous/unknown cause of death	7	6.2
Total	112	100.0

Mean ages of deer were 6.0 (SD = 4.5, $n = 39$), 5.8 (4.6, $n = 18$), 6.1 (4.0, $n = 25$) and 5.6 (4.4, $n = 30$) years at Inguadona Lake, Dirty Nose Lake, Shingle Mill Lake and Willow Lake, respectively. Following the first year of recruitment, the age distribution of the overall at-risk study population (i.e., number surviving on the last day of each year) remained relatively stable with mean ages of 5.0 (SE = 1.0), 8.1 (0.8), 8.2 (0.8), 7.4 (0.7), and 7.0 (0.6) years on January 1, 1992, 1993, 1994, 1995 and 1996, respectively. Based on these results, ages of deer at recruitment were comparable at the four study sites, and the study population did not exhibit an age trend since 1992. Thus, any observed treatment effects on survival will be free of confounding with aging effects in the pre-impact cohort. Although survival curves in Block 1 (Figure 1A) appear well matched, the impact site in Block 2 (Figure 1B) appears to have longer survival than its control. We believe this reflects a lower proportion of hunting mortality at the impact site. However, since the BACI design allows both internal and external control, this observed disparity in the baseline survival should not pose a problem to the final interpretation of the treatment effects.

Survival Plots

Survival curves at each of the four sites are plotted in Figure 1. Comparison of the survival curves and their associated hazard plots (not shown) suggested that treatment and controls should be paired (i.e., blocked) as shown. Variation of survival curves among sites is expected in natural populations, but for purposes of testing hypotheses of impact/effect, it is desirable to reduce this natural variation. This is accomplished best by pairing the control and impact sites such that their survival curves are as similar as possible. Although median survival at the four sites is similar (range = 0.8-2.5 years), survival at the sites in Block 1 is poorer than at the sites in Block 2. This blocked structure will be maintained in the present and all future analyses of the data.

Age-specific survival curves pooled over sites and cause of mortality, and pooled over sites only, are compared in Figure 2. Hunter-caused mortality occurred earlier in life (median survival time = 2.5 years) than either wolf-caused mortality (median = 6.5 years) or than from miscellaneous causes (median = 10.3 years). Moreover, mortality from wolves and miscellaneous causes appeared to occur at fairly constant but gradual rates over the lives of deer, whereas deer < 3 years-old appeared to be at much greater risk of hunting mortality than older deer.

Anderson-Gill Survival Models

Interval estimates of RR from the death-from-all-causes, blocked AG model did not indicate that deer in the impact sites were at significantly greater risk of death than deer at the control

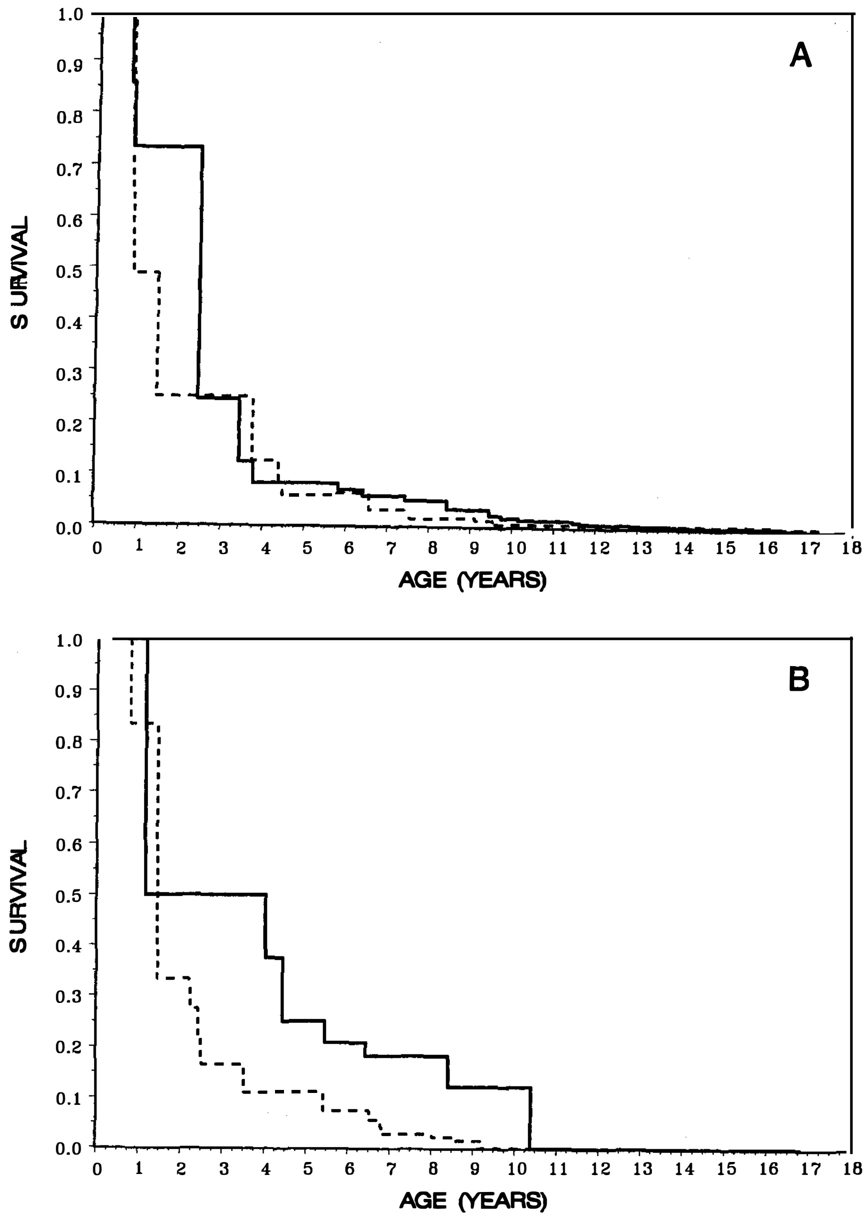
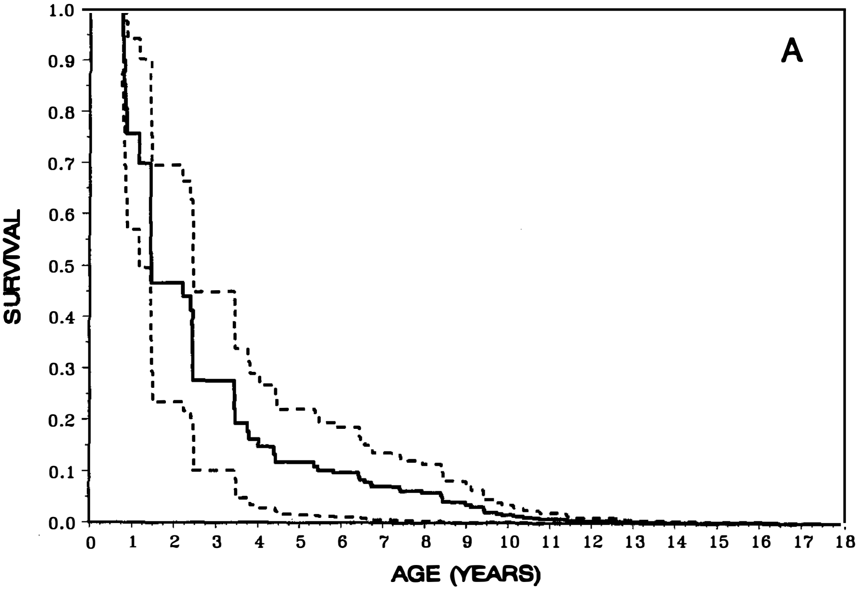


Figure 1. Estimated cumulative survival of free-ranging, female white-tailed deer for matched pairs (blocks) of impact (solid lines) versus control (broken lines) sites, northcentral Minnesota, January 1, 1991 to December 31, 1995. Block 1 = Inguadona Lake (impact) and Dirty Nose Lake (control) sites (A). Block 2 = Shingle Mill Lake (impact) and Willow Lake (control) sites (B). (Data for Dirty Nose Lake and Shingle Mill Lake were collected January 1, 1993 to December 31, 1995.)



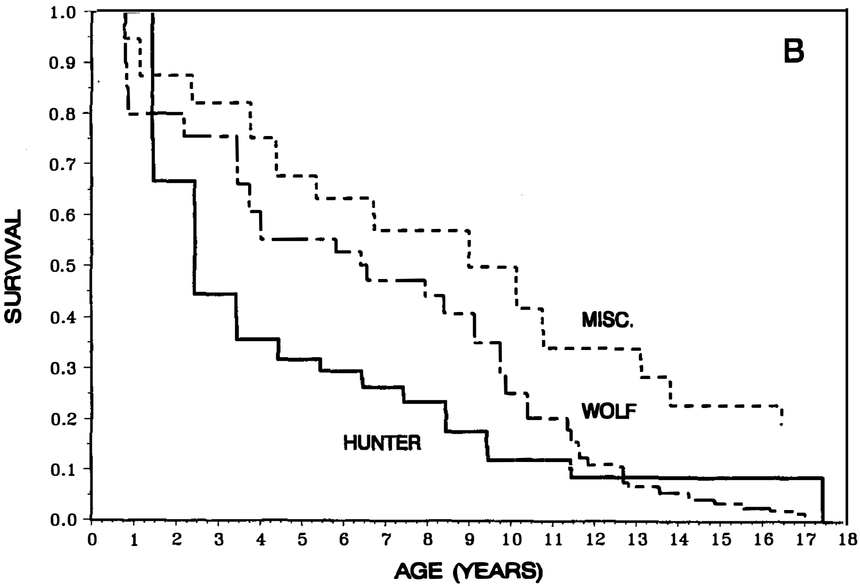


Figure 2. Cumulative survival from all causes of mortality (± 95-percent confidence limits) of free-ranging, female white-tailed deer (A) and cause-specific cumulative survival (B). Data are pooled over four study sites, northcentral Minnesota, January 1, 1991 to December 31, 1995.

sites (RR = 0.73 [0.41, 1.32]) after adjusting for the effects of age (RR = 1.36 [0.76, 1.71]) and weight (0.99 [0.95, 1.03]) at recruitment. Thus, it appears that in the five-year pre-impact period, deer at the impact sites were not exposed to a different hazard than those at the control sites. Competing risks analyses of three cause-specific, blocked AG submodels did not indicate that either impact-control or covariate effects differed by cause from those in the overall model (X^2 = 1.51 df = 2, P = 0.8249).

A Quasi-Experimental Approach

We chose a replicated manipulative design (e.g., BACI) over alternative designs for field research to enhance our capacity for inference concerning the relationship between conifer thermal cover and the survival of deer (Romesburg 1981, Tilman 1989, Ratti and Garton 1994). Ours is a quasi-experiment because the treatment is nonrandomly (due to planning constraints of cooperating agencies) assigned to the experimental units (Cook and Campbell 1977, Kleinbaum et al. 1982). Compared with classical, controlled randomized experiments of captive animals, we sought the inherent advantages of greater overall scale, realism (i.e., natural environment), scope of manipulation and generality afforded by the relatively uncontrolled field setting (Ratti and Garton 1994).

A primary disadvantage of any field study is the need to control or account for numerous, confounding environmental and biotic factors that singly or in combination may exert direct and/or indirect effects on the response variable(s) of interest (Darwin 1859, Brown et al. 1986, Tilman 1989, Ratti and Garton 1994). For example, there is abundant evidence of direct and indirect effects of winter weather conditions on habitat use, thermal balance, food habits, and vulnerability of northern deer to predation and other causes of mortality (Verme and Ozoga 1971, Moen 1973, Nelson and Mech 1986, Mech et al. 1987, Brown and Doucet 1991, Doenier 1996). Indeed, in northern environments, winter weather probably has the most pervasive influence on the ecology and survival of deer.

Any field assessment of treatment/impact effects must take into account the potential of highly variable and unpredictable ambient environmental factors to confound observed impact effects. According to a *functional* relationship between snow depth and deer, energetic costs of movement become critical at depths of at least 16 inches (40 cm) (Moen 1976). During the pre-impact phase of our study, we found appreciable monthly and annual variation (i.e., January to March, range = 0 to 63 days) in the number of days with snow depths of at least 16 inches (40 cm) (Figure 3A). The effective critical temperature (the temperature threshold at which heat losses exceed energy expenditure for standard metabolism and activity in nonfasted animals) of an average size doe (132 pounds: 60 kg) during winter was approximately 19.4 degrees Fahrenheit (-7 C) (McDonald 1973) and, again, during the pre-impact phase, the number of days per month and winter with maximum temperatures at or below 19.4 degrees Fahrenheit (-7 C) varied considerably (Figure 3B). Morphological, behavioral and physiological adaptations of deer enable them to mitigate the energetic and nutritional consequences of deep snow and low temperatures (Moen 1973), but such responses come at a cost. Thus, the negative effects of challenging winter conditions rarely can be avoided by deer completely.

Toward the same aim of evaluating other possible direct or indirect effects of thermal cover on deer movements, distribution and survival, we are monitoring deer migration patterns, home range size and habitat composition, deer densities, food habits, nutritional restriction, physical condition, and pregnancy rates on each of the control and impact sites during the pre- and post-impact periods.

Reliability of Long-term Versus Short-term Studies

Long-term studies are seriously underutilized in ecology and wildlife science. One review has shown that 80 percent of experimental and observational studies last three years or less, and most two years or less (Tilman 1989). A long-term approach is essential to testing the hypothesis we have posed, because the question clearly involves processes and phenomena that may be expected to be slow, rare, highly variable, subtle and complex (Strayer et al. 1986, Franklin 1989, Tilman 1989). Thus, we expect the results of our field manipulation to be time-dependent. When such processes and phenomena are involved, many long-term efforts have demonstrated the misleading nature of short-term studies (Lutz 1945, Brown et al. 1986, Tilman 1989, Franklin 1989).

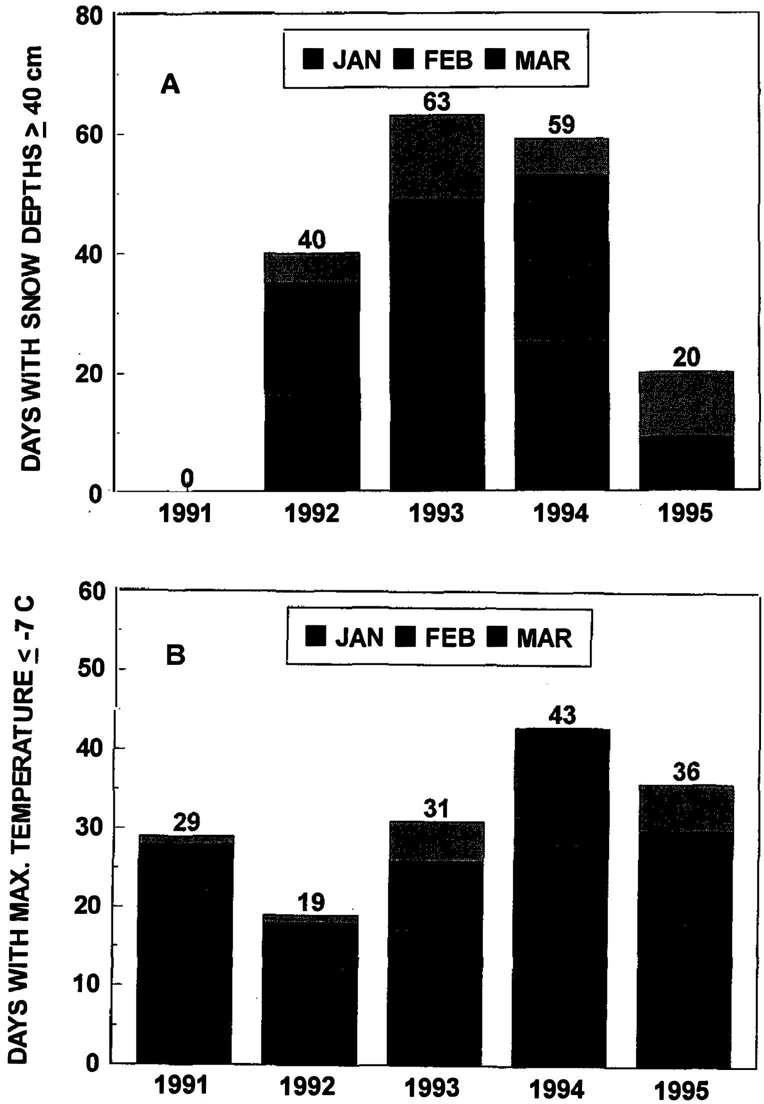


Figure 3. Number of days with snow depths of at least 40 centimeters (A) and maximum ambient temperatures at or below 19.4 degrees Fahrenheit (-7 °C, effective critical temperature for an average-sized doe [60 kg]) (B) in northcentral Minnesota, January through March, 1991 through 1995.

Again, Figure 3 demonstrates the high temporal variability of weather captured by the five-year pre-impact phase of our study. Clearly, the full extent of that variability and its implications relative to deer energetics, cause-specific mortality and survival would have been missed in a one-, two- or three-year study conducted sometime during 1991 to 1995. Any impact assessment confined to such years would have potential for confounding idiosyncratic short-term weather effects with the impact effects. Furthermore, seasonal variability in weather and migration between winter and summer ranges (G.D. DelGiudice unpublished data) may expose deer populations to fluctuating levels of plant productivity and competition, insect densities, and other factors which may influence the deer's seasonal nutritional status. A major advantage of long-term designs is the ability to measure and apply model-based adjustments for annually varying effects of weather conditions (Tilman 1989).

One constraint in our study is that we had only limited control over the number of deer we captured and radio-collared each winter and, practically speaking, we had no control over their ages at capture (range = 0.6-15.7 years old). The survival analysis illustrates several important points related to long-term versus short-term studies. Because probability of deer survival varies with age, inferences at the level of the actual study sites, both pre- and post-impact, will be dependent on the number and distribution of ages of deer recruited, and this is at least partially time-dependent. Age composition of study deer will be influenced by both the age structure of the target population and by trapping success. As shown in Figure 4, the survival curve changes (approaching a smooth curve) with each year of the study, as additional, variously aged deer are incorporated

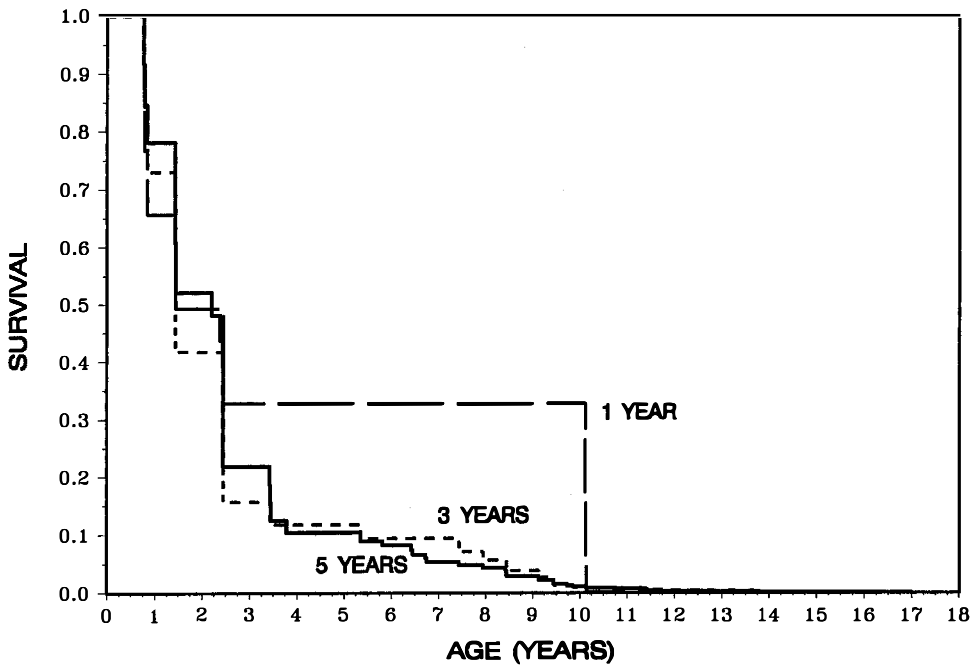


Figure 4. Comparison of cumulative survival of free-ranging, female white-tailed deer based on one, three and five years of data collection, northcentral Minnesota, January 1, 1991 to December 31, 1995.

into and lost (e.g., death) from the study. A short-term version of this study would have been very misleading because sample sizes of the risk sets would have been smaller and numerous ages underrepresented. Biases due to these problems are of special concern for left-truncated survival curves (Tsai 1987).

Finally, several investigators have demonstrated the inaccuracy of studies in which the post-impact phase was too brief. Abbreviated post-impact studies have led to confusion of transient dynamics of the induction state with the final stable equilibrium state of the impacted system (Lutz 1945, Brown et al. 1986, Tilman 1987, 1989). Transient dynamics of newly disturbed systems often are characterized by greater instability during transition from its original state to its new stable state, and the more complex the system, the greater the likelihood of complex transient dynamics (Tilman 1989). Our deer/conifer thermal cover study is in the impact or manipulation phase; thus, we do not have data to illustrate transient dynamics. However, recognition of their existence will ensure that they will be afforded careful consideration in determining just how long this study should be continued. In seeking the long-term stable state, it has been argued that the study should be extended until fluctuations of the induction state subside and the stable state can be characterized (Tilman 1989).

The Value of Long-term Research to Management

Research is a "knowledge-generating process, not a problem-solving process" (Gill 1985: 20). Our long-term study has benefited from the full and generous support and foresight of the management segment of our agency, but the research hypothesis and design of this long-term study were devised with the above characterization in clear focus. Our goal is to generate data that will add to our knowledge of the white-tailed deer/conifer thermal cover relationship and contribute to improved deer management in the future.

For several reasons, the findings of our study alone cannot serve as the sole ecological basis for management policy or decisions concerning conifer harvest and management of winter range of white-tailed deer in Minnesota. First, as stated earlier, natural systems are complex and dynamic. This makes relating the relatively short-term scale of field research to long-term management objectives difficult; often, they do not align. Wildlife is managed for long-term persistence ($\geq$100-200 years), a scale which dwarfs even what we have referred to as "long-term research" (Ruggiero et al. 1988).

Second, extrapolation of findings from both short- and long-term field studies are constrained by their restricted spatial scales. Spatial variability of the numerous site-specific factors (including site history) that may affect the relationship between conifer thermal cover and deer survival can be substantial (Berkowitz et al. 1989, Tilman et al. 1989). It is noteworthy that a given site can have multiple stable equilibria dependent on biotic interactions and site history, further complicating spatial extrapolation (Lewontin 1969, Tilman 1989). Practical considerations in making inferences at the level of the forest region include issues of the minimum required number of matched pairs of control/impact sites. Many more than two may be required. After five years of experience with this study approach, we believe that logistical and cost constraints would preclude inclusion of additional replications. This problem has been the focus of considerable debate/discussion in the ecological literature (Stewart-Oaten et al. 1992).

There are risks to extrapolation; however, the aforementioned constraints do not preclude it. Findings of long-term research may serve as part of the basis for specific management plans and predictions, particularly where manipulations (e.g., conifer harvests) are involved, and where incorporation of well-designed, rigorous monitoring serves to continue the research on new sites

(Macnab 1983, Murphy and Noon 1991). There are safeguards for extrapolation of long-term research results (Berkowitz et al. 1989) which should be considered as we work toward integrating management and research designs for improving the future management of deer and other wildlife.

Finally, it has been our experience that findings of long-term research in progress may be of immediate value to wildlife managers. A by-product of the extensive annual monitoring of winter weather conditions, deer migrations and movements on winter ranges, food habits, body weights, and nutritional restriction is that it permits quantitative assessment of the current status of the local population. Often, this information is useful to managers' objectives and their interactions with interested and concerned citizens.

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Effects of Research on Sage Grouse Management

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Sage grouse (*Centrocercus urophasianus*) are dependent on shrub-steppe rangelands dominated by sagebrush (*Artemisia* spp.), especially subspecies of big sagebrush (*A. tridendata tridendata*, *A. tridentata vaseyana*, *A. tridentata wyomingensis*), grasses and forbs (Patterson 1952). The species occurred historically from eastern California north into southern Canada, east into the western Dakota's and south to New Mexico and southern Utah (Aldrich 1963). Sagebrush has been considered a noxious plant by many private landowners and several public land-management agencies (Pechanec et al. 1954), and extensive efforts have been made to reduce its abundance (Schneegas 1967, Vale 1974, Braun et al. 1976). As a consequence, the distribution and abundance of sage grouse have been markedly affected from presumed historic levels (Johnsgard 1973, Braun 1995).

Long-term research on sage grouse in Colorado was initiated in North Park, Jackson County, Colorado in 1963, although short-term localized studies had been conducted starting in 1939 (Dargan and Keller 1940, Rogers 1964). The research effort in 1963 followed notice in 1962 of plans by the Bureau of Land Management (BLM), of their intent to eradicate, by aerial application of herbicide, sagebrush from approximately 1,619 hectares near Lake John in northwestern North Park (Gill 1965). This was one of the best sage grouse habitats in Colorado (Rogers 1964). Purpose of the sagebrush eradication project was to improve rangeland forage for livestock and, if successful, treatments were to be expanded to all BLM-controlled lands within North Park (Braun and Beck 1976).

Research on sage grouse in North Park, Jackson County, Colorado initially was focused on designing (Gill 1965) and evaluating (Carr 1967, Braun and Beck 1976) responses of sage grouse to sagebrush treatments. The preliminary work (1965-1975) illustrated the lack of knowledge about sage grouse population integrity, movements, winter habitat needs, validity of counts of males per female on leks, nesting, effects of hunting, etc. Consequently, a series of research studies was implemented to expand knowledge on basic questions of sage grouse biology (Beck 1975, Emmons 1980, Petersen 1980, Schoenberg 1982, Remington 1983), especially as related to harvest strategies (Braun and Beck 1985, Zablan 1993). These studies included intensive long-term monitoring of the sage grouse population in Jackson County, Colorado. This paper reviews the impacts of long-term research on management of sagebrush habitats in North Park and elsewhere, and on harvest strategies for sage grouse.

Study Area

North Park is a large intermontane basin within Jackson County in northcentral Colorado (Figure 1). The elevation is 2,395 to 2,600 meters with surrounding mountains to 3,800 meters. Drainage is to the north via the North Platte River. The area is relatively flat and characterized by

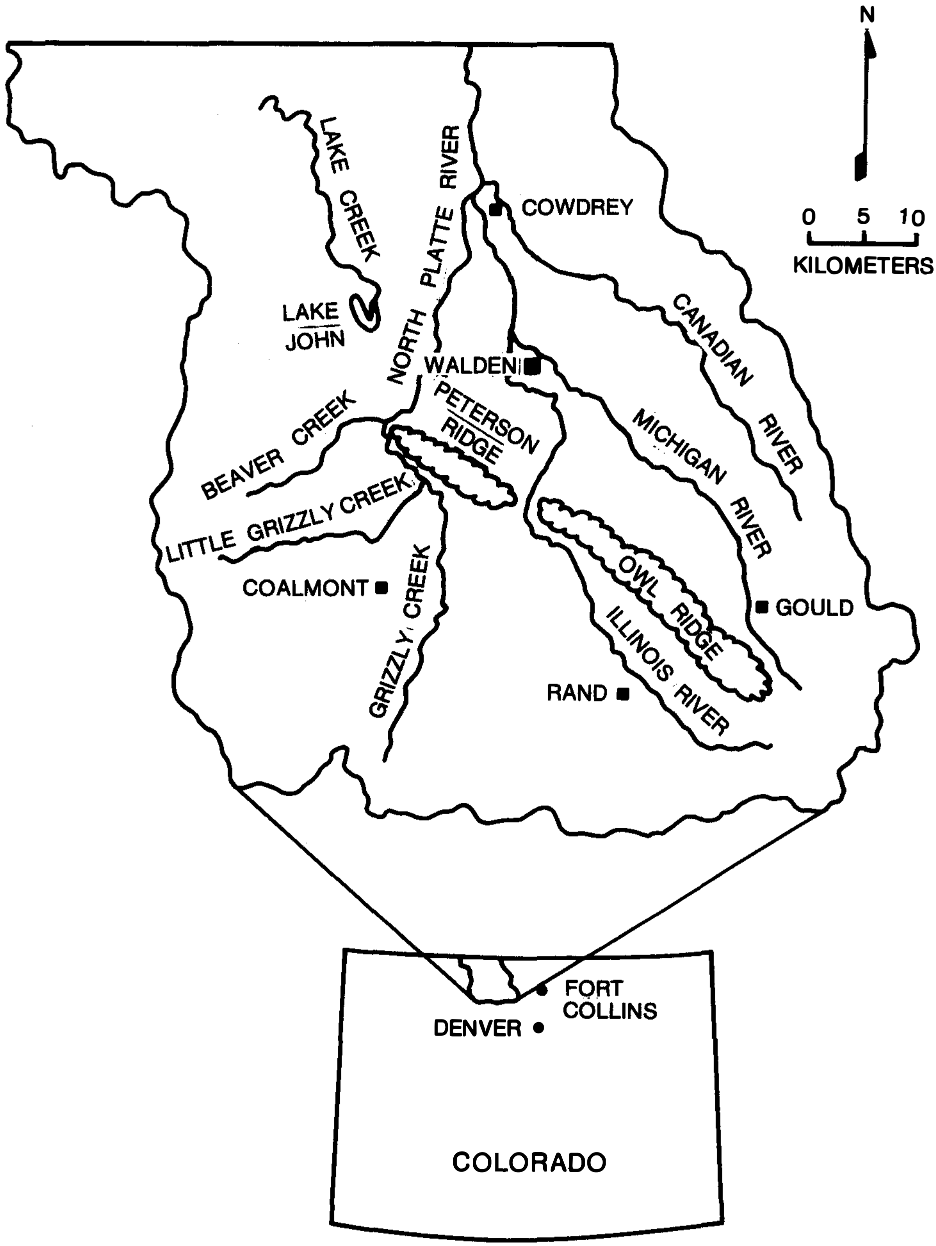

Figure 1. North Park, Jackson County, Colorado.

low undulating benches and ridges separated by drainages with the east-west Owl and Peterson ridges being exceptions. About 1,868 square kilometers of sage grouse habitat occur in this area, of which about 619 square kilometers are irrigated meadows of native sedges and grasses (Braun and

Beck 1976). Most irrigated meadows are managed for hay production. Excluding hay meadows along water courses, most vegetation is a sagebrush shrub/bunchgrass type dominated by *Artemisia tridentata vaseyana* and *A. t. wyomingensis*, *A. longiloba*, *A. cana*, and *A. argilosa*. Other important shrubs include rabbitbrush (*Chrysothamnus* spp.), snakeweed (*Gutierrezia* spp.), willows (*Salix* spp.) and black greasewood (*Sarcobatus vermiculatus*). Herbaceous vegetation is primarily low-growing perennial forbs and perennial bunchgrasses, with few annual forbs (Braun and Beck 1976).

The climate of North Park is cold and dry. Mean monthly temperatures range from -10 (January) to 15 degrees Celsius (July), with 24 to 36 centimeters of annual precipitation (U.S. Department of Commerce 1973). Prevailing winds are from the southwest, with frequent high velocities, particularly in winter and spring. Drifting of snow is common because of constant winds and rolling terrain. The average frost-free season in Walden (county seat) is 46 days, from mid-June to early August. Consequently, the area is used for livestock grazing, hay production, recreation, with some oil, gas and coal production.

Methods

The apparent size of the sage grouse population from 1973 through 1995 was monitored from intensive counts of males on leks (four counts per lek, spaced at 7- to 10-day intervals from April 1 to May 15), following recommendations of Emmons and Braun (1984). Prior to 1973, count procedures followed the recommendations of Patterson (1952) as modified by Rogers (1964) (three counts per lek evenly spaced between April 15 and May 1) for Colorado. The problems of the early counts for use as a population index were reviewed by Beck and Braun (1980). Searches for new or relocated leks were made at three- to five-year intervals using fixed-wing aircraft, helicopters and/or intensive ground searches. We estimate that more than 90 percent of all active leks were located from 1973 through 1995.

Sage grouse production was measured using ratios of young per hen in the harvest from wings collected during field checks, at hunter-check stations and volunteer wing-collection stations (Hoffman and Braun 1975, Braun and Beck 1985). Age and sex classes of birds harvested were assigned following Beck et al. (1975). Unknown bias may exist in vulnerability to harvest between young and adults (C.E. Braun unpublished data), but little hunter selection was evident from interviews with hunters at check stations (Braun and Beck 1985).

The design of the initial sagebrush treatments in the Lake John area of North Park was developed by Gill (1965) and featured both block and strip spray treatments. Two areas (208 and 729 ha in size) were sprayed with 2,4-D in blocks on June 2 through 5, 1965, along with two adjacent areas (196 and 478 ha in size) sprayed in strips of varying width (5, 10, 15, 20 and 25 meters), with intervening untreated 20-meter wide strips of sagebrush. Carr (1967) reported on the evaluation design and initial (two-year) responses to treatments. We remeasured the vegetation on 21 permanent macroplots (each 31.5 m2) in 1973 and analyzed the available data on movements among leks and trends in numbers of males counted on leks, and in total harvest (Braun and Beck 1976).

Results

Habitat Responses

Live sagebrush crown cover decreased by 70 to 73 percent in all height classes following spraying and remained low in 1973. Relative frequency of forbs also decreased (7-52 percent) from 1966 to 1973, while relative frequency of grasses increased (8-10 percent). Percentage sagebrush kill was lowest (47 percent) in strip-sprayed areas and highest (> 95 percent) in the block spray areas. Thus, spraying of sagebrush with 2,4-D resulted in marked decreases of live sagebrush and forbs through 1973 (eight years) and a modest increase in relative frequency of grasses. Differences were most evident in the block spray areas where more than 95 percent of the sagebrush was killed. While not quantified, the block spray and treated strip areas still were visually apparent in 1995, 30 years after treatment.

Sage Grouse Responses

Known active sage grouse leks within the original Lake John study area decreased from 14 to 8 from 1961 through 1965 to 1975, with 6 leks being abandoned and 3 new leks found. This was a 43-percent decrease in number of pre-treatment leks that remained active after spraying. However, three new leks were located in or near the treatment area by 1975. Thus, the net loss was three leks (21 percent). We believe that lek abandonment occurred because of the treatments and lek formation resulted from changes in sage grouse distribution caused by spraying. While cause and effect seemed apparent in the block spray areas, the lack of adequate controls in the strip spray areas and concurrent treatments in adjacent areas made unambiguous conclusions difficult. Thus, all data from counts of male sage grouse throughout North Park were examined.

Total male sage grouse counted each year throughout North Park decreased from 765 in 1961 through 1965 to 661 in 1966 through 1970 and to 575 in 1971 through 1975 (Table 1). This was a decrease of 25 percent within 10 years of the original treatments. The sage grouse population expanded in 1976 through 1980 and remained high in 1981 through 1985 (Table 1). The number of active leks located throughout North Park was lower in 1966 through 1970 than in 1961 through 1965 (Table 1). This low number continued through 1975 when the population expanded, especially after 1976. Lek extinction rates from 1961 through 1965 to 1995 averaged 23.5 percent per five-year period and were highest (40.0-44.4 percent) from 1965 through 1970 to 1971 through 1975.

Table 1. Male sage grouse counted on leks in North Park, Jackson County, Colorado, 1961-1995.

		Total males counted		
Period	Leks (*n*)	Five-year mean	Range	Percentage change
1961-65	15-22	765	466-948	
1966-70	14-19	661	414-831	-14.0
1971-75	14-19	575	525-700	-13.0
1976-80	21-35	1,109	669-1,521	+93.0
1981-85	22-32	989	466-1,283	-10.8
1986-90	21-26	674	497-800	-31.9
1991-95	24-26	641	571-757	-4.9

Sage grouse production indices for North Park decreased in the five years following treatments and remained low through 1975 (Table 2). We suspect that a combination of lower nest success and chick survival resulting from the reduced live sagebrush cover and forb production may have caused the observed decline in percentage of young sage grouse and young per hen in the harvest.

Sage grouse harvest regulations in North Park were conservative through 1970 and, starting in 1975, seasons were gradually lengthened and bag and possession limits were increased (Table 3). The designed habitat treatments had no direct impact on harvest regulations and total harvest was unknown prior to 1974. Changes in regulations resulted from knowledge gained through banding studies that were initiated in 1963 and intensified in 1973.

Table 2. Measures of sage grouse production in North Park, Jackson County, Colorado, 1961-1995.

	Percentage young in harvest		Young per hen	
Period	Five-year mean	Range	Five-year mean	Range
1961-65	47	31-58	1.4	0.8-2.0
1966-70	42	30-58	1.2	0.6-2.2
1971-75	44	33-50	1.2	0.8-1.4
1976-80	50	42-58	1.5	1.1-2.2
1981-85	53	47-57	1.6	1.3-1.9
1986-90	49	39-62	1.3	0.8-2.0
1991-95	44	37-56	1.1	0.9-1.8

Table 3. Sage grouse harvest regulations in Jackson County, Colorado, 1961-1995.

Period	Season length in days	Bag/possession limits
1961-65	1-3	2/2, 2/4, 3/3
1966-70	2-4	2/4
1971-75	3-9	2/4
1976-80	9-16	3/6
1981-85	23-30	3/6
1986-90	23-30	3/6
1991-95	17-34	2/4, 3/6, 3/9

Discussion

The effects of sagebrush spraying on distribution and abundance of sage grouse in North Park were difficult to assess because of initial project design, more treatments than were planned, no control over contemporary treatments and a lack of knowledge about sage grouse in the area. Within five years of the original treatment project, an additional 506 hectares of sagebrush were sprayed and 1,461 hectares were plowed and seeded. Thus, sagebrush on at least 28 percent of the land within the original study area was treated (Braun and Beck 1976). It was clear that spraying of large blocks (> 200 ha) of sagebrush was negative for sage grouse as leks were abandoned, distribution of grouse was altered and large areas became unusable for all life processes of sage grouse. This knowledge, coupled with information concurrently being learned about sage grouse in other portions of their range, was used to prepare reports (Braun et al. 1976), guidelines (Braun et al. 1977) and recommended management practices (Autenrieth et al. 1982) to benefit sage grouse. These guidelines and management practices have been widely accepted, adopted and incorporated into management plans in Colorado and throughout the range of sage grouse.

Our analysis of the results of the initial 9 to 10 years of banding data and lek counts in the Lake John treatment area revealed that sage grouse moved freely throughout the treated and adjacent areas (Braun and Beck 1976). Additional work by Beck (1975, 1977) revealed that sage grouse from throughout North Park aggregated in selected sites during winter, with mixing of birds from all drainages and leks. Thus, sage grouse in North Park were one population with limited movements north into Wyoming and south into Middle Park. This knowledge led to recommendations (Autenrieth et al. 1982) and implementation of lek surveys by discrete geographical areas. The need for understanding lek counts (Beck and Braun 1980) led to studies of lek attendance by radio-marked male sage grouse. This study resulted in the present recommendations for use of lek surveys (Emmons and Braun 1984).

Sage grouse were banded throughout North Park from 1973 to 1991, versus only in the Lake John treatment area from 1963 to 1969 because it became clear that sage grouse moved throughout the park. This necessitated improved techniques for reliably capturing grouse as reported by Giesen et al. (1982). Band recoveries by hunters were used to calculate harvest rates (first-year recovery rates) (Braun and Beck 1976, 1985). These data provided the basis for liberalization of hunting regulations starting in 1975 and continuing through 1994 (Braun 1987). Banding of sage grouse also increased the need for reliable harvest data by age and sex classes. Thus, techniques for classifying age and sex from wings from hunter-harvested sage grouse were improved (Beck et al. 1975, Braun in preparation). This improved the knowledge of composition (young, yearlings, adults, males and females) of the autumn population, provided harvest samples adequately reflected true population composition (Braun 1984).

No relationship was demonstrated among hunting regulations and harvest rates and subsequent breeding population size (Braun and Beck 1985, Zablan 1993). Further, total harvest was most closely related to apparent spring population size (Braun and Beck 1976, 1985).

Habitat alteration activities, such as coal mining (Braun 1986) and oil and gas development (Braun 1987), in North Park negatively impacted sage grouse numbers in local areas but primarily altered distribution of breeding grouse (Remington and Braun 1991). These results, coupled with those from the 1965 spray treatments in the Lake John area of North Park, demonstrate the need for long-term monitoring of grouse populations on a geographic basis. Short-term monitoring of sage grouse in local areas is inappropriate, as the data collected would be inadequate to examine population responses at a landscape level.

Conclusions

The need for knowledge about sage grouse responses to sagebrush treatments resulted in research studies in North Park, Jackson County, Colorado that spanned 30 years. Results from the original study indicated that sage grouse responses to the 1965 treatments were negative and resulted in a population decline as measured by number of active leks, total males counted, and percentage young and young per hen in the harvest. These responses continued for at least 10 years following treatments. Findings from the 1965 through 1973 research efforts, in conjunction with results of studies in other states, greatly affected sagebrush management in Colorado and throughout the range of sage grouse through development of guidelines for habitat management. The weaknesses of the initial study spurred development and improvement of techniques for lek surveys, trapping procedures, harvest data collection and age/sex classification from wings. As a result, management of hunting recreation opportunities was enhanced. Further, the value of long-term collection of population data for management has been repeatedly demonstrated, as different habitat alteration actions have been suggested and implemented. However, any value has been severely restricted by lack of cause/effect studies of habitat-population relationships.

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Research Contributions to Management of Canada Geese in the Mississippi Flyway

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When winter counts of Canada geese (*Branta canadensis*) began in 1936, numbers tallied in the Mississippi Flyway were about 100,000 (Reeves et al. 1968). In 1995, the tally was about 1.7 million (Gamble 1995). Geese have benefited from conversion of deciduous forests and prairies to agriculture. Large-scale mechanized agriculture provided an abundance of open landscapes and waste grain. However, the phenomenal growth of Canada geese in the Mississippi Flyway was no ecological accident or unintended result of human alteration of the landscape. Growth of Canada goose populations was a result of careful regulation, diligent enforcement and population management enlightened by results of long-term research. The purpose of this paper is to describe some of the links between long-term research and the development of Canada goose management in the Mississippi Flyway.

Methods

Many fine studies of Canada geese were completed before 1960 in many parts of North America. However, we generally restrict this review to studies or investigations of five years or more on populations of Canada geese on their breeding ranges in the Mississippi Flyway. For the most part, we also restricted our review to studies conducted or reported on since 1965. We took a broad view of what constituted population research on Canada geese; we included taxonomic studies, banding and marking, and population and harvest surveys.

Some readers might argue that banding and surveys are descriptive, monitoring and/or operational management, not research. We argue that these activities began as question-oriented research, and that they have been used, tested and modified in the mode of adaptive research-management models. Furthermore, even after 30 years, they still are not operational to the extent that they are institutionalized in agency budgets.

Research/Management Links

Rediscovery and Restoration of Giants

The world authority on Canada goose taxonomy is Harold C. Hanson of the Illinois National History Survey. His taxonomic collections and band analyses formed the basis for delineation of populations (Figure 1) and the foundations for both population research and management of Canada geese in the Mississippi Flyway (Hanson and Smith 1950). We believe his rediscovery of the giant Canada goose (*B. c. maxima*) at Rochester, Minnesota in January 1962 (Hanson 1965) was the most important research/management link for Canada geese. He established the wild existence of a subspecies thought to be extinct for several decades; that discovery set the stage for the restoration of giant Canada geese to all of their former range (Figure 1) and all of the states and provinces of the flyway (Rusch et al. in press). Had giants not been rediscovered and restored, they probably would be extinct or endangered today, rather than the most important geese in the harvest of many states and provinces. And, as we shall describe later, the restoration of giants had profound and largely unforeseen implications for management of all Canada geese in the flyway.

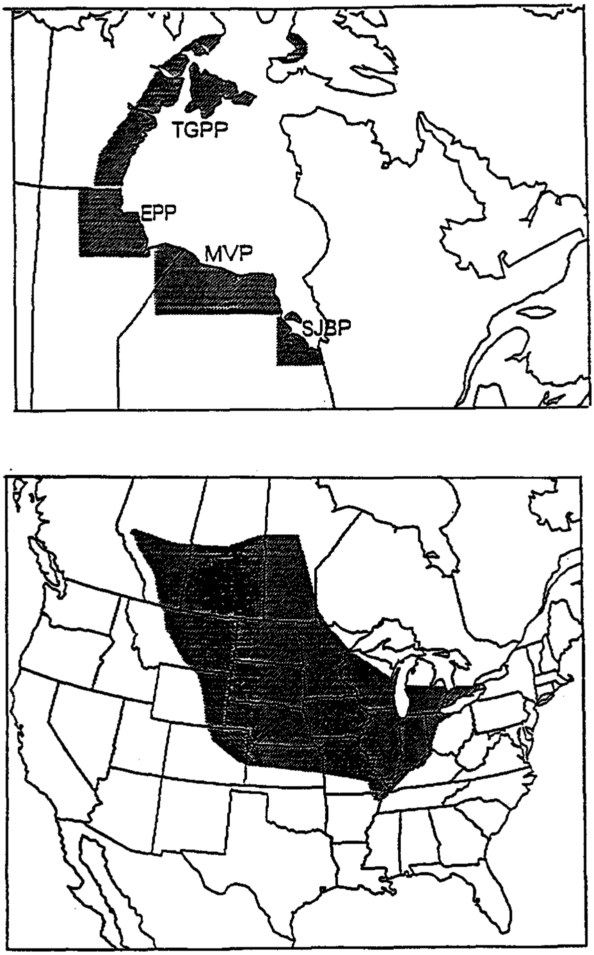


Figure 1. Recognized breeding ranges of Canada geese of the Tall Grass Prairie Population (TGPP), Eastern Prairie Population (EPP), Mississippi Valley Population (MVP) and Southern James Bay Population (SJBP). Also shown (bottom) is the approximate historic breeding range of the giant Canada goose (after Hanson 1965). In 1995, giant Canada geese bred in every state of the Mississippi Flyway and in the southern portions of Manitoba and Ontario.

Banding and Marking

Large-scale banding of Canada geese in the Mississippi Flyway began with Jack Miner in Ontario (Miner 1972) and was followed by intensive work on the wintering areas in Illinois (Wright and Kasul 1980) and Missouri (Vaught and Kirsch 1966). The patterns of band recoveries confirmed earlier designations of the Mississippi Valley (MVP), Eastern Prairie (EPP) and Tennessee Valley populations (TVP; later Southern James Bay [SJBP]) of Canada geese (Hanson and Smith 1950, Cummings 1973). Direct band recoveries provided an index to harvest rates, and winter inventories provided an index to population size. These indices allowed managers to control harvest to the degree necessary to promote population growth of Canada geese in the flyway (Figure 2).

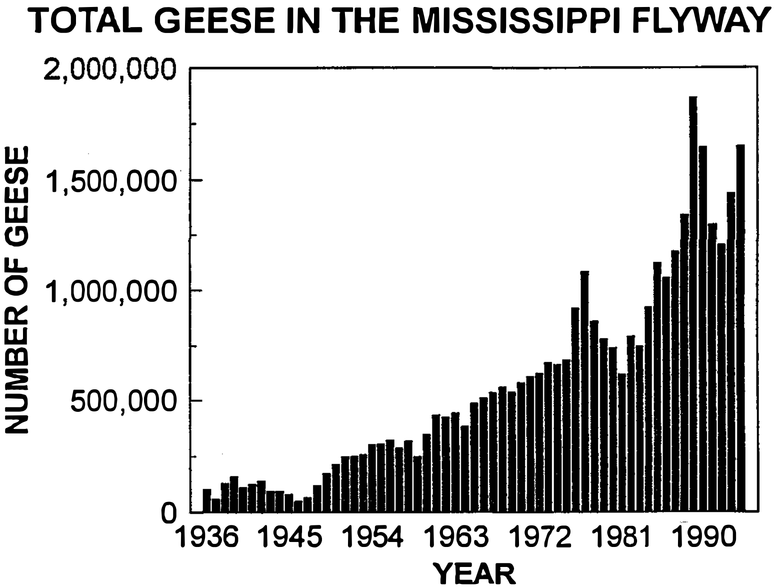


Figure 2. Total numbers of Canada geese tallied from aerial surveys conducted in December and January, 1936 through 1995 in the Mississippi Flyway.

The successful restoration and subsequent growth of populations of giants in all of the states and provinces of the Mississippi Flyway changed the ways in which population information could be gathered. Capture and counts of geese on wintering areas included increasing numbers of giants which sometimes could not be distinguished by biologists on the ground and never by biologists in aircraft. In the 1970s, Mississippi Flyway biologists began to count and band geese on their breeding areas in spring when populations were geographically discrete. Some flightless Canada geese on northern breeding grounds were captured by researchers on foot or in boats in the 1950s, but researchers and managers took advantage of development of aircraft and aviation facilities that made travel and work in remote Arctic and subarctic areas possible. Modern, large-scale banding near Hudson and James Bays began in 1967 with the use of helicopters to drive flightless geese (Pakulak 1969, Pakulak and Schmidt 1970). Annual banding of 300 to 3,000 flightless Canada geese began in 1968, 1980, 1976 and 1987 for the EPP, MVP, SJBP and Tall-grass Prairie populations (TGPP), respectively. Many of the flightless adults also were marked with coded plastic neckbands after 1976. Extensive banding and marking of flightless giants generally began in the 1980s.

Distribution. Recoveries and especially observations of geese marked in various parts of their breeding areas allowed managers to describe the extent of the breeding range of geese associated with particular migration routes and wintering areas (Craven and Rusch 1983, Samuel et al. 1991, Smith et al. 1992). Knowledge of breeding range boundaries allowed researchers and managers to design spring surveys to estimate size of populations and banding/marking programs to provide information on distribution, harvest and survival of individual populations.

Analysis of band recoveries from SJBP Canada geese showed clear northward shifts in wintering distributions of geese over four decades (Smith et al. 1992). These changes in wintering distribution of SJBP geese were associated with large declines in numbers of geese wintering in the southern portions of the Mississippi and Atlantic flyways (Orr et al. 1991).

Harvest and survival. Biologists long have assumed that harvest controls survival, which in turn controls population growth in Canada geese. Indeed, this model probably has been the cornerstone of successful Canada goose management throughout the world (Raveling and Rusch 1991). The extent to which harvest mortality is compensated for by density-dependent survival or reproduction is an important and contentious issue in waterfowl management. Many studies of compensatory and/or additive mortality have been published for ducks (Burnham et al. 1984) but only a few have been published on geese (Rexstad 1992, Raveling and Rusch 1991). Harvest rates and survival rates estimated from band recoveries suggest that hunting accounts for most of the mortality in adult Canada geese. In the Mississippi Flyway, for example, adult direct recovery rates averaged about 0.05 in 1988 to 1994 and adult survival averaged about 0.78 in the same period; assuming a band reporting rate of 0.33 and a retrieval rate of 0.80, the estimated harvest rate would be 0.19 (0.05/0.80/0.33). Thus, about 86 percent (0.19/1.00-0.78) of all mortality was accounted for by harvest if our estimates and assumptions are reasonable. This indicates that predation, disease, accidents and other forms of adult mortality account for only 14 percent of the total, and suggests little opportunity for compensation in the mortality process. Generally, survival and harvest rates estimated from band recovery data should not be used in correlation analysis of compensatory mortality. Both estimates are calculated from the same data and, thus, lack independence. However, harvest rates from band recoveries and survival rates from neckband observations are independent, and the correlation of many such estimates from various populations in the Mississippi Flyway suggests a weak inverse relationship (Figure 3). However, Canada goose population management strategies in the Mississippi Flyway tend to stabilize adult survival. Also, some variance in direct recovery rates probably is due to variance in reporting rates rather than harvest rates.

Recoveries and observations of geese banded and marked on the breeding grounds have allowed biologists to monitor the distribution and control the harvest rate. These data are essential for modern population management of Canada geese in the Mississippi Flyway.

Breeding Season Surveys

In the Mississippi Flyway, experimental aerial surveys of Canada geese in the breeding season began with the EPP in 1971 (Malecki et al. 1981). The pilot surveys indicated that aerial surveys were practical and feasible, and provided reasonable estimates with relatively tight confidence intervals. Spring surveys became operational for the EPP in 1974. Spring surveys were initiated in 1989, 1990, 1992 and 1992 for MVP, SJBP, TGPP and giants, respectively.

Early aerial surveys of EPP and MVP Canada geese provided estimates that generally were comparable to midwinter indices (Figure 4). However, the breeding season estimates of the SJBP and the giant populations presented some big surprises. In 1985 to 1988, the midwinter index for SJBP Canada geese averaged about 154,000. Experimental banding (H. Lumsden personal communication: 1988) and early analyses of band recoveries (Kasul and Wright 1984) pretty well described the population boundaries. Researchers and managers expected to estimate at least 150,000 geese during the 1989 breeding season survey and were perplexed to estimate only 80,000 (Figure 5). Dramatic restrictions in regulations were implemented immediately. Improved and expanded surveys in 1990 to 1993 provided generally similar estimates, all well below 150,000. Mississippi Flyway biologists became increasingly suspicious that a large and growing number of giants in midwinter counts had masked a decline in numbers of SJBP. That suspicion was confirmed when spring surveys of giants were conducted in the Mississippi Flyway in 1994 and 1995. Spring estimates indicated that giant numbers were approximately 1.0 million, about three to four times the number suggested by the midwinter index.

Management efforts to control large and growing numbers of giants were intensified almost immediately. These included expanded early and late seasons, various forms of control of nuisance flocks and a draft management plan.

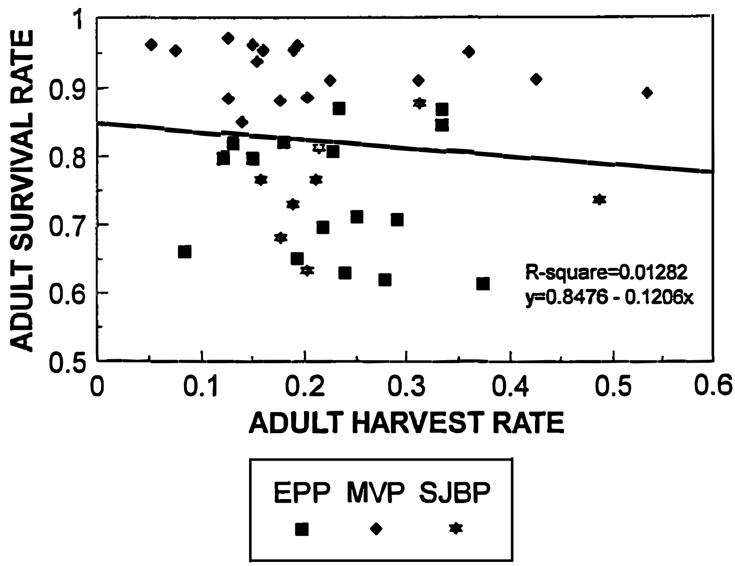


Figure 3. Direct recovery and survival rates of adult EPP, MVP and SJBP Canada geese, 1977-1994. Direct recoveries rates are estimated from leg-band recoveries and survival rates are estimated from neckband observations by capture/recapture methods.

Reproductive Ecology

A long-term study of the reproductive ecology of EPP Canada geese began in 1967 with the work of A. J. Pakulak (1969) near Cape Churchill, Manitoba. Pakulak's studies in 1967 to 1969 were followed by those of Malecki (1975) in 1971 to 1974 and Rusch and others in 1976 to 1995 (Didiuk 1979, Moser 1987, Allen 1996, Walter 1996).

Natality. Early studies of giant Canada geese suggested that many or most geese first nested in their second year of life. Early population models used by the Mississippi Flyway Technical Section assumed most *B. c. interior* female geese also nested at two years of age. Some biologists even suspected that EPP females, because of their small size and northerly breeding distribution, might nest in their first year of life. However, studies of age-related reproduction in the EPP demonstrated that most females did not nest until their fourth or even fifth year of life (Moser 1987, Moser and Rusch 1989). Similar results were obtained from observations of family sizes of neck-banded geese of the MVP (Hardy and Tacha 1987). Research results on age of first breeding in interior Canada geese were incorporated into improved population models and management plans which led to reduced harvest rates and improved growth of populations toward flyway goals.

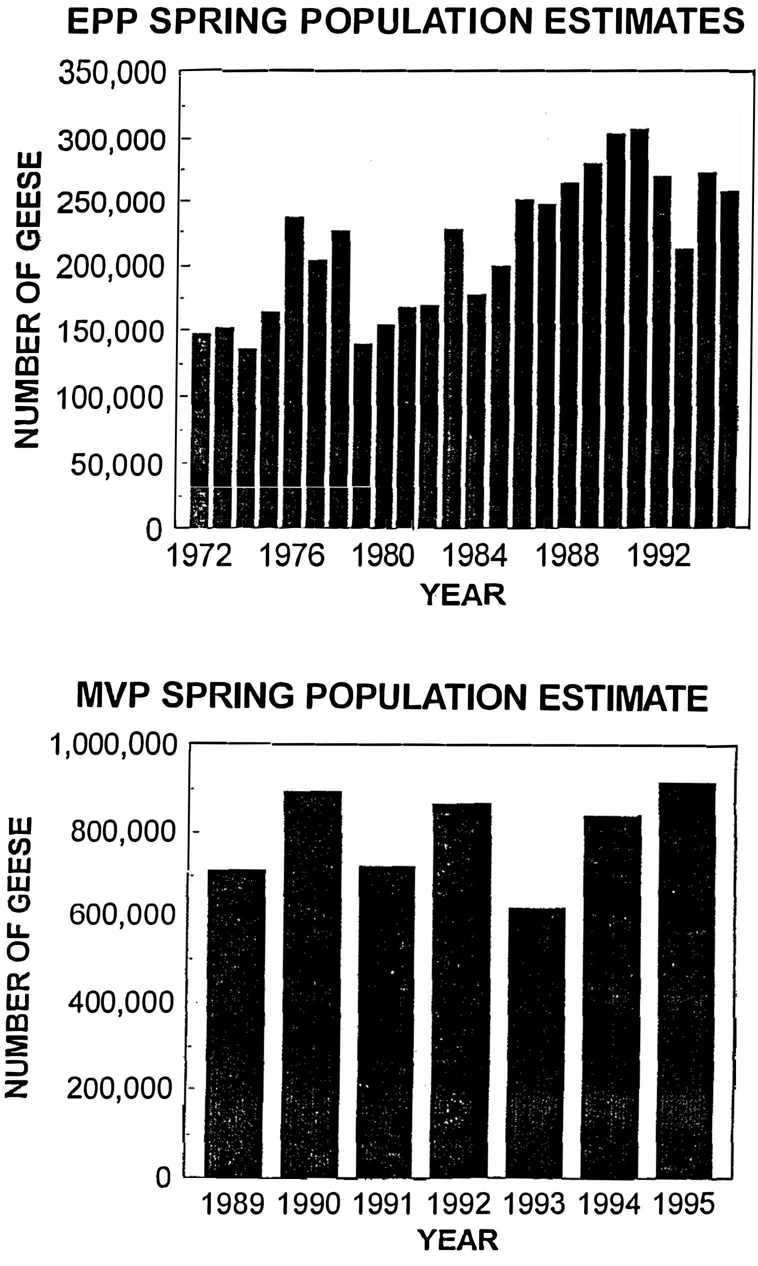
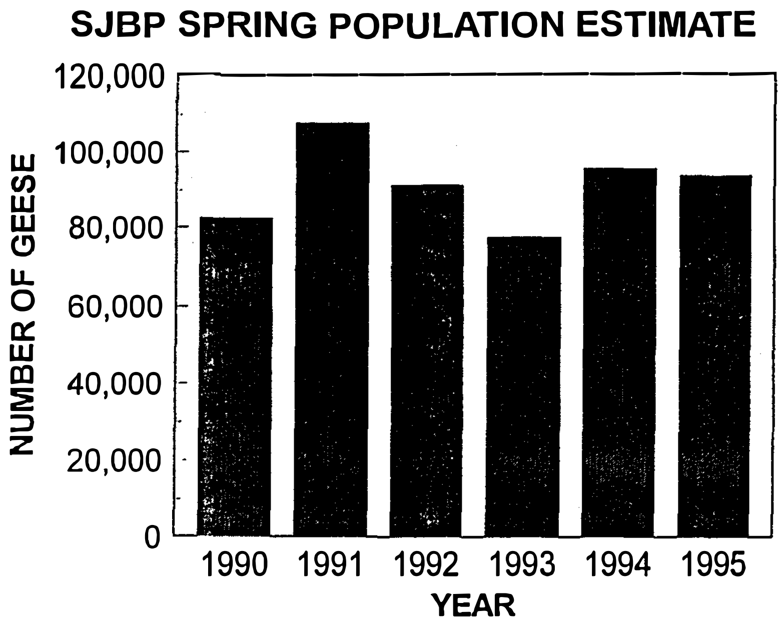


Figure 4. Estimates of numbers of EPP and MVP (bottom) Canada geese from spring aerial surveys flown in Manitoba and Ontario. The 1972 to 1995 EPP estimates are from Malecki et al. 1981, and D. Humburg, P. Tealander and R. Foster (unpublished data). The 1989 to 1995 MVP estimates are from J. Leafloor (unpublished data).



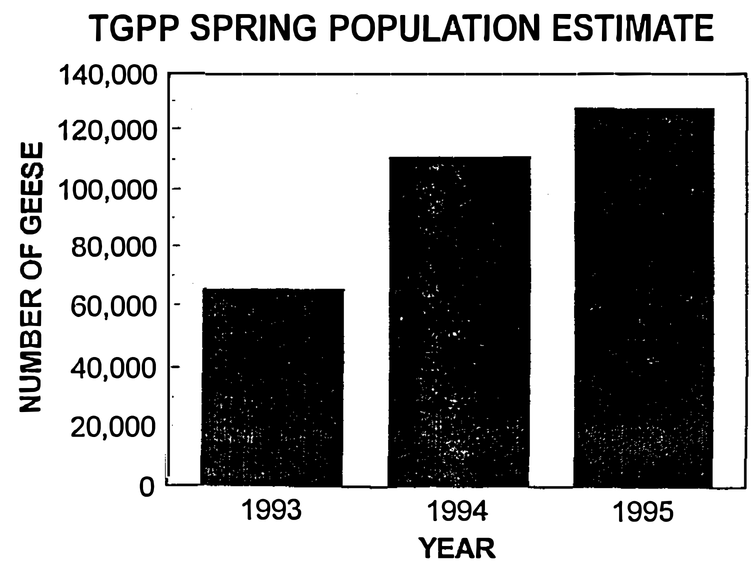


Figure 5. Estimates of numbers of SJBP and TGPP (bottom) Canada geese from aerial surveys flown near the western shore of James Bay (J. Leafloor unpublished data) and on Baffin Island (F. D. Caswell unpublished data). TGPP estimates from 1993 include breeders only.

Production and weather. The relationship between fat reserves, spring weather and clutch size in Arctic geese was suggested decades ago (Ryder 1970) and since has been demonstrated in several other studies. In the Arctic, a near-complete failure of reproduction of small Canada geese occurred in late spring of 1992 on Baffin Island (F. D. Caswell unpublished data), but the effect of late springs on breeding effort in subarctic Canada geese is not as well documented. The spring phenology/clutch size relationship is evident in 25 years of data from Cape Churchill (Figure 6), but the difference in clutch size in an early versus late year was only 1.4 eggs. In very late years, clutch size was about 82 percent of the long-term mean of 3.9. An 18-percent reduction from average clutch size is significant, but would it be worthy of a major change in regulations to protect breeding stocks? Very low clutch size occurred at Cape Churchill in 1978, 1983 and 1992. Results were reported at flyway meetings, but no drastic restrictions in harvest regulations were implemented because of: 1) uncertainties about the magnitude and scope of poor production; 2) inability to incorporate "late" information into the regulatory process; 3) hope that improved adult survival might compensate for low recruitment of young; and 4) willingness to "wait and see" if poor production really impacted abundant goose stocks and, if it did, either to accept lower populations or reduce future harvests. In all cases, late springs and low clutch sizes were followed by unusually low age ratios and substantial decreases in subsequent spring estimates. In hindsight, it appears that production was low over most of the range in late springs and that the magnitude of reduction was much greater than the 18 percent predicted from clutch sizes. So what happened? A post-hoc analysis of the long-term data on Canada goose nest density and reproduction at Churchill provides some strong inference.

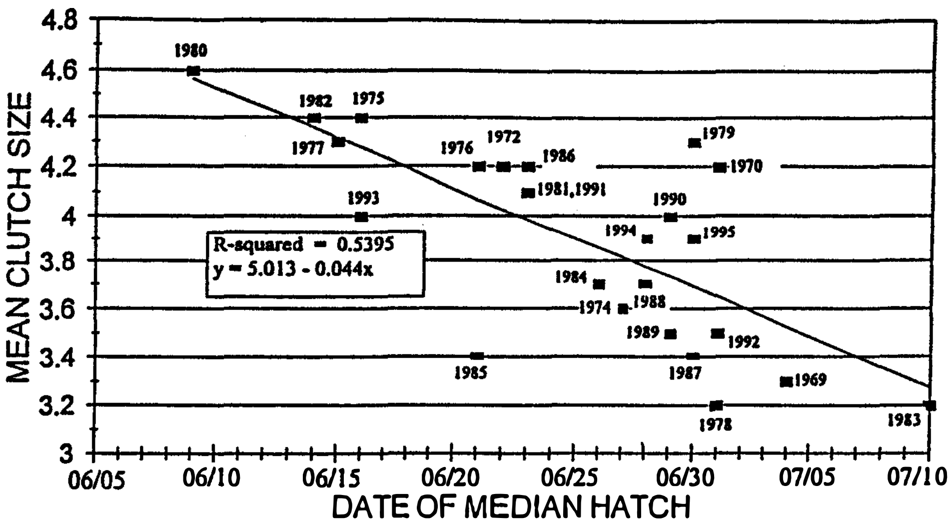


Figure 6. Relationship of median hatch dates and mean clutch sizes in Canada goose nests found near Cape Churchill, Manitoba, 1969 to 1995.

We suggest that the general trend in numbers of nests at Cape Churchill (Figure 7) was a function of normal mortality of adults and low recruitment of young. The latter was mainly related to increased mortality due to increased fox predation and perhaps also due to increased competition with snow geese for grazing areas (Walter 1996). The years below the trend line all are the four years of latest hatch. We suggest that female geese of the EPP were alive and present in those years but did not nest (Allen 1996). Likewise, few goslings were fledged in the MVP after the late spring of 1992. A June snowstorm was suspected as the cause of heavy mortality of goslings.

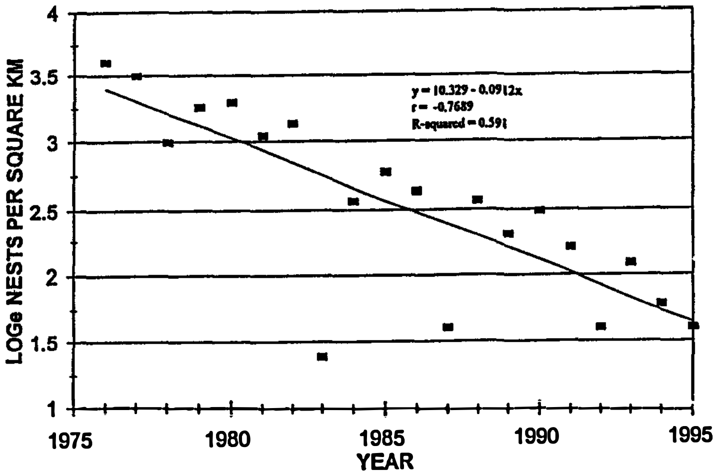


Figure 7. Decline in density of goose nests found near Cape Churchill, Manitoba, 1976 to 1995.

Autumn Flight Models

We used accumulated knowledge of the spring phenology/reproduction relationship at Churchill to develop models to predict autumn flights. Autumn flights were estimated as the sum of the midwinter index and the harvest of the previous hunting season. Our most successful models incorporated midwinter counts and April/May heating-degree days at Churchill to form predictions that accounted for 75 to 90 percent of the observed variation in autumn flight in 1967 to 1985 (Weiss et al. 1991). Since 1985, predictions explained about 50 percent of the observed variation in autumn flights of the EPP and MVP (Figure 8). Preliminary analyses and model recalibrations suggest that substitutions of breeding season surveys for midwinter counts and use of refined harvest estimates from derivation analyses will improve coefficients of determination to 90 to 95 percent.

The size of the spring population clearly is the most important predictor of autumn flight. Canada geese are long-lived birds with relatively low rates of reproduction. In years with late springs, like 1992, Arctic populations such as the TGPP produced almost no young. Even in years with early springs, immatures seldom comprise more than 40 percent of the autumn flight.

Heating-degree days are an index of cumulative warming and probably are related to soil temperatures which, in turn, are primary determinants of plant growth. New plant growth probably is crucial to early gosling survival. Cumulative warming obviously is related to snow melt, but the date of snow disappearance also is determined by the amount and timing of snowfalls. In some warm springs, goose nesting is retarded by persistent snow cover. On the other hand, nesting is retarded by cold temperatures *per se* in the occasional cold but snowfree spring. Researchers and managers in the Mississippi Flyway generally agree that autumn flights of northern goose populations can be predicted from weather-reproduction models. However, the extent to which autumn flight predictions are incorporated into the regulatory process is dependent not only upon the accuracy of predictions, but also on factors such as the numerical status of the population and joint harvest agreements among countries, provinces and states.

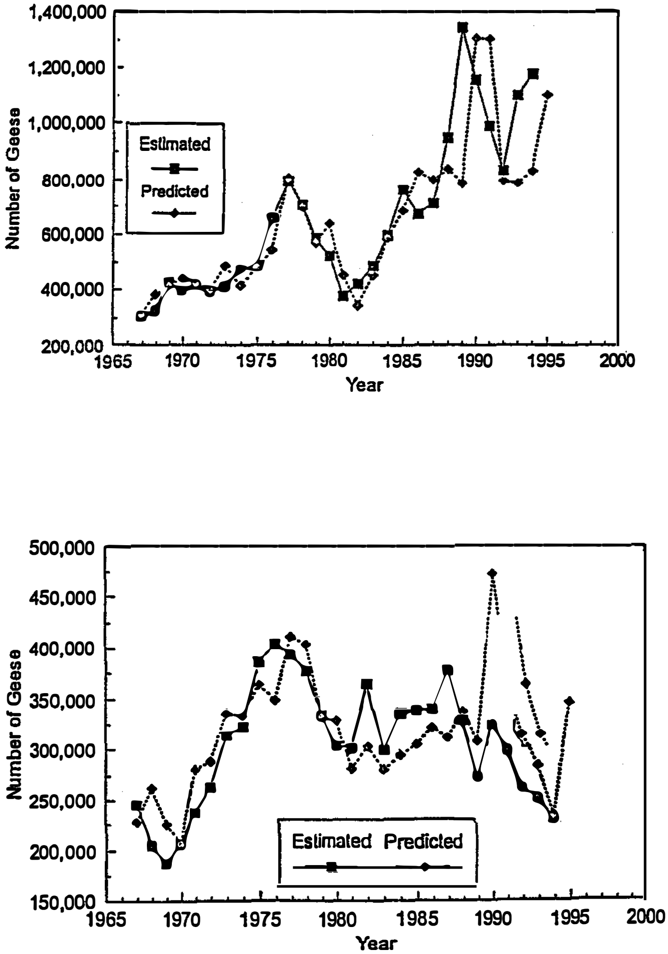


Figure 8. Comparisons of predicted and estimated autumn flights of MVP (top) and EPP Canada geese (bottom). Estimated autumn flights are sums of midwinter counts and harvests of the preceeding hunting seasons (Weiss et al. 1991). MVP autumn flights were predicted from previous midwinter counts, April heating-degree days at Churchill, Manitoba and mean March temperatures (degrees Fahrenheit) at Horicon (Y=127.92 + 2.12 MWC - 0.00195 ADD + 0.0185 MMT; R2 = 0.82 for 1967-85). EPP autumn flights were predicted from midwinter counts and May heating-degree days at Churchill (Y=102.95 + 2.06 MWC - 0.00155 MDD; R2=0.77 for 1967-85).

Harvest Derivations

In the past, Canada goose harvests were estimated from stamp holder response to questionnaires and species composition from tail fans submitted by hunters. These estimates seemed reasonable at the flyway, state and provincial levels, but biologists were unable to separate Canada goose tail fans by subspecies and population. In modern goose management strategies, population-specific estimates of harvest are needed to monitor efficacy and population effects of regulatory changes. In recent years, Mississippi Flyway researchers and managers have used analysis of weighted band recoveries to calculate the derivation of the Canada goose harvest (Munro and Kimball 1982) in each state and province. The method requires that each population is of known size, is banded and produces band recoveries during the hunting season. The weight per band recovery is estimated from the relationship between size of the population and number of bands available. The number of bands available is estimated from the number of bands recovered divided by the harvest rate: harvest rate is the direct band recovery rate divided by 0.33, the assumed band reporting rate. An estimate of population-specific harvest is generated from the product of the appropriate population weights and number of bands recovered. Alternatively, area-specific weighted harvests can be converted to percentages and multiplied by Canada goose harvest estimates from questionnaires. The latter procedure is preferred if geographic variation in reporting rates is known or suspected. Population-specific harvest estimates of Canada geese are used as the primary means of monitoring effects and efficacy of regulations in the Mississippi Flyway.

Population Models

In the mode of adaptive management, Canada goose research in the Mississippi Flyway provides a population model; management plans use the model as a base for strategies to attain the population or harvest goal. Harvest, population and other demographic parameters are monitored, and the models are replaced or revised as populations invariably fail to respond exactly as predicted. Some populations in the Flyway have survived several generations of models and management plans. Current models in the Mississippi Flyway share these common hypotheses: 1) Canada geese are composed of diverse stocks with discrete breeding distributions and overlapping autumn/winter distributions; 2) population growth is controlled mainly by adult survival which, in turn, is controlled by harvest; 3) Canada geese are long-lived birds with delayed reproduction and relatively low natality rates; 4) annual variation in reproduction generally is related to spring weather and is more pronounced at higher latitudes; and 5) harvest rates are related to exposure to hunting. Northern populations have longer migrations, subsistence harvest and more exposure to hunting.

Acknowledgments

We thank the hundreds of biologists of the Mississippi Flyway who helped find goose nests, marked and banded geese and observed neck-banded geese. We thank A. Didiuk, T. Moser, B. Allen, R. A. Malecki and S. Walter for access to unpublished goose nest data from Churchill. We thank D. Humburg, P. Tealander, R. Foster and other members of the Mississippi Flyway Technical Section for allowing us to use their unpublished survey data. We thank J. C. Wood for technical assistance. Last, but certainly not least we thank the U.S. Fish and Wildlife Service, The Canadian Wildlife Service, Ducks Unlimited, and The Mississippi Flyway Council for their vision and consistent financial support of long-term research that has led to state-of-the-art management of Canada geese in the Mississippi Flyway.

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Research and Effective Management of Neotropical Migrant Birds

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Wildlife managers have been dealing with the complexities of migratory bird management for much of the past century (Rappole and Warner 1978). The Migratory Bird Treaty Acts among the U.S., Canada and Mexico articulated a clear, early recognition of the need for international cooperation in management of these species. Since the 1930s, the extent and location of refuges in the National Wildlife Refuge System of the U.S. Fish and Wildlife Service likewise has reflected awareness of the complex ecological requirements of migrants on breeding grounds, during migration and on wintering grounds. More recently, the Western Hemisphere Shorebird Reserve Network, established in 1985, maintains and protects winter habitat and stopover sites for these species. Though it has not been easy, professional wildlife managers in the U.S., with the cooperation of managers from Canada and Mexico, have been able to maintain huntable populations for many species of migratory waterfowl, shorebirds, rails, doves and cranes, despite substantial growth in the human population and tremendous development pressure on wildlands. This is a remarkable achievement, especially considering that populations for a significant number of these species were in serious decline or were extirpated in the eastern half of the United States in the early 1900s.

Wildlife managers increasingly are being assigned a new challenge. Whether they like it or not, and whether they are prepared for it or not, they are being asked to manage migratory birds that breed on the lands under their care, but use stopover and wintering sites far beyond the borders of the U.S., species otherwise known as "neotropical migrants" (DeGraaf and Rappole 1995, Schneider and Pence 1992). This assignment is an extremely difficult one, and probably not fair given the background and training of most of our managers. Nevertheless, in order to deal with this mandate effectively, land managers in the U.S. and Canada are going to have to familiarize themselves with the new and growing body of research findings pertinent to the study of the ecology and effects of management on neotropical migratory bird populations.

The management decisions regarding neotropical migrants are particularly critical because many of these species are declining, threatened or endangered: 28 species of neotropical migrants have been classified as being "endangered" or "of management concern" by the U.S. Fish and Wildlife Service (Table 1), and another 79 species have been reported as having undergone significant population declines (DeGraaf and Rappole 1995: 15-21).

In this paper, we summarize some of the principal difficulties relating to the management of neotropical migrants during the different phases of their life cycle, and we attempt to point out the major management questions requiring further research. We also emphasize that there is a very real possibility that declines of many species could be caused largely by agents acting on these populations at times and in places that are beyond the control of land managers in the United States and Canada.

Table 1. Neotropical migrants classified by the U.S. Fish and Wildlife Service as endangered or as being of management concern.

Species	Status	Source	Suspected cause
Brown pelican	Endangered	USFWS 1991	DDT poisoning
American bittern	Management concern	USFWS 1987	Habitat loss
Least bittern	Management concern	USFWS 1987	Habitat loss
Reddish egret	Management concern	USFWS 1987	Habitat loss
White-faced ibis	Management concern	USFWS 1987	Habitat loss, environmental contaminants
Wood stork	Endangered	USFWS 1991	Habitat loss
Northern harrier	Management concern	USFWS 1987	Habitat loss
Peregrine falcon	Endangered	USFWS 1991	DDT poisoning
Black rail	Management concern	USFWS 1987	Habitat loss
Whooping crane	Endangered	USFWS 1991	Hunting, habitat loss
Snowy plover	Management concern	USFWS 1987	Habitat loss, human disturbance
Piping plover	Endangered	USFWS 1991	Habitat loss
Eskimo curlew	Endangered	USFWS 1991	Hunting
Gull-billed tern	Management concern	USFWS 1987	Habitat loss, human disturbance
Roseate tern	Management concern	USFWS 1987	Hunting, habitat loss
Least tern	Endangered	USFWS 1991	Habitat disturbance
Black tern	Management concern	USFWS 1987	Habitat loss
Olive-sided flycatcher	Management concern	USFWS 1987	Habitat loss
Southwestern willow flycatcher[a]	Endangered	USFWS 1992	Cowbirds, habitat loss
Vermilion flycatcher	Management concern	USFWS 1987	Habitat loss, cowbirds
Loggerhead shrike	Management concern	USFWS 1987	Habitat loss, human disturbance
Least Bell's vireo[b]	Endangered	USFWS 1991	Habitat loss, cowbirds
Black-capped vireo	Endangered	USFWS 1991	Cowbirds, habitat loss
Bachman's warbler	Endangered	USFWS 1991	Winter habitat loss
Golden-winged warbler	Management concern	USFWS 1987	Habitat loss, hybridization
Golden-cheeked warbler	Endangered	USFWS 1991	Habitat loss
Kirtland's warbler	Endangered	USFWS 1991	Cowbirds, habitat loss
Cerulean warbler	Management concern	USFWS 1987	Habitat loss, human disturbance

[a]Southwestern willow flycatcher is a subspecies of willow flycatcher.
[b]Least Bell's vireo is a subspecies of Bell's vireo.

Breeding Ground Management

In most instances, management of migratory birds on breeding grounds has focused on maintenance or preservation of breeding habitat. This strategy is reasonable: species must be able to breed to continue to exist. However, this approach is incomplete for most migratory species and has limited potential effectiveness. For instance, the cerulean warbler (*Dendroica cerulea*), a bird of mature deciduous forests (see Robbins et al. 1992), has undergone marked population declines over the past two decades. Therefore, it has been suggested that large tracts of mature forest (at least 4,000 ha) should be managed for cerulean warblers by regulating timber harvest and allowing immature stands to reach maturity (Hamel 1992: 385).

In this case, as in others, the prescription for management is based on the logic that since we don't know what is causing the declines, preserving and increasing the bird's breeding habitat constitutes the best management effort. However, there are limits to the fiscal and human resources we can dedicate toward species preservation. If we expend those precious resources on buying or otherwise preserving breeding habitat alone, and it turns out that breeding habitat loss is not the primary cause of the decline, then the resources are gone, perhaps along with the species and our credibility. In the case of the cerulean warbler, mature (i.e., sawtimber-size) deciduous forest breeding habitat has, in fact, been increasing in recent decades in the midwestern and northeastern U.S. (Table 2) without any significant timber-harvest regulation focused on that species. We note that the amount of this increase that is in blocks of continuous forest larger than 1,000 hectares, which is the apparent minimum area for occurrence of cerulean warblers (Askins et al. 1987, Robbins et al. 1989), is unknown and needs to be ascertained. However, it does not seem wise to commit limited resources based on the possibility that a species is declining primarily due to restrictions in breeding habitat, especially in areas where breeding habitat conditions generally are improving.

Table 2. Area[a] of sawtimber-size and total timberland for the current and prior forest surveys and percentage change between surveys for selected states in the north-central and northeastern United States.[b]

	Sawtimber size			Total forest area			
State	Prior survey	Current survey	Percentage change	Prior survey	Current survey	Percentage change	Source
Minnesota	3,484.4	4,890.3	+40.3	13,613	14,723.2	+8.0	Jakes (1980), Miles et al. (1990)
Wisconsin	3,098.4	4,654.7	+50.0	14.536.8	14,759.4	+1.0	Spencer and Thorne (1972), Raile (1986)
Michigan	5361.0	8,604.9	+60.5	17,472.6	18,615.9	+6.5	Spencer (1983), Leatherbery and Spencer (1996)
Iowa	854.8	1,458.7	+70.6	1,264.7	1,943.5	+53.7	Spencer and Jakes (1980), Brand and Walkowiak (1991)
Missouri	4,002.1	6,604.6	+65.0	12,364.7	13,370.8	+8.1	Spencer and Essex (1972), Spencer et al. (1992)
Illinois	2,148.4	2,561.3	+19.2	3,761.4	4,029.9	+7.1	Essex and Gansner (1965), Hahn (1987)
Indiana	2,036.5	2,770.0	+36.0	3,895.8	4,295.4	+10.3	Spencer (1969), Smith and Golitz (1988)
Ohio	3,078.7	4,010.4	+30.1	7,175.3	7,567.4	+5.5	Birch et al. (1982), Griffith et al. (1993)
Pennsylvania	7,625.5	8,416.7	+10.4	15,923.7	15,872.8	-0.3	Considine and Powell (1980), Alerich (1993)
New York	6,674.5	8,191.5	+22.7	15,448.3	15,405.5	-0.2	Considine and Frieswyk (1982), Alerich and Drake (1995)
Southern New England[c]	1,903.6	2,931.4	+54.0	5,217.3	5,455.7	+4.6	Kingsley (1974), Brooks et al. (1993)

[a] In 1,000s of acres.

[b]See the referenced publication for definition and differences among states and surveys.

[c]Rhode Island, Connecticut and Massachusetts.

It is true that we may be able to justify the expenditure, even if it does not help cerulean warblers, by claiming that preservation of cerulean warbler breeding habitat provides habitat that supports many other species as well. But if preservation of habitat for the entire community is our purpose, then it should be stated as such. Otherwise, the very real possibility exists that we will spend resources preserving breeding habitat for a species only to have that species decline further or become extinct. The cerulean warbler, for example, winters in primary, humid evergreen forest in an extremely narrow elevational zone in the foothills of the Andes, a zone that is among the most intensively logged and cultivated habitats in the Neotropics (Robbins et al. 1992). Thus, habitat constraints likely are more severe on the wintering than on the breeding grounds. The best hope for the bird's preservation is establishment of a series of preserves to maintain primary forest tracts between 600 and 1,400 meters along the Andes foothills in Colombia, Ecuador and Peru (Robbins et al. 1992), as well as ensuring that a sufficient number of large blocks of continuous forest are maintained to provide breeding habitat.

The cerulean warbler situation is not unique. The wood thrush (*Hylocichla mustelina*) also shows both long- and short-term significant declines even though mature forest breeding habitat exists in ever-increasing abundance in New England, the Midwest and the Lake States (Table 2). For many of our declining migrant birds, the causes of decline are not known (Rappole and McDonald 1994, Rappole 1995, DeGraaf and Rappole 1995), yet the principal recommendation provided for managers almost always is to preserve or enhance the breeding habitat (U.S. Fish and Wildlife Service 1987, Schneider and Pence 1992).

If it is our intention to save the cerulean warbler and wood thrush, and we do not know why they are declining, then the wisest first step is to identify and maintain the best remaining areas of breeding and wintering habitat. Determining the cause of declines is a long, laborious process—in some cases, it may take too long. We eventually must be able to demonstrate scientifically that our management efforts are not the problem. We can then focus on solving real problems. Managers should not be assigned the job of trying to make efforts to save the species until that critical first step has been achieved and specific, efficacious management actions have been identified.

Population declines have been reported for almost one-third of the nearctic migrant birds that winter in the Neotropics (these species now are also commonly called neotropical migrants). Rappole and McDonald (1994) present and discuss a number of predictions to evaluate the hypothesis that, in general, populations of Nearctic migrants are declining as a result of breeding-ground events. Three are especially pertinent to the issue of land management, especially forest management, in North America:

1. *If breeding habitats are limiting populations of Nearctic migrants, then apparently suitable but marginal breeding habitats (those lower in relative fitness than optimal breeding habitats) should be filled with individuals of both sexes attempting to breed, regardless of pressures from nest predation, parasitism or fragmentation effects, because the principal alternative would be to forego breeding altogether.* In reality, abandonment of breeding habitat, rather than occupation of marginal breeding habitat by Nearctic migrants, has occurred. This abandonment is known as the "area effect" or species' "area sensitivity," in which small or medium-sized patches (up to 500 ha, depending on species) with apparently suitable breeding habitat are not occupied (Galli et al. 1976, Robbins et al. 1989a, Askins et al. 1990, Freemark and Collins 1992). This is not to imply that patches unoccupied by certain migrants are of little value to other species, however.

If populations are controlled by events on the wintering grounds, the "area effect" would result from the fact that too few breeding adults are returning to occupy all available patches of breeding habitat (Wilcove and Terborgh 1984, Askins et al. 1990, DeGraaf and Rappole 1995: 24-27). If such were the case, i.e., if the amount of breeding habitat did not increase and fewer birds were returning in spring than necessary to fill all available breeding space, it would be reasonable to predict that breeding habitats would be abandoned in a regular, predictable manner from poorest to best as suggested by the Brown-Fretwell-Lucas model of habitat use (Brown 1969, Fretwell and Lucas 1970, Krohn 1992). In sum, the "area effect" would be the result of fewer birds returning to breed than the habitat could support.

2. *Migratory bird declines should not be observed in breeding habitats that are undisturbed and presumably optimal.* Contrary to this prediction, declines in Nearctic migrants have been reported from several long-term studies conducted in apparently undisturbed habitats (e.g., Hall 1984, Marshall 1988, Holmes and Sherry 1988). These studies are based on counts of singing males, which can vary markedly depending on the number of unpaired males in the survey area (Rappole and Waggerman 1986, Gibbs and Wenny 1993). If wintering-ground factors cause a large reduction in numbers of adults returning to breeding territories, such a decline should result in fewer unpaired males because more breeding territories would be available to them, a decline in amount of song and a concomitant decline in population estimates based on counts of singing males. Such a decline has been reported from a 15-year study of a banded population of Kentucky warblers (*Oporornis formosus*) in a mature Virginia oak forest; in 1979, year one of the study, 60 (89 percent) of 73 territories used at one time or another during the 15-year period were occupied. By 1993, only 36 (45 percent) of the apparently suitable territories were occupied, a highly significant decline, yet rates of predation, brood parasitism and number of young successfully fledged per pair have remained unchanged over the years (Rappole and McDonald 1994).

It must be noted, however, that all evidence does not support the above prediction; there was no overall change in populations of neotropical migratory birds in the Great Smoky Mountains between 1947 and early 1983 (Wilcove 1988). Also, populations of forest migrants have increased significantly in a large forest in northwestern Connecticut (Askins et al. 1990). Last, population trends of migrants at Hubbard Brook Experimental Forest have been shown to be correlated with nesting success in the previous summer(s) (e.g., Holmes et al. 1986).

3. *Declines should not occur in species where no apparent change has occurred in breeding habitat.* Remote sensing eventually will make comparative assessment of the absolute amounts of breeding and wintering habitats possible (e.g., Powell et al. 1992). Lacking the information to complete such a comparison, researchers have examined subsets of Nearctic migrants for which declines have been reported and which winter in lowland wet forest, one of the most threatened tropical habitats. These comparisons show a strong correlation, not with loss or degradation of breeding habitat, but with loss of winter habitat (Robbins et al. 1989b, Askins et al. 1990).

In fact, there is debate about whether or not total forest breeding habitat (all cover types combined) has declined at all for many forest-dwelling migrants in recent decades. Breeding habitat for mature-forest (i.e., sawtimber-size) related species has increased and continues to increase in the northeastern and northcentral United States (Table 2). As indicated earlier, it is critical to maintain large forest blocks of several thousand hectares where possible. Surveys of many forests in settled landscapes in southern New England (Askins et al. 1987) and in the Mid-Atlantic region (Robbins et al. 1989) show remarkably consistent results concerning the minimum area requirements of migratory birds. Even if patterns reflect the contraction of species' ranges away from "marginal habitats" due to population declines due to loss of winter habitat, they still would indicate that large forests away from agricultural fields and residential areas provide the best breeding habitat (R.A. Askins personal communication: 1996). Maintenance of large blocks applies to both mature and early successional habitats. Even in regions where the total amount of forest is increasing, permanent fragmentation by roads and powerlines poses a major problem for species that have low reproductive success in small patches (Askins 1994, Robinson et al. 1995).

The primary trend in the Lake States and Northeast, however, is toward increasing forest size class; most of the land that is available to revert to forest already has begun to do so, and increases in total forest area are much less than increases in sawtimber-size forest acreage (see Table 2). In contrast, wintering habitat for the wood thrush has declined by 23 percent in southern Belize, 73 percent in northeast Costa Rica and 95 percent in southern Mexico since pre-Columbian times (Rappole et al. 1994). Shade coffee and cacao plantations and shifting agriculture once provided considerable habitat for species that winter primarily in forest, but these have given way to monocultures in many areas (G. Stiles personal communication: 1996).

Examination of these and other predictions proposed and discussed by Rappole and McDonald (1994) does not support the hypotheses that populations of Nearctic migrant birds are, in general, declining primarily as a result of breeding-ground events. Alteration of wintering-ground habitats provides important explanations for many observed trends.

The purpose of the foregoing discussion is not to minimize the importance of breeding habitat. Habitat is the key factor determining whether or not a species is present as part of the breeding bird community (e.g., DeGraaf et al. 1991: 2-4). Nevertheless, there are other factors as well. As an example, consider the Kirtland's warbler (*Dendroica kirtlandii*) which breeds in second-growth jack pine (*Pinus banksiana*) stands in Michigan. There evidently are extensive areas of apparently suitable jackpine breeding habitat for the bird, but the species remains on the endangered species list. Intensive study has shown that low nesting success as a result of nest parasitism by the brown-headed cowbird (*Molothrus ater*) may pose the principal threat to the species (Mayfield 1992); Kirtland's warbler well might be extinct now were it not for intensive management of cowbirds on the breeding grounds.

In time, enough data will accumulate to allow assessment of factors controlling populations on a species-by-species basis. Present information indicates that populations of cerulean warblers and wood thrushes probably are controlled by wintering-ground events, while Kirtland's warblers are controlled by breeding-ground events. The population dynamics of most species are less understood. Other factors that have been targeted as potential causative agents for observed declines in migrants include: habitat fragmentation, loss of early successional habitats (especially shrublands), loss of critical microhabitats, interspecific competition, browsing and/or grazing, and contaminant poisoning (DeGraaf and Rappole 1995).

Postbreeding Management

The fact that several species of ducks require special "molting ground" habitats has been known to managers for some time (Salomonsen 1968, Palmer 1975, Bellrose 1976, Jehl 1990). However, it is only recently that we have begun to realize that other species of migrants also might have special habitat requirements during the post-breeding, pre-migratory phase of the life cycle. In the past, it generally has been assumed that once young passerine migrants fledged, they and their parents remained on or near the breeding site until it was time to depart on migration (Rappole 1995: 75-78). Research by Nolan (1978) on the prairie warbler (*Dendroica discolor*) has shown that, at least for this species, the situation is much more complicated. A number of individuals in this species not only leave the breeding territory, but also the breeding habitat, to undergo the prebasic molt. Rappole and Ballard (1987) observed apparent changes in habitat use during the post-breeding/pre-migratory period for several songbird species in northern Georgia. The fact is that we know very little about either the needs of passerine migrants during this period or the potential threats to their populations. Without knowing more about the biology of migrants during the post-breeding/pre-migratory period of their life cycle, it is difficult to know what form threats to population survival might take. Certainly, habitat alteration or loss, contaminants, predators and competitors all could affect songbird species adversely during this portion of the life cycle, although in what ways we do not yet know.

Stopover Site Management

Many species of migrants occur on management areas only as transients. Although biologists long have been cognizant of the fact that management of such sites was critically important for waterfowl and shorebirds (Bellrose 1976, Morrison et al. 1980), recognition that stopover areas could be of vital importance for songbirds as well has been much slower to develop. Parnell (1969) observed that there was evidence of habitat selection by transients during stopover, a phenomenon since documented by Winker et al. (1992a, 1992b, 1992c) for a large number of migrant species at stopover sites in Minnesota and Mexico (Winker 1995a, 1995b). Schwartz (1963) observed territoriality in transient northern waterthrushes in Venezuela, as did Rappole and Warner (1976) in Texas. Rappole and Warner also documented weight gains in waterthrushes successfully defending stopover territories, indicating that stopover habitat and resources were both critical and in short supply (Brown 1964). There have been various observations made of aggressive intraspecific interactions or changes in fat levels to indicate that stopover sites are important for a number of other songbird species (Rappole and Warner 1976), but as yet, little is known regarding species' requirements during this period or the nature of potential threats.

Wintering Ground Management

The phase of the migrant life cycle spent on the wintering ground is better known for many species than either the post-breeding or transient period. Furthermore, the requirements for individuals of a species are less complicated during this and other non-breeding portions of the life cycle, as compared with the breeding period, because mating, nesting and care of young are not part of the fitness equation. All that is necessary for successful completion of this phase is that the individual survive in sufficiently good condition to migrate north to the breeding area at the correct time and rear young. Despite these apparently simple requirements, the data necessary to make pro-active management decisions to improve migrant population survival on the wintering grounds still are scarce. Part of the problem is that we know very little about the principal causes of failure to survive the winter period. Without such knowledge, it is very difficult to know the nature of possible threats. Predation? Poisoning? Starvation? Exposure? Disease? All of these are possible proximate causes, but what about the ultimate causes: intra- or interspecific competition, habitat loss, pollution? We know very little about the relative importance of these factors for declining migrant species.

Considerable work has been done both on the habitat needs and the causes of death in wintering populations of the wood thrush (Rappole and Warner 1980, Rappole et al. 1989, Winker et al. 1990a, 1990b), a long-distance migrant that winters from southern Mexico to Panama. At least for this species, conversion of tropical, lowland, broadleaf forest to pasture and cropland may be the principal factor causing declines (Rappole et al. 1994). Unfortunately, few species have been studied sufficiently on their wintering grounds to allow development of this level of understanding regarding the nature of the threats to the species, as well insight into the possible management solutions.

What Is a Land Manager To Do?

If the evidence turns out to indicate that population trends of Nearctic migrants are partly controlled by wintering ground events, what should we do? First, acknowledge that land is managed for many species and for several purposes. Only in rare instances, such as the Kirtland's warbler cited earlier, is land management tailored to the needs of individual Nearctic migrant bird species. Public forest land generally is managed to maintain a balanced (i.e., desired) size-class distribution to achieve wood products and wildlife habitat goals. There are many species requiring early or mid-successional breeding habitat; about one-third of Nearctic migrants breed in such habitats. Declines in these species probably are due to loss of breeding habitat, not wintering habitat. Considering all species' requirements—breeding Nearctic migrants and resident birds, as well as other vertebrate and invertebrate taxa—management should be ecologically based and designed to mimic natural disturbance regimes to the extent possible.

In New England, extensive forests of uniform age or vegetation structure provide habitat for a limited number of species. When a variety of upland openings and aquatic habitats is present, the number of species increases dramatically. For example, landscapes of extensive mature forests have about 100 vertebrates; forests and early successional habitats, about 200; and forests with early successional and aquatic habitats, about 300 vertebrates (DeGraaf et al. 1992).

Second, recognize that "one size does not fit all"—management practices must vary regionally because natural disturbance regimes and severity of habitat fragmentation vary among regions. Historically, gap-phase disturbance dynamics dominated the forest region of present-day Ohio, for example, while a combination of gap-phase, fire and big blowdowns dominated southern New England (Runkle 1990). Both disturbance patterns are consistent with management of forest habitats in as large blocks as are practical, regardless of the habitat type or timber size-class, but a regional context is critical. Forest cover trends in the northeastern and northcentral states are ones of increasing extent and size-class (Table 2), while trends in the agricultural Midwest and suburban mid-Atlantic indicate increasing fragmentation (e.g., Robbins et al. 1989a); forest management options are different among these regions. Regarding Nearctic migrant birds, several studies suggest that rates of predation and parasitism in small forest patches vary among landscapes or regions. In small Illinois woodlots, nest predation and cowbird parasitism are so high for wood thrushes that the number of young produced is too low to sustain the population (Robinson 1992).

Rates of nest predation and cowbird parasitism varied with the amount of forest cover in the Midwest; areas with little forest cover in agricultural landscapes were population "sinks" for forest-breeding neotropical migrants, and dependent on dispersal of birds from "source" populations in heavily forested landscapes for continued species occupation (Robinson et al. 1995).

In contrast, in small Delaware forests, wood thrushes produce enough young in most years to replace themselves because rates of predation and parasitism are low (Roth and Johnson 1993). Lower bird species richness in small forest tracts is more severe in agricultural landscapes than in more extensively forested landscapes (Freemark and Collins 1992); both regional and landscape forest-cover characteristics must be included when selecting management alternatives. In general, maintaining habitats in as large blocks as are possible is best. Whether or not current declines of individual migratory species are caused by breeding or wintering ground events, it is clear that these species ultimately depend on habitat where they can produce enough young to replace themselves and, for many species, it is the interior of large forests. Conservation of forest birds can be accomplished most effectively in many regions by maintaining working forests wherein timber management can be used to create the shifting mosaic of successional stages that will sustain the full diversity of forest birds that are characteristic of the area.

Last, the full weight of conservation of internationally shared resources that Nearctic migrants constitute cannot be borne by managers of breeding habitats. Management for natural communities, of which Nearctic migrants are a temporal part, still can proceed wisely if it is done in the context of regional land-use trends and background disturbance regimes, and if adaptive management is practiced. Adaptive management treats management prescriptions as hypotheses and adjusts them according to outcomes. Truly effective management awaits additional information on controlling factors in populations of Nearctic migrant populations, and the application of sensitive management practices on stopover and wintering ground habitats. Until more is known, a species approach and a regional management context seem reasonable.

The history of land clearing and reforestation in eastern North America bears some thought. Clearing of the eastern deciduous forest from the Atlantic coast westward to the edge of the prairie occurred as a wave of deforestation followed by a wave of forest regrowth caused by land abandonment. When more than half the original forest had been removed in Ohio, New England forests already had shown substantial recovery, and when forests in Minnesota and Wisconsin were largely cleared, Ohio farms were reverting to forest. The low point of forest cover for the eastern deciduous forest as a whole was in 1872, when approximately 48 percent of the area covered by the eastern forest in 1620 still was wooded (Pimm and Askins 1995). When half of the eastern forest breeding habitat was removed in the late 18th century, presumably an excess of winter habitat existed for neotropical migrant bird populations. Current rates of destruction of tropical habitats soon may render wintering habitats limiting for many species of Nearctic migrants, as they appear to be already for wood thrushes and cerulean warblers. The consequences will be severe for endemic tropical residents—tropical habitats have high numbers of endemic birds compared with those in eastern North America (Pimm and Askins 1995).

Conclusions

We conclude that, despite obvious declines for a number of migratory bird species, many of them serious, there is insufficient information to manage most of these birds properly. This situation presents the manager with little in the way of alternatives except to concentrate on providing a range of breeding habitats for which reliable information on management effects are available. Land in the U.S. and Canada is managed for many species and purposes; it may not be a wise use of limited management resources to put them solely toward management of breeding habitat for Nearctic migrants *per se* under the assumption that such management will improve populations. For most species, the combined effects of breeding- and wintering-ground events likely control populations. We ultimately must be prepared to support management of wintering ground and stopover habitats as well. A cooperative effort to maintain managed breeding and wintering habitats, and stopover sites in between, would be the most successful conservation strategy.

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Linking Research and Management: Conceptual Designs and Case Studies

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A tradition of pursuing short-term studies has developed over the past several decades among scientists. This situation arose from an interrelationship among constraints imposed by funding duration, the needs of land managers to have rapid answers to pressing questions, the need to finish graduate programs within a few years and the pressure placed on researchers to publish (Likens 1983, 1989, Wiens 1984, Strayer et al. 1986, Leigh and Johnston 1994). As summarized by Wiens (1984), a preoccupation with brief studies can lead to short-term insights into ecological processes. By restricting the duration of studies, we can only hope that the glimpses of patterns and processes that we see depict reality and that a critical factor has not been missed because we looked at the system too briefly.

Obviously, the limitations of our research have unpleasant implications for the design of future studies, and design and implementation of management plans for our lands and their wildlife (Romesburg 1981). Although people have acknowledged the need for long-term work, implementation of such work is difficult for the reasons noted above. We often are called on to test for changes in a system against a background of temporal and spatial variation, usually without the benefit of adequate baseline data. This makes it difficult to minimize the confounding effects of sampling and natural variation. However, our desire to develop a comprehensive knowledge of the system must be balanced against the costs of conducting the studies and the level of certainty necessary to reach useful conclusions (Wiens and Parker 1995). For example, although a biostatistician may desire high precision before rendering a conclusion, a policy maker or resource manager may be willing to accept an answer with less, yet reasonable, certainty because of limited time and budgets.

Our goal in this paper is to develop several approaches for addressing the needs for long-term information that acknowledge the difficulties, yet provide reasonable insight into ecological processes. We approach this task first by setting the necessary study length in the context of different speeds and magnitudes of ecological processes. We then apply study designs from the field of environmental impact assessment to questions of general resource management. Rapidly advancing theoretical and practical development of impact assessment is occurring because of

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increasing academic and legal interest in understanding how human-induced impacts affect the environment. The field of impact assessment applies especially well because many of our land-management issues concern local situations with little opportunity for adequate replication and limited funding, yet still require reliable results and management prescriptions.

Long-term Studies

The importance of long-term studies to the understanding of ecological processes depends on the magnitude of the process. For example, results obtained from any short-term (1-5 years) period of the 20-year curve depicted in Figure 1A could differ substantially from other periods, including exhibiting either a decreasing or increasing trend. Data obtained from any of these short-term glimpses could be gathered rigorously and analyzed properly; yet, they could lead to erroneous conclusions because of the slow rate of this ecological process. Although continuous sampling may not be necessary to identify this relationship, repeated sampling is indicated (we develop this in detail below). Well-known examples of slow processes are forest succession, vertebrate population cycles, accumulation of contaminants in the environment and gradually increasing human disturbance (see also Strayer et al. 1986, Franklin 1989).

Ecological phenomena also can occur irregularly, as shown in Figure 1B. These phenomena include catastrophes, such as fires, floods and diseases; population irruptions; and human-caused environmental accidents. Without adequate baseline data, studies of the initial impact of the event and recovery of the system from it can be difficult to quantify. In addition, short-term studies are poor at predicting the frequency and magnitude of events, and to what level the system will return after varying degrees of impact.

Processes that change over time in a regular manner, but show large year-to-year variance relative to the magnitude of the longer-term trend, are difficult to identify in short-term studies. As depicted in Figure 1C, although the long-term trend is up, any short-term sample could provide an upward, downward or confusing indication of direction. This is a pattern that frequently is encountered in wildlife populations of any abundance. Here, however, the ramifications of falsely concluding that a rare species is increasing can lead to no management when rapid action actually is indicated. Some wildlife populations also may undergo changes of a cyclical nature that can only be recognized through long studies.

How long is long enough for determination of the true ecological process of interest? Strayer et al. (1986) suggested that a study should be as long as the generation time of the dominant organism in the system (e.g., top carnivores), or long enough to include examples of the important processes that structure the system. The dynamic speed of a system can be determined, for example, by reviewing how major food resources cycle. A prominent example is the cycling of cone crops which, in turn, influences the abundance of rodents, which then provides adequate food for breeding predators. In the White Mountains of eastern California, for example, Morrison et al. (unpublished data) found that population abundance, inter- and intraspecific interactions, reproductive behavior (numbers of litters and length of breeding period), and movements of mice (*Peromyscus*) all were keyed to the periodic production of pine cones. Such information is available from many literature sources for most vegetation types.

Long-term studies, no matter how appealing, are fraught with practical difficulties. In addition to the issues raised above concerning time and funding limitations, other problems include the training and maintenance of staff, the difficulties in keeping institutional decision makers interested in the projects (especially with likely staff turnovers), changes in priorities, the tendency for a project to become unproductive, maintaining consistency in methodology and the quantity and quality of data collected, and the difficulties in managing large volumes of data. Further, changes

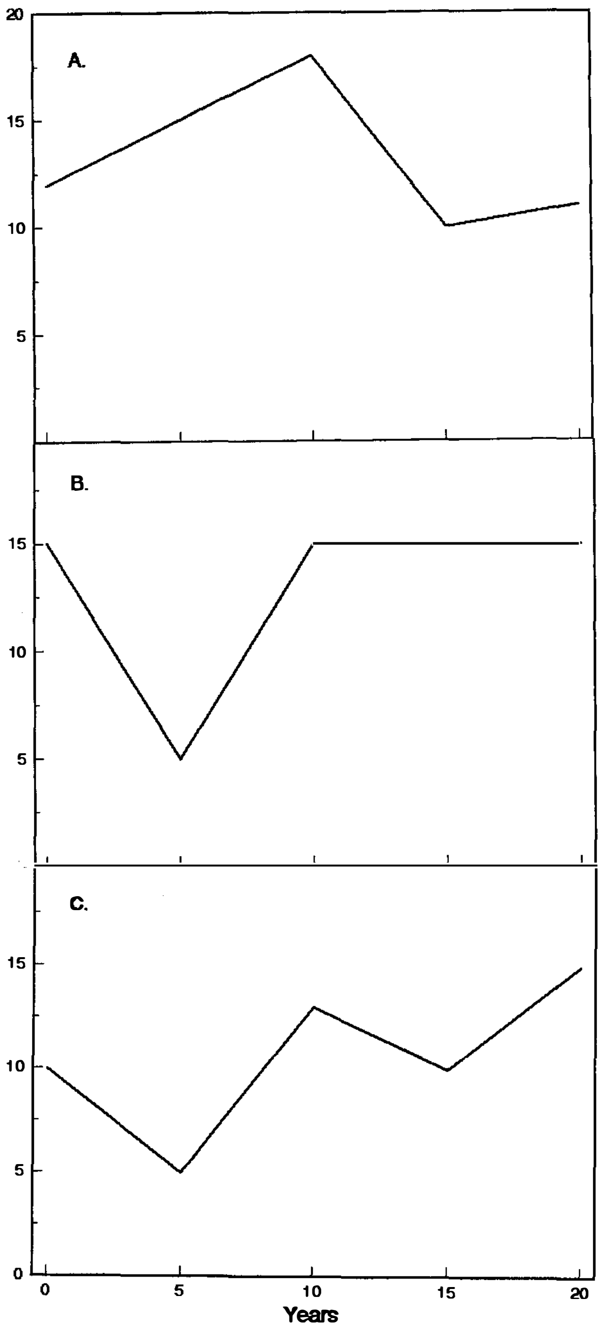

Figure 1. Hypothetical 20-year curves representing a slow process (A), rare event (B) and long-term trend with high between-period variance (C).

in technology and advances in study designs can make monitoring studies obsolete (Morrison and Marcot 1995). However, the broad area of Adaptive Resource Management (ARM) (Walters 1986) can be applied here. As we learn from past and current efforts, methods can be adjusted or refined to do a better job in the future. This all hinges, of course, on having credible approaches from the start that include the flexibility for improvement.

One advantage of monitoring programs is the accumulation of baseline data. If designed properly, these data help us understand the type of ecological processes driving the system of interest (as depicted in Figure 1). Unfortunately, such studies must assume that the factors affecting levels and conditions of a resource are in a steady-state equilibrium. That is, that natural variations in these factors are similar both within and between the baseline and post-baseline sampling periods. Analysis of covariance seldom is possible in such monitoring programs because other relevant factors probably have not been collected due to limited budgets and limited understanding of what to collect in any case (Wiens and Parker 1995). Also, given that most biotic and abiotic elements are interrelated, the assumption that variations are similar during and after baseline data collection is tenuous at best, and the ramifications of violating such an assumption are largely unknown.

Various alternatives to long-term studies of ecological processes have been proposed, including retrospective studies (Davis 1989), substitutions of space for time (Pickett 1989), the use of systems with fast dynamics as analogues for those with slow dynamics (Strayer et al. 1986) and population modeling (Shugart 1989). Retrospective studies are useful but require that background information be available and that the conditions occurring during data collection are appropriate for comparison with the current situation. Substitutions of space for time are used when no baseline data are available. Such designs, as examining an age-class distribution of previously cut forested stands, require many replicates and the assumption that all sites have the same environmental characteristics and history. Using systems with fast dynamics as substitutes, such as using population dynamics of rodents as a substitute for those of larger mammals, has not and probably should not gain acceptance. Modeling, such as minimum viable population (MVP) and population viability analysis (PVA), is gaining acceptance, but still requires a good understanding of ecological processes if it is to be reliable.

Although we agree that long-term studies are the best method for understanding ecological processes, it is obvious that few such studies will be implemented and carried to fruition. Further, and as outlined above, it is unlikely in any case that institutional structures will be available to allow implementation of even the most basic of these studies. Most intensive, long-term research likely will be confined to state and federal threatened and endangered species. We think, however, that the field of environmental impact assessment offers many solutions to the dilemma of the need for long-term information in a world of short-term constraints. Below, we outline some of the most salient designs being developed by workers in impact assessment, and their application to measuring ecological processes.

Study Designs and Case Studies

Multiple-time Designs

Several designs are available in the impact assessment field that do not require the accumulation of baseline or long-term data, but have direct applicability to understanding ecological processes. Two such designs, impact level-by-time interaction and trend-by-time interaction, fall under the general classification of multiple-time designs and are summarized below from Wiens and Parker (1995). Another general design, termed time series, also is available. However, this design requires many restrictive assumptions, including the presence of steady-state system dynamics (see Wiens and Parker 1995), and likely is untenable.

Impact level-by-time interaction. Due to yearly changes in natural factors, the factors of interest may change in value from year to year. A difference in magnitude of these annual changes between sites is evidence that a change has occurred. If the change results from a human impact (e.g., logging), a natural catastrophe (e.g., fire, disease) or even an experimental treatment, the use of multiple sites means that reference ("control") sites will be available for comparative purposes. Following the sites for an extended period of time (likely two to five years) will reveal how the trajectory of recovery compares with that on reference sites; interpretation of change will not be masked by the overriding ecological process (i.e., the assumption of steady-state dynamics is relaxed). Factors can differ between sites, but temporal changes in the resource are expected to be similar to reference sites in the absence of the impact. It is thus assumed that a dynamic equilibrium exists between factors affecting the resource and the state of the resource. It also assumes that some recovery occurs during the course of the study.

For example, a chemical spill could directly kill animals, or force them to leave an impacted area. Here, the chemical impacts specific locations at different general levels (e.g., light, moderate and heavy spills). As the chemical dissipates or after it has been cleaned-up, animals might start returning to the site, or those that remained during the spill might begin to reproduce. In either case, the abundance of animals on the impacted site should recover to the pattern of abundance being shown by the reference sites during the same time period. It is the change in pattern between impact and reference sites that indicates effect.

Impact trend-by-time interaction. Here, continuous variables are used (rather than distinct levels) to compare trends between measures of the resource and levels of change (or impact) over time. In the absence of change, one expects that, although resource measures may differ over time because of natural variation, they will show no systematic relationship to any gradient in change (or impact). This design is superior to the level-by-time design only in that the use of a gradient means that specific exposure levels need not be determined *a priori.*

Alternative Approach

Because it is unlikely that powerful "before" sampling will be available in most circumstances, we need to select alternative approaches to understanding ecological processes and the effects of planned and unplanned impacts on them. We need to determine the rates of change and the magnitude of spatial differences for various populations. An initial step could involve the selection of priority species and vegetation types. For example, we know that logging, agriculture, housing, recreation and hunting will continue. Thus, it makes sense to monitor examples of such systems that still are in a relatively undisturbed state. A set of locations could be monitored where effects of human disturbance are minimal. These sites would collectively constitute baseline information that then could be used to contrast with perturbed areas when the opportunity or need arose in other geographic locations. Thus, baseline information already would exist to address a number of specific needs. This would eliminate the need for specifically acquired "before" data. Such an analysis would be powerful because many different locations are used. It also would lower the overall cost of conducting environmental assessments, because of the reduced need for location- and time-specific "before" data. And it also would improve our ability to predict the likely impact of proposed developments through the accumulation of data necessary to develop population models (Underwood 1994). This stresses the need for careful development of an appropriate sampling design, including assessment of the number and placement of locations to be monitored. Such considerations typically are ignored, even though most statistical tests emphasize adequate randomization and replication of the sampling units.

This suggestion partially addresses the problem of implementing long-term research programs by reducing the time- and location-specificity of data collection. The multiple-time designs outlined above would benefit from such a program by being placed in the context of longer-term estimates of variance and system dynamics. In addition, these designs can incorporate before/after data (Green 1979, Osenberg et al. 1994, Underwood 1994, Wiens and Parker 1995). Very rare species, especially those that are state and federally threatened and endangered, likely will require more intensive, site- and time-specific sampling because of the relatively small margin of error involved in managing these groups.

Sampling Intensity and Frequency

Recognizing the need for long-term information raises the related issues of the sampling intensity and frequency required to detect a certain rate of change. For example, Figure 2 (from Gerrodette 1987) shows that the length of the study necessary to detect a trend is a function of the number of surveys being conducted per year. If the rate of increase in this example is 10 percent, at one flight per year, about seven years will be required to detect that change. Increasing sampling intensity to five flights per year reduces the length of study to about four years (because of a reduction in sampling variance). Naturally, this example only indicates what effort is necessary to detect a change initially. Longer-term trend analysis will require longer-term sampling. However, exercises such as this are needed to determine how preliminary sampling should be conducted.

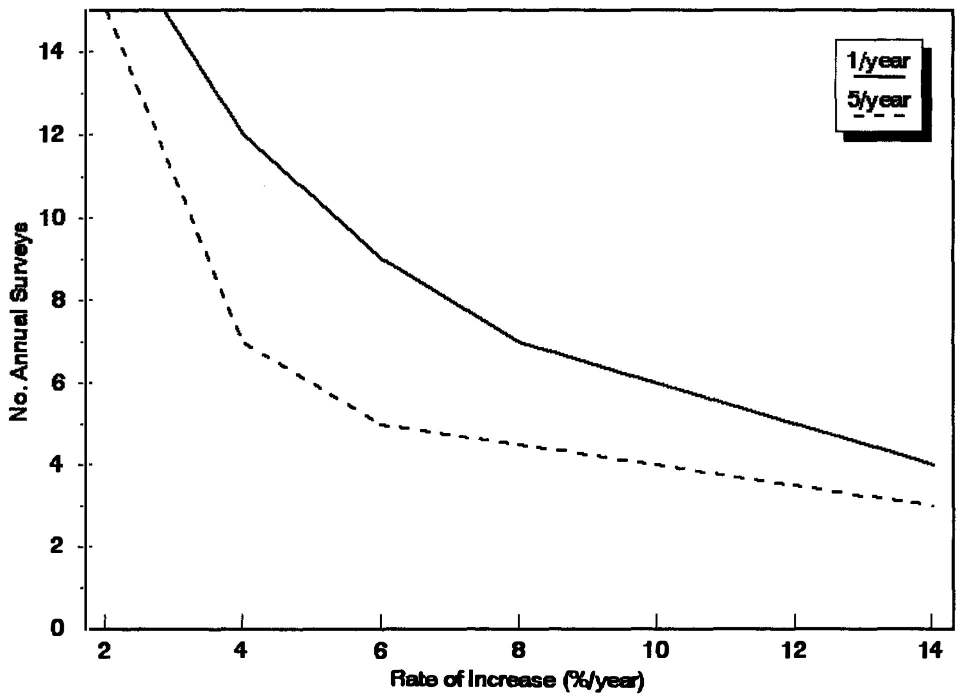

Figure 2. Minimum number of annual surveys required to detect various rates of annual increase in population size of sea otters (adapted from Gerrodette 1987).

Annual sampling, however, might not be necessary to sample most populations adequately. Given the substantial natural annual variation commonly seen in animal populations, often combined with a slowly changing trend (Figure 1), annual sampling may not be the optimal frequency. As the interval between surveys increases, the effective rate of change per time interval increases and, thus, the number of surveys that are necessary per year decreases. In Table 1, for example (Gerrodette 1987), we see that, at a sampling interval of three years, only half the number of surveys is required to detect that 5-percent change per year is occurring compared with the number of annual surveys required. The weakness in this strategy is that it would take two years longer to detect that the change is occurring. When dealing with rare species, the total percentage change which will have occurred by the time a significant difference is detected may be the most critical factor to consider (Allen 1980 *in* Gerrodette 1987). Non-annual sampling will, however, be the most efficient strategy for most species. Gerrodette (1987) presents equations for determining the sampling trade-offs depicted in our examples. The sampling protocol also depends on the methods used and types of variables collected. For example, a population study to examine the change in *lambda* based on a Leslie matrix approach requires annual estimates of survival and reproduction. Such an approach would require data to be collected each year during model development.

Table 1. Effects of different survey intervals on number of surveys required to detect a 5-percent - per-year increase in sea otter population size (adapted from Gerrodette 1987).

Number of years between surveys	Number of surveys required	Effective percentage change per interval	Number of years years to detection
1	8	5.0	7
2	5	10.3	8
3	4	15.8	9
4	4	21.6	12
5	3	27.6	10

Population Trends of a Threatened Species: Mexican Spotted Owl

The Mexican Spotted Owl Recovery Plan (U.S. Fish and Wildlife Service 1995) provides a template for monitoring population trends of the owl. Inherent to the monitoring design are considerations of the owl's generation time, annual variation in population size, and defining both the effect size (i.e., percentage change that is to be measured) and statistical power *a priori*. The owl's generation time was estimated using preliminary results of survival rates calculated from ongoing population demography studies. Based on these estimates of survival, it was determined that 50 percent of a new cohort would turn over (i.e., die) in about 5.9 years, and 90 percent in about 19.6 years. Because of the relatively high survival rates of adults (about 0.89) and documentation that some recruitment occurs each year, the recovery team assumed that little variation in population numbers should occur between successive years. Thus, the recovery team advocated that monitoring should occur for at least 15 years, based on owl population characteristics and the assumption that the population would have been subjected to and influenced by adequate variations in environmental conditions.

Even so, the results of such a monitoring design apply only to the period when the data were collected. Likely, certain rare and stochastic phenomena will not occur within the sampling time frame; thus, the effects of such events on the population trend would go unmeasured. Regardless, the objective of the monitoring program is to determine if the population is stable or increasing to allow the owl to be removed from the list of threatened species. The rigor of the monitoring design, including the minimal length of time for it to be conducted, should provide an adequate measure of population trend to meet this objective.

Conclusions

Addressing long-term questions requires a basic infrastructure, including permanent areas to serve as reference sites and long-term commitments of resources from administrators. It makes sense to monitor priority species and vegetation types in a rigorous manner, rather than spreading our efforts across many species and systems. The framework developed by Underwood (1994), as outlined herein, offers a real chance of obtaining quality baseline data for both long-term analyses and studies of impact effects. Short-term questions can be imbedded in long-term research programs so that a project can both modify the methodology as needed and be productive by publishing shorter-term papers (Strayer et al. 1986, Morrison 1988). There also needs to be a general improvement in the quality of data collected in resource-management areas, including the rigorous development of study designs and more advanced (and continuing) training of personnel (Morrison and Marcot 1995).

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Long- Versus Short-term Research and Effective Management: A Case Study Using the Wild Turkey

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Effective wildlife management is a function of habitat, people and the wildlife population (Giles 1978). A fourth factor that binds these components is obtaining reliable data on which to make sound decisions involving these three factors. Regardless of whether it is a decision concerning how an animal species interacts with its environment (wildlife population), how land management practices affect habitat quality (habitat) or how people respond to hunting regulations (people), it requires sound data derived from well-designed research programs (Green 1979, Skalski and Robson 1992) founded on scientific principles (Romesburg 1981). The importance of research has been expounded throughout the history of wildlife management. Leopold (1933: 411-423) discussed the importance of research, stating "All factions,...should unite to make available known facts, to promote research to find the additional facts needed, and to promote the training of experts qualified to apply them." However, since Leopold's time, the focus of research has changed from simply gathering facts for knowledge's sake, to a greater emphasis on management-oriented research (Gilbert and Dodds 1987). With decreasing federal and state funds for wildlife management and research, and changing philosophies regarding wildlife values and uses, society will demand clear and precise management actions based on reliable data. Last, with specific reference to the wild turkey, Weinstein et al. (in press) proposed a conceptual model to evaluate population dynamics holistically, with special reference to long-term evaluation.

The importance of long-term research has been cited, directly or indirectly by numerous authors. Leopold and Hurst (1993) emphasized the need for long-term (exceeding 10 years) research to understand dynamics of wildlife populations and their interaction with habitats more fully, thereby enabling scientists to explain better the variance attributable to environmental factors not under control of the research biologist (e.g., weather). Caughley's (1977) classic text implied that long-term studies are essential to derive and understand parameters of populations, including survival and fecundity rates and, most importantly, rate of increase. Mendez et al. (1995) indicated that long-term multi-taxonomic monitoring is essential, as long as goals and objectives are clearly defined and linked to improving environmental management. The Committee on Forestry Research (1990) recommended that "basic forestry research should provide for designing and implementing landscape-level and other large scale, long-term projects." Giles (1979: 335) stated "this will require studying densities...as well as starting studies for controlled, long-term analysis." Newton (1993), in his review of predation and avifauna, suggested that studies of limited length could show no long-term effects of predator control, nor the level that breeding bird numbers could achieve in the absence of predation.

Management decisions based on results from long-term studies, however, are uncommon. Forest and wildlife ecologists often base management plans, practices or policies on limited information. Short-term (i.e., two or three years) research projects often form the basis for management decisions when managers should use information from long-term (i.e., 10 or more years) research programs. Credibility, accountability and reliability of management will increase by promoting data-based decisions. It is important, therefore, to examine the importance of long-term studies and to determine implications of basing management decisions from data derived from short-term research programs.

Objectives and Rational

Our objective is to examine importance of long-term research and monitoring in decision making by examining data from our long-term (1983 to present) study of the eastern wild turkey (*Meleagris gallopavo silvestris*) in central Mississippi. We will examine impacts of differing research durations (2, 3, 5 and 10 years) on management conclusions drawn. Choice of the number of years was based on number of years commonly associated with research projects; 2 to 3 years for a Master of Science, 5 years for either a doctoral dissertation or a full Pittman-Robertson funding cycle, or 10 years as the minimum study length suggested by Leopold and Hurst (1994).

Methods

Study Area

Our study area was the 14,410-hectare Tallahala Wildlife Management Area (TWMA) located within the Bienville National Forest in parts of Scott, Newton, Jasper and Smith counties, Mississippi. It was located within the Lower Coastal Plain Province and the Blackland Prairie Resource Area (Pettry 1977). Most (95 percent) of TWMAwas forested with 30 percent in mature bottomland hardwood, 37 percent in mature pine *(Pinus* spp.), 17 percent in mixed pine/hardwood (30-70 percent pine), and 11 percent in 0- to 14-year-old loblolly pine *(P. taeda)* plantations. The effective study area size of 17,343 hectares derived for TWMA (Lint et al. 1992) was used to estimate wild turkey density.

Hunter Effort, Success and Harvest

We estimated hunter effort (number of hunters/day) and success (percentage of hunters harvesting a gobbler) from permit cards that were required to be completed after hunting on TWMA. Hunters also were required to check harvested gobblers at TWMA headquarters; dates of all gobblers harvested on TWMA and wing-tagged gobblers caught on TWMA that were killed off the area were recorded from this. Compliance to these regulations was estimated as 86 percent by Palmer et al. (1990) and 95 percent by Gribben (1986).

Wild Turkey Capture

We captured wild turkeys with cannon nets (Bailey 1976) or alpha-chloralose (Williams et al. 1966) from January 7 to March 4 and July 1 to August 25, 1987 through 1995. Both capture procedures used cracked corn for bait. We removed cannon-netted turkeys from the net and placed them into special cardboard boxes, sized for wild turkeys. We sexed turkeys, classified them as adults or subadults (Williams and Austin 1988), and marked them with two patagial wing tags (Knowlton et al. 1964) and two metal, triple-lock leg bands. We fitted hens and gobblers with 108-gram mortality sensitive radio-transmitters (Wildlife Materials, Carbondale, Illinois), attached backpack-style. We released cannon-netted turkeys within 10 to 45 minutes of capture, depending on number caught; tranquilized turkeys were transported to study area headquarters for marking and recovery and were released the next day. We released all turkeys at the capture site.

Turkey reproductive parameters. Beginning March 14 of each year, we monitored hens at least once daily using a three-element, hand-held Yagi antenna and a Telonics TR-2 receiver (Telonics, Inc., Mesa, Arizona). During nesting periods, hens found in the same location for two consecutive days, or those with a transmitter emitting a mortality signal, were considered incubating. After 9 to 12 days of incubation behavior, we approached nests to a distance of approximately 50 meters. We recorded azimuths toward nests on flags at various points encircling nests to facilitate location once incubation ended. During incubation, we located hens twice daily to determine hatching date, nest destruction/desertion or hen mortality (Palmer et al. 1993). We approached nests to determine fate as soon as incubation stopped. Causes of nest destruction or hen death were determined, if possible, by evidence left at nest/death sites (Davis 1959).

Small sample sizes precluded estimating reproductive parameters independently for subadult (after hatching year) hens, therefore, we excluded them from all analyses due to probable age-related differences in reproductive parameters (Vangilder 1992). Nest success was the proportion of hens initiating incubation that successfully hatched at least one egg on their initial nesting effort.

Population size and survival estimates. The Buckland open capture-recapture model was used to estimate gobbler and hen population size and survival rates. Buckland (1980) offered an extension of the general Jolly-Seber model where more data concerning marked individuals can be used by recording known deaths as recaptures. Data on gobbler and hen deaths were obtained through telemetry or from mandatory checking of harvested gobblers at TWMA headquarters.

Carnivore Population Trends

In 1989, bobcats were captured, equipped with radio transmitters and monitored. By 1992, all major mammalian carnivore species (coyote [*Canis latrans*], fox [*Urocyron* sp. or *Vulpes* sp.], skunk [*Mephitis* sp.], Virginia opossum [*Didelphis marsupialis*], raccoon [*Procyon lotor*]) were being studied as part of the turkey-predation study. We used bobcat numbers (number of adult animals captured and released) as a minimum index of bobcats on the study area. Reliable population indices of other carnivores were not initiated early enough for valid conclusions regarding trends in predator numbers.

Results

The first two years of the study reflected a relatively stable turkey population using gobbler harvest numbers (Table 1). Although gobbler harvest declined 14 percent between 1984 and 1985, hunter success was relatively high (12 percent), as was nest success (52 percent). Density was not estimable because we were unable to estimate gobbler population size. Hen survival was 0.89, relatively high compared with rates reported in other studies.

At the end of the third year, one would conclude that the population was declining, going from 1.87 turkeys per square kilometer to 1.44 turkeys per square kilometer, where most of the change was attributed to declines in gobbler numbers (46 percent). Gobbler density was 0.50 gobblers per square kilometer, but considerably higher for hens at 0.87 hens per square kilometer. Gobbler survival was 0.68, while hen survival was 0.74. However, gobbler harvest remained relatively stable, with only a 2-percent decline, as did hunter success (12.4 percent to 11.6 percent). Nest success was 40.3 percent.

The turkey population, particularly the gobbler population, was declining significantly (22 percent) by the end of the five-year period, while the hen population increased by 15 percent. Regressing population size with year indicated that the gobbler segment was declining at a rate of 4.4 gobblers per year, but not significantly ($r = -0.231$, $P = 0.769$). The hen segment was increasing at a rate of 21.2 hens per year, but not significantly ($r = +0.565$, $P = 0.435$), and total population was increasing at a rate of 16.8 turkeys per year, but again, not significantly ($r = +0.354$, $P = 0.646$). Survival of gobblers and hens was 0.62 and 0.69, respectively. Average densities were 0.63 gobblers per square kilometer, and 0.98 hens per square kilometer. Mean hunter success was 10.7 percent, with the lowest rate in 1988 at 7.1 percent. Nest success also declined with the addition of two years of data, averaging 33.2 percent.

Table 1. Population parameters for wild turkey hens and gobblers for 2, 3, 5 and 11 years since study initiation on Tallahala Wildlife Management Area, Mississippi, 1984-1995.

Study period	Gobbler harvest	Hunter effort	Hunter success	Nest success	Population size		Survival rates	
					Male	Female	Male	Female
1984-1985	59, 51[a]	476, 443	12.4, 11.5	62.5, 41.2	[c]	200, [c]	[c]	0.91, 0.88
	(55)[b]	(460)	(11.95)	(52.1)	(NA)	(186)	(NA)	(0.89)
1984-1986	59, 58	476, 497	12.4, 11.6	62.5, 16.7	131, 72	194, 177	0.92, 0.41	0.88, 0.44
	(56)	(472)	(11.8)	(40.3)	(87)	(151)	(0.68)	(0.74)
1984-1988	59, 29	476, 406	12.4, 7.1	62.5, 20.0	131, 103	196, 230	0.92, 0.44	0.91, 0.56
	(52)	(483)	(10.7)	(33.2)	(110)	(171)	(0.62)	(0.69)
1984-1995	59, 14	476, 345	12.4, 4.1	62.5, 25.0	123, 41[d]	125, 117[d]	1.0, 0.88	0.89, [c]
	(35.6)	(447)	(7.8)	(28.6)	(50)	(92)	(0.70)	(0.68)

[a] First numeral is for first year of study period, second numeral is for last year of study period.
[b] Numerals in parentheses represent averages, except for population sizes, where they represent time period specified.
[c] Unable to estimate the parameter with available data.
[d] Population size estimates for 1993 and later were not computable because of low recapture rates.

The last examination of the turkey population is for 11 years (1984 to 1995) and the dynamics of the population become clear. Average gobbler survival was 0.70 until 1992, in part attributed to a significant decline in hunter effort: 476 hunters per year in 1984 to 345 hunters per year in 1995, and is associated with a corresponding decrease in hunter success (from 12.4 percent in 1984 to 4.1 percent in 1985). Hen survival was 0.68. Average nest success for the 11-year period was 28.6 percent, and, although variable, was decreasing (Figure 1). By the conclusion of the study, the gobbler population declined 67 percent (from 123 in 1984 to 41 in 1992) and cannot be estimated beyond 1992 because too few tagged gobblers were recaptured (Figure 2). However, hen population size, over the 11 years, declined by 28 percent until 1991, then 7 percent until 1992. Regressing population size with year indicated that the gobbler segment declined significantly ($r = -0.784$, $P = 0.012$) at a rate of 6.90 gobblers per year. The hen segment decreased at a rate of 2.78 hens per year, but not significantly ($r = -0.292$, $P = 0.445$), and total population decreased significantly ($r = -0.668$, $P = 0.049$) at a rate of 9.68 turkeys per year. Additionally, the carnivore population increased correspondingly ($r = +0.71$, $P = 0.013$), with 9 adult bobcats caught in 1989, compared with 20 caught in 1995 (Figure 3).

Discussion

To form the basis for comparisons regarding what constitutes a declining, stable or increasing turkey population, estimates of critical population parameters are necessary. Nesting success in Missouri ranged from 14.3 to 47.4, averaging 30.7 (Vangilder et al. 1987); 40.0 to 45.8, averaging 44.6 in Texas (Campo et al. 1984); and 23.1 to 42.3, averaging 35.9 in New York (Porter et al. 1983). Thus, average nesting success ranges from 30.7 to 44.6. Survival rates for gobblers were 0.71 in Texas (Campo et al. 1984), 0.64 in Minnesota (Porter 1978), 0.627 in Michigan (Kulowiec 1986), and between 0.44 and 0.64 in the Georgia Piedmont (Ielmini et al. 1992). Hen survival rates were 0.81 in Alabama (Everett et al. 1980), 0.78 in Massachusetts (VanderHaegen et al. 1988), and 0.44 to 0.69 in Missouri (Vangilder and Kurzejeski 1995). Little is published on hunter success, and thus, no estimates exist. Turkey density estimates in a similar habitat were from 1.1 to 12.4 turkeys per square kilometer (gobblers and hens) (Speake et al. 1975).

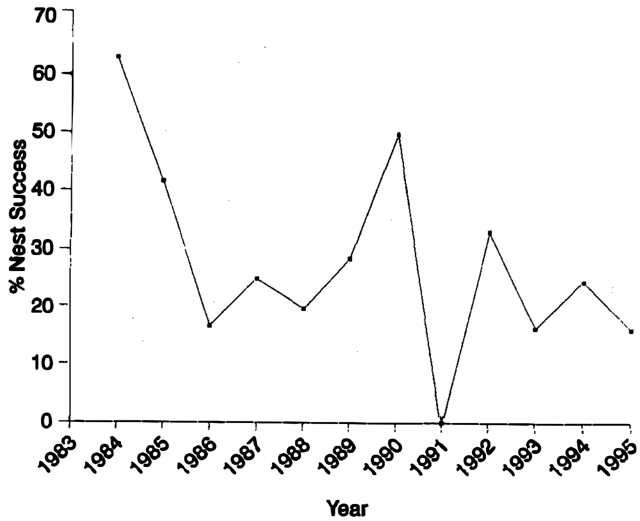

Figure 1. Population trends for wild turkey gobblers and hens for Tallahala Wildlife Management Area, Mississippi, 1984 through 1995.

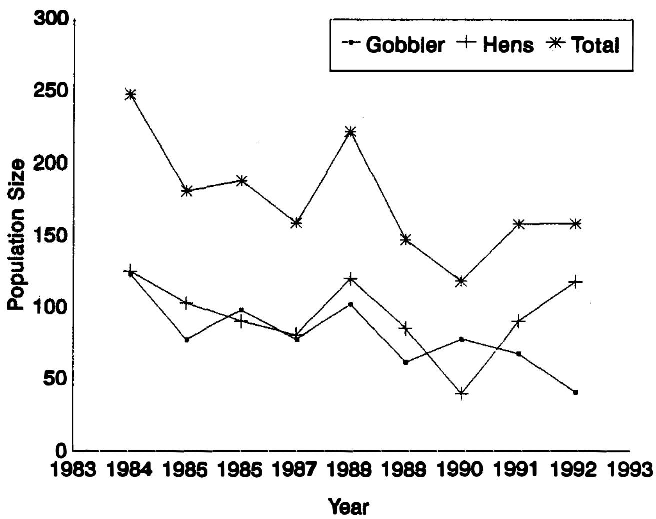

Figure 2. Trends in nesting success for adult wild turkey hens on Tallahala Wildlife Management Area, Mississippi, 1984 through 1995.

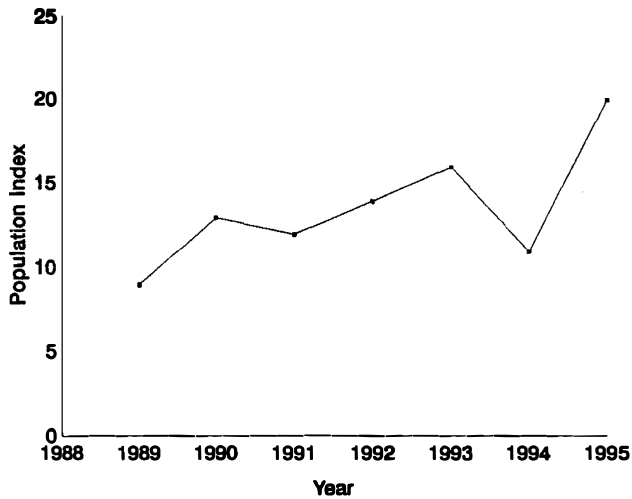

Figure 3. Population trend for adult bobcats on Tallahala Wildlife Management Area, Mississippi, 1989 through 1995.

The turkey population on TWMA significantly (P = 0.049) declined during the study, gobblers (P = 0.012) more so than hens (P = 0.445). However, this is based on the full 11 years of data. Relying on only the first two years, the conclusion that the population was declining would have been unfounded, even with a 14-percent decline in gobbler harvest, primarily because hunter success remained relatively stable between 11.5 and 12.4 percent. Hunters would have been satisfied and, thus, would not have lodged any complaints. Population estimates were not possible because of only two years of data and recapture histories.

The addition of the third year and the ability to compute population estimates for the first two years reflected a declining population, with gobblers declining 46 percent and hens declining 9 percent. However, all other estimates of population parameters reflect a population in "good health," including high survival rates (hens = 0.74, gobblers = 0.68), nest success ranging from 16.7 to 62.5 percent and averaging 40 percent, hunter success unchanged (1984 = 12.4 percent, 1986 = 11.6 percent), and only a slight (2 percent) decline in gobbler harvest (= 56 turkeys). Average gobbler and hen densities for the three-year period were 0.50 gobblers per square kilometer and 0.87 hens per square kilometer, with an overall density of 1.37 turkeys per square kilometer, which is within the lower limit found by Speake et al. (1975) for Alabama pine woodlands. For the average research project involving a M.S. degree student, the project would have ended with the conclusion that the population is stable, exhibiting some variation in population numbers. However, all population statistics reflect, when compared with other studies, a stable, healthy population, including nest success exceeding that of Missouri by 10 percent, survival rates within reported ranges of survival rates for Texas, Alabama and Missouri, and hunter success unchanged.

Conclusions drawn for the two- or three-year studies would not have been the same for the five-year study. Although population estimates became more reliable and reflected a declining gobbler population (22 percent for gobblers; 4.4 gobblers/year), estimates indicated that the hen population was increasing (15 percent), but not significantly. However, other population estimates reflected characteristics of a declining population. Survival rates (average: hens = 0.69, gobblers = 0.62) were considerably lower for the latter two years, nest success also was lower for 1987 to 1988 at 25.0 and 20.0 percent, respectively. Hunter success had declined significantly to 7.1 percent (by 1988), and a gobbler harvest of 29 birds (in 1988) represented a 51-percent decline from the 1984 harvest. Density estimates for the five-year period would have remained misleading, as gobbler and hen densities were 0.59 gobblers per square kilometer and 1.33 hens per square kilometer, respectively. The overall density of 1.92 turkeys per square kilometer exceeds the density for the three-year period. In fact, the hen population would have been assumed to be increasing and the gobbler population decreasing.

Remarkably, it is not until 10 years of data had been collected on this turkey population that the true trend in the population is observed, in part because population and survival estimates are more reliable because of greater precision in estimation from the greater number of recapture periods. Effect of improved number of recapture periods on parameter estimation is demonstrated in Table 2. Except for 1985, population size is overestimated when relying on 5 years of data compared with 10, and percentage overestimation ranges from 6.11 to 24.27 percent. What is of concern rests with estimates of the hen population, which were overestimated in the five-year period by 36.2 percent to almost 69 percent. Thus, the "false" conclusion that hens were increasing when, in fact, their population was decreasing in a similar manner to gobblers resulted in the conclusion that the turkey population, at the end of the five-year study, was stable, especially for the hen population.

Table 2. Comparison of population estimates derived from the Buckland mark/recapture model for wild turkeys captured on Tallahala Wildlife Management Area, Mississippi, 1984-1987.

	Population size					
	Gobblers			Hens		
Year	5-year	10-year	Percentage difference	5-year	10-year	Percentage difference
1984	131	123	-6.11	196	125	-36.22
1985	72	78	+8.33	178	103	-42.13
1986	112	98	-12.50	288	90	-68.75
1987	103	78	-24.27	230	81	-64.78

One of the objectives of this long-term study of the wild turkey was determining if an autumn either-sex harvest could be imposed on this population with little impact. If this had been the more common two- or three-year study, or even, to a degree, a five-year study, the estimated population parameters would have indicated that the population could have sustained an either-sex autumn harvest, as the hen segment of the population was stable, or as in the five-year case, increasing. Following the 10-year study, the Mississippi Department of Wildlife, Fisheries and Parks now is convinced that an autumn either-sex harvest would have been disastrous, not just for the population, but for the agency's credibility. The population obviously was declining and an autumn either-sex harvest would have been "blamed" for the decline.

An additional factor that undoubtedly exacerbated the decline was the decline in fur prices and, thus, fur trapping in the state and on the study area. By 1990, trapping license sales, trapper harvest and subsequent hunter harvest of furbearers had declined significantly (Lovell et al. in press), undoubtedly allowing carnivore populations, including the bobcat, to increase. Predation rates on turkeys increased and hen success declined significantly (Palmer et al. 1993). The exception was an excellent hatch in 1992, resulting from favorable weather conditions, combined with a canine distemper outbreak in 1991 within raccoon, fox and skunk populations. In addition, USDA Forest Service policies changed, and increased timber sales and cutting occurred on the study area, resulting in increased acreage of early successional stages more favorable for carnivore populations (Leopold et al. 1993). Lastly, a tornado in November, 1992 decimated more than 1,000 hectares of forested land, creating early successional habitats favorable to carnivore species. Again, if, based on the two-, three- or five-year studies, the actions of more liberalized harvest of turkeys (either by increasing season lengths, bag limits), allowing baiting (another issue discussed during 1990-1992) or instituting an autumn hunting season would have been detrimental to the turkey population and the state agency.

The importance of long-term research is exemplified by the evolution of our project. Its objectives have changed over time as more data were accumulated. We initiated our project as a population dynamics study of the wild turkey. As the population started declining, causes of the decline were examined, which reflected predation as a major limiting factor (Palmer et al. 1993, Miller et al. in press). This led to the expanded predation project (Miller et al. 1995). Thus, the long-term project allowed us to identify the problem so that further research efforts were maximized by coordinating research objectives.

Summary and Recommendations

Our study reflects the importance of long-term research, both in the context of fully understanding dynamics of wildlife populations to manage them better and determining effective means of monitoring these populations to allow sound management decisions. Our 11-year study of the wild turkey population on TWMA supports our contention that decisions regarding natural resource management based on short-term research (less than 5 years) pose a danger to wildlife biologists and managers, and thus, state, federal and even private wildlife management agencies. The most striking result of our study was that, had the decision been made to implement an autumn either-sex season around year four or five, the population would have declined drastically, perhaps more than it did, and the credibility of the state agency would have been significantly harmed.

Therefore, it is critical that research biologists and managers continue to ensure that sound data are obtained to allow for effective, adaptive natural resource management (Walters and Hilborn 1978). We advocate the level of study we have employed in our wild turkey-predation study because it has demonstrated the need to continually monitor important game populations to ensure that any desired changes in policies are based on data, rather than opinion or the biologist's "best guess." This implies that wildlife biologists require effective monitoring (indexing) devices that reflect population trends. Thus, another benefit of long-term research, which directly relates to management, is the ability to assess effectiveness of indices in reflecting population trends with the level of sensitivity necessary to detect significant changes in population numbers. In our study, we found that simple indices related to harvest (Lint et al. 1995) were effective and accurately reflected the decline in the turkey population. We currently are examining indices to monitor carnivore populations.

Effective natural resource management requires sound data upon which to base management decisions. This implies the need to understand fully the complex interactions of game and non-game wildlife to the biotic and abiotic components of their environment. This may only be achieved through long-term research, coupled with long-term monitoring of population parameters. In this manner, natural resource management agencies may be responsive to changes in the environment and, thus, the wildlife populations being managed. Leopold and Hurst (1994) advocated this approach for predation studies involving gallinaceous birds, but the need applies to all species.

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The Precautionary Principle, Weakening the Link Between Long-term Research and Management

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The precautionary principle is a little-discussed, but significant policy concept influencing resource decisions on the international level. It is also found in the conservation policies of the United States (Bodansky 1993), although, in tenns of wildlife, the precautionary approach often is referenced as "erring on the side of the species." In its current application, it is a concept that promotes research and discourages management.

The precautionary principle was initiated as a conceptual precaution for governments and regulatory bodies to address "unknown" effects of an environmental activity on a common resource, such as air or marine pollution (Bodansky 1992). It was a guideline for uncertainty in choices giving the benefit of the doubt to the environment. If there was uncertainty that an activity could have risk, then regulators should act in anticipation of environmental harm to ensure this harm does not occur (Bodansky 1993). It is a contentious issue. How that uncertainty is determined and, separately, how it should be managed, are the keys to the debate over the implementation of the precautionary concept.

Because of the exhaustive nature of the subject matter and diversity of resources, limits will be placed on this discussion. The resources under discussion are those in which some form of private or governmental property rights can be assigned. The precautionary principle discussed will relate to its international aspects, although it may equally be applicable to North America.

The precautionary concept first appeared under the name of vorsorgeprinzip in West German domestic legislation in the early 1970s. Since then, it has addressed a wide range of environmental issues including: climate change, the ozone layer, genetically modified organisms, radioactive and other hazardous wastes, sustainable development, and conservation of endangered species (Brunton 1994a).

Development to Current Use

It is significant to recognize that initially, the precautionary principle was a concept of reducing risk through modification of use. In the November 1987 Ministerial Declaration of the Second International Conference on the Protection of the North Sea, resources of the marine ecosystem were to be safeguarded by reducing polluting emissions (assumed but not proved) of substances by the "use of the best available technology and other appropriate measures for reduction of effect" (Cameron and Abouchar 1991). It was, at the outset, a concept compatible with sustainable use.

But in the climate of regulatory solutions to conservation problems, within the last 15 years or so, the precautionary concept has been interpreted as a call for prohibitive "prevention" of use unless no harm can be proven (Brunton 1994a, Warren 1993). This plateau of certainty can be achieved only through the complete removal of uncertainty, limiting the risk of an action to a resource or species to zero.

Limitations of the Precautionary Principle

The precautionary principle currently is being used, in some situations, as a tool against sustainable use of resources (Wold 1993), especially in developing countries. On the surface, the principle appears logical and part of a holistic approach. But its application in conservation has three limitations that render it counter to good conservation. First, it ignores any consideration of the real costs to wild species by prohibiting a management activity (Dickson 1994). Second, it ignores the effect on the usually politically weak local people who live with the resource (Dickson 1994), and third, it ignores the elasticity of ecosystems and resiliency of species (Brunton 1994b) by assuming only negative impacts and inability of species to adjust. Any use of the environment or wild animals under the precautionary principle often is denied by requiring scientific substantiation for "no harm" prior to use. In more recent times, this has led to a shift in not only what kind of proof was required, but also who is required to provide the "proof."

"Burden of Proof" Shift

With the apparent acceptance of a prohibitive approach of the precautionary principle, and the further acceptance of it as a principle of international law (Cameron 1993), the required burden of proof also shifted (Brunton 1994b). The shift was from requiring governmental/regulatory bodies to prove harm will occur to that of requiring the proponent of the activity to "prove" there is no risk (even unknown) of "harm to the environment" (Favre 1993). While seemingly reasonable, the key to the difficulty of this task is the joint use of the terms "proof" and "no risk of harm."

Uncertainty and Risk

The precautionary principle was to guide choices about decisional uncertainty and to provide information on the range or boundaries of risks of harm from an activity (Bodansky 1993). The guidelines, when faced with uncertainty, were to be in favor of the environment (a worst-case scenario). However, the process of determining uncertainty was not intended to require proof that there was no management risk in an activity. Uncertainty produces a concern (and often clarification) about the risk (of action and non-action) involved in an activity. Under a precautionary concept, if there is not certainty, then the assumption is "worst case" regarding that uncertainty and will be in favor of safety. Risk, on the other hand, "is a function of the magnitude and probability of harm" (Bodansky 1993).

Unintended Effects

Herein lies the dilemma for those managing wildlife resources in developing countries living with the resources, as well as the resources themselves. The precautionary concept ignores the reality of human need for use, when used as a guiding principle to arbitrarily restrict use, and while waiting for perfect knowledge. There are many situations where reduction, or even abolition, of existing restrictive regulations probably would be more efficient in achieving given environmental goals (Brunton 1994a). Nowhere is this more evident than our own Endangered Species Act that punishes landowners for having endangered species on their property rather than providing incentives. When this option is not considered, the real costs to the species are ignored. Brunton (1994a) further points out that one reason for this approach might be concern of the regulatory institutions themselves: "To some extent this [resistance to deregulation] may be explained by the origins of the principle in bureaucratic thinking, and the asymmetries of bureaucratic costs and incentives. Bureaucrats rarely have to consider the increased dangers that their regulatory actions may bring about in areas beyond their responsibilities, . . . the risks of non-restriction tend to be much more visible and institutionally threatening."

Resource Use

A failing of the current use of the precautionary principle is the assumption that resource use is optional. Natural resources will be used and wildlife will be harvested worldwide (Edwards 1995). Edwards furthers mentions that we, as humans, eat, wear, heat, build, cure illnesses and have many other uses for resources, including wildlife species. How we view (and structure) that use legally or illegally is where the attention should be focused.

Most African nations and some other developing countries consider the sustained use of wildlife to be "culturally acceptable" and the "marketing of wildlife and its products is seen as a sensible economic enterprise and an effective means of promoting conservation" (Cumming 1991). Resources must address people's needs (Africa Resource Trust 1992). If the resource does not benefit the people living with it, then it is in danger of being destroyed. De Voos (1991) states: "it should be recognized that unless the people in the developing world benefit more from wildlife through increased provision of meat and other wildlife products, they can be expected to make little effort to safeguard its survival, and are more likely to bring about its destruction."

In contrast, it is widely recognized that the converse is true, conservation will succeed when the people are involved with and benefit from wildlife (Morrill 1993, Bromley and Cernea 1993, Kiss 1990).

Restrictive Interpretation

However logical this seems, there are those who reject the concept that use and conservation can occur when the "knowledge of harm (or no harm)" is not perfect.

According to Favre (1993), "The logical starting point for a sustainable use management program is the determination that a particular use is sustainable." In Favre's world, sustainability must be proved prior to use. Paradoxically, that proof requires use, but that use cannot occur unless sustainability can be proved. Wold (1994) states that "the precautionary principle requires the proponent of the activity to "prove that it is safe before the action is taken." The Environmental Investigation Agency (EIA) commenting on sustainable use states: "Conservation requires such exploitation [of wild species] to stop until it is proved beyond a doubt that renewed use will be sustainable." Brunton (1994b) questions the motivations of such positions.

Dickson (1995) points out, referring to advocates of non-use: "their version (of the precautionary principle) requires a halt to a practice even in the absence of evidence that the practice is dangerous. Simply not knowing whether it is dangerous is sufficient." If we abide by this interpretation, we are stuck with Yousarian's dilemma in Joseph Heller's *Catch 22*.

Complexities of Interrelationships

A seemingly legitimate justification for the precautionary principle is the complexities of interrelationships of ecosystems and the economic, legal and cultural considerations of conservation decision making (Wold 1994). But there, again, is contradiction. Citing concern for the species or resource, proponents of the need for "proof of no harm" faction ignore the negative effects of non-use, while assuming use will only have negative effects: "history indicates that human use of species are highly unsustainable," therefore, bad for the species (Wold 1994). Yet, the benefits of that use are ignored in the evaluation.

Brunton (1994b) points out another fundamental paradox in the precautionary concept: interrelations between elements of highly complex ecosystems, dangers of substances in isolation and uncertainty of scientific knowledge all are reasons for the precautionary principle. However, once the precautionary principle is accepted, the complexity, as well as the multifarious human social, cultural, political, economic and environmental facts, all are ignored. Most importantly, Brunton points out, the "unpredictable results of human actions" are ignored in the current precautionary principle.

Unintended Impacts

The precautionary principle, as currently defined, requires surety of no harm (no risk) and ensures the need to "do more research." By shifting the burden to proving an activity does no harm before it is initiated (and to the one desiring the activity), the costs to the species of non-use, the potential positive benefits to the humans, and this interrelationship all are ignored and the evaluation takes on a worst-case scenario. For instance: reliance on waiting to prove there is no harm can reduce or even destroy the legal value of a species, which may very well be the avenue for its survival. This would create one of two other values for the species, both with negative effects. It creates illegal value (such as poaching), whereby an individual is willing to risk being apprehended to capture that value, and no value (when compared with other land uses), where an alternative use of the land is chosen.

Research and Management

There are two parallels in the management of wildlife for uncertainty and risk: research determines the boundaries of uncertainty and management is implemented to handle risk. While the precautionary principle is considered sound for addressing uncertainty (risk identification through research), it is less than appropriate for management questions dealing with uncertain risks. "Even with perfect scientific knowledge [thereby satisfying the precautionary principle], considerable management problems would remain" (Bodansky 1994).

The goal of a researcher is to reduce uncertainty (through knowledge) about how a particular system works, whereas the goal of a manager is to produce a desired response in the face of known and unknown risk (Lancia et al. in preparation).

Within the conservation community, the precautionary concept of requiring more knowledge (sometimes certainty) prior to an activity taking place has been embraced by scientists, as well as non-scientists (Lancia et al. in preparation, Warren 1993). The precautionary principle, founded on the need to use science to protect a resource, has become a political tool to be used against those who need to use their resources legally, sometimes for their very survival (Dickson 1994).

This prevention of use demonstrates a lack of understanding of the dynamic quality of ecosystems and their resilience addressed by Botkin (1990). Taken a step further, when viewed only from the perspective of biology, removing an individual from a population might or might not biologically enhance the survival of the species. But when the impact for that individual's removal on the funding of agencies and local people, as well as incentives (for conservation) to local people, are considered, the survival may be enhanced greatly (Morrill 1993). To ignore the full range of benefits puts the species at risk. But, rejecting a use because "no harm" was not proved presents a very real risk to the species the precautionary principle was invoked to help. Lee (1995) points out, in some instances, "there is a cost [to the species] in not acting."

This one sided approach lends the precautionary principle to political misuse. Not restricting its political use has removed it as a concept of science (Brunton 1994a).

Scientists often become pawns in this game of political high stakes. While attempting to address biological uncertainties of an action and looking for answers, they often are faced with incomplete information. Often, the response to uncertainty is the familiar: "We must err on the side of the species." But "erring on the side of the species" requires a judgment that includes those factors beyond just the scope of biological assessment, involving choices based on conflicting fundamental values (Lee 1993), such as jobs and endangered species.

Given that research will never provide perfect knowledge, under the current use of the precautionary principle, the link between research and management will not be as strong as it might be. In a world where resources will be used, research is a foundation for management and should be involved intimately with that management. The current use of the precautionary principle discourages application of that research in management. Research without application is like fuel with no machine to power—its existence cannot be denied, but its usefulness will be questioned forever.

Resource Use

Resources always will be used. The key to conservation of a species is that the individuals, no matter how few, can be used at some level within some time period. This is the application of adaptive management for both plentiful and limited resources and a method for strengthening the relationship between long-term research and management.

Adaptive Management

Adaptive management for some wildlife should be considered the concurrent use and research of resources. Adaptive management uses hypothesis, implementation, monitoring, evaluation and adapting the implementation of the resource. The strongest asset of adaptive management is its implementation at the local level. "Adaptive management can help evaluate whether what is perceived as a 'desired' outcome of management is still in the light of new knowledge, desirable or even attainable. Thus, adaptive management can lead to an inspection of values and implicit assumptions that frequently underlie policies for management prescriptions" (Lancia et al. in preparation). The authors further call for the use of adaptive management as the "standard protocol" for research within planned management activity. This is the procedure that is being employed in developing nations (Zimbabwe, Tanzania, Mongolia and others) with the need to sustain their management and conservation activities through some level of use.

The Marco Polo Example

The management of the Marco Polo argali (*Ovis ammon poli*) in Tadjikistan's Pamirs Mountains in middle Asia provides an example. In considering only the biological or managerial information, it is obvious that there is much uncertainty. A recent regional revolution, extensive poverty, an armed civilian population and U.S. State Department travel restrictions are just some of the problems facing Tadjikistan. Therefore, under the current application of the precautionary principle, because of the uncertainty, the Tadjikistan argali should not be used until the uncertainty is resolved. This approach requires "protection" from use (prevention of use) for this sought-after hunting trophy.

However, there are data showing more than 10,000 argali in that region of Tadjikistan. Tadjikistan has established a quota of 20 animals and desires tourist hunters from the United States (seen as some of the best clients in the world) to hunt their argali. This is demonstrated in that government's correspondence sent to the U.S. Fish and Wildlife Service (USFWS) (C. Dane, USFWS, Office of Scientific Authority from Tadjikistan Minister of Environmental Protection: 1994; S. Khairulloev, correspondence to M. Jones, USFWS Deputy Director, International Affairs, jointly from N. Safarov, Tadjikistan Deputy Minister of Nature Conservation and A. Lailibekov, Deputy Chairman of Nature Conservation Committee of Gorno-Badahshan, autonomous region: 1996). Less than 0.2 percent harvest would have the effect of stabilizing their tourist hunting market and providing funds (therefore incentive) for argali management. Removal of a quota of 20 animals from that population is intuitively a negligible effect. But as the precautionary principle currently is misapplied, it must first be proven that removal causes no harm. That is a daunting and very expensive task, with no source for that funding. Paradoxically, it has been stated that only a non-hunting "ecotourism industry" could save the argali in Tadjikistan, despite the very limited access and limited infrastructure in the country. This recommendation has the echo of Marie Antoinette's famous remark on being informed that the peasants were starving and needed bread: "Let them eat cake."

Tourist hunters are the only source of foreign exchange in that impoverished region of Tadjikistan. There is no conservation money (or much other money) available unless it is generated from tourists who come to hunt. But the misapplied precautionary principle assumes biological harm (no harm must be proved), rather than objectively considering the benefits of use, regardless of the considerations in management. Tadjikistan has repeatedly emphasized the beneficial effects of argali hunting to U.S. Fish and Wildlife Authorities. In a 1994 correspondence from N. Safarov, Tadjikistan Deputy Minister of Nature Conservation to Dr. Charlie Dane of the USFWS, Safarov states that the benefits of foreign hunters include instilling significant economic value and, therefore, importance to wild sheep: "An argali ram is worth 100 domestic sheep." It does not take a degree in range science to understand the comparison of impact on grazing lands. In a region where domestic livestock competition with the argali for grazing habitat and poaching for subsistence by pastoralists have been considered significant problems, assigning competitive value to wild sheep has real survival benefits. Under the misapplication of the precautionary principle, those values are ignored.

Black and White Example

The Western concept of "protecting" (or "preservation") relies on the assumption that enough guns and policemen can be purchased through a centralized authority, but that requires funds eventually impossible to find (Botkin 1994). Without legal value and regulated use, the argali, despite the large numbers, like the black rhino (*Diceros bicornis*), could be "protected" to the verge (and possibly over the cliff) of extinction.

Black rhino numbers fell from estimates of more than 30,000 in the early 1980s to under 2,500 in the early 1990s. This decline occurred under complete protection from any legal use. Simply put, it has been decimated under protection (were the risks of its non-use ever considered?). That situation can be contrasted with that of the white rhino (*Ceratotherium simum*).

In the 1970s, with stocks of less than 80 animals, steps were taken in South Africa to prevent the southern white rhino from becoming extinct. Those steps included management for use. Certainly, it was not prudent to use them all (seeking a sustainable level of use) or even to use a large number too soon (choosing the appropriate timing of use), but under the adaptive management "use" strategy in South Africa, the white rhino has climbed to more than 7,500 individuals and the population, under continued utilization, is robust. The population is protected, not in the precautionary principle sense, but because those managing it are benefiting from it. Elephants (*Loxodonta africana*) in Zimbabwe are hunted and thriving, just as elephants in Botswana are thriving—a testimony to the species' resiliency under sustained-use programs. Responsibility, coming with some level of local control and definitive incentives (and disincentives), is necessary for successful conservation (Morrill 1993).

Summary

The precautionary principle, in its initiation as a modification of use, was applicable and contributed to conservation. Even as a policy to give the benefit of the doubt in uncertainty to the environment, it is applicable. But, turned into a political tool to be used against people to prohibit the use of natural resources, the precautionary principle's application becomes limited. That use will occur, legally or illegally, and because resources are finite, the use must be managed.

Management includes varying the level and timing of use and monitoring. Use without monitoring ignores risk and is not conservation. Under the application of an adaptive-management approach, the needs for both research and management are recognized and the link between research and management is strengthened. Conservation of wildlife is the ultimate beneficiary.

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Linking Temporal with Spatial Scales in Wildlife Research

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The appropriate linkage of temporal and spatial scales is an important step toward achieving reliable predictions from wildlife research data. Failure to do so may compromise the reliability of data results. Results are compromised if qualitatively different explanations become relevant as scale boundaries are crossed; in effect, data are transmuted. Scale domains have not been appreciated until recently (Addicott et al. 1987, Wiens 1989, Pickett et al. 1994). Scale domains are those regions along temporal and spatial scales where data collected within a scale boundary are reliable (Figure 1). The potential for transmutation and unreliability arises when data collected at one scale are misapplied at a different scale, e.g., across several scale boundaries. Data collected at one scale typically are used to discover the mechanisms responsible for phenomena at the next higher level (O'Neill et al. 1986, Wiens et al. 1993, May 1994). The potential for difficulty arises when several levels are crossed.

Unreliable data may arise from two entirely different sources. The investigator may have failed to sample at the appropriate temporal and spatial scales, thereby capturing only a part of the actual dynamics. This is not a problem of emergent properties; rather, it is a problem with the scale of the study design and sampling methodology. Contrarily, truly emergent properties may be involved. However, we must guard against the tendency clearly identified by Kareiva (1994: 1), i.e., using "spatial complications...as a catch-all for explaining away surprising results" or automatically invoking emergent properties when dynamics arise that our data do not explain. The onus is rightly placed on the investigator to show that reductionist explanations, i.e., at the next lower hierarchical level, are insufficient.

Emergent Properties

Emergent properties first appear at scale boundaries and cannot be explained by lower-level phenomena or measurements (Allen and Starr 1982, Lidicker 1988), i.e., they cannot be decomposed (sensu O'Neill et al. 1986). Some biologists have used the term "emergent property" almost synonymously with emergent measurement, e.g., composition, connectedness, interpatch fluxes (Lidicker 1995: 6); others have written of 'emergent patterns' (Keitt and Johnson 1995). However, properties and measurements are not the same. Few would disagree that emergent *measurements* exist that can only be measured at the specific level in the biological hierarchy. For example, birth and death rates, as well as rates of immigration and emigration are emergent measurements at the population level, while species number, composition, relative abundance and various trophic measurements emerge at the community level. Whether and under what circumstances emergent measurements measure emergent properties is much less clear. We must adhere to a rigorous definition in order for an emergent property to have significant biological meaning. For a property to be emergent means that the property must not only be *measured*, but also only *explained* at the level it emerges (Allen and Starr 1982, Lidicker 1988). If a property can be explained by mechanisms at the next lower level, the property is not really emergent, and complexity is explained by a reductionist approach. I make a distinction between properties at any level of organization and emergent properties.

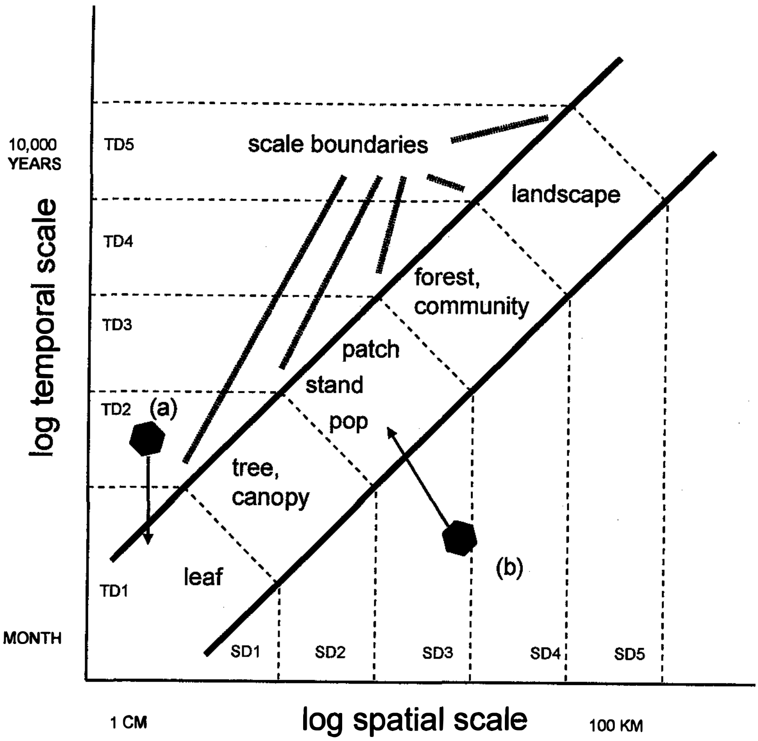

Figure 1. Theoretical match of temporal and spatial scales in ecological research. The diagonal 45-degree solid lines represent hypothetical boundaries encompassing the area of space/time scale intersections for research studies. Solid hexagonal dots represent hypothetical studies. Arrows represent the direction that we intend the space/time intersection to move as we change the duration of the study, number of sample replicates, distribution of sample replicates, sampling interval and other components. SD1,2...5, are spatial domains, represented by characteristic ranges of grain sizes and extents. TD1,2...5 are temporal domains, represented by characteristic ranges of resolutions and time horizons. Where they intersect, i.e., within the bold 45-degree diagonal lines, are the relevant temporal/spatial domains. Adapted from Wiens (1989) and Holling (1992).

The concept of emergence in ecology is much more onerous than we may have realized. Brown (1995) has suggested that diffusion is an emergent property. The movement dynamics of single molelcules of a gas are characterized as stochastic and random, i.e., Brownian movement. At this small scale, each molecule acts independently. At the next larger scale, one predictable movement of a "population" of gas molecules is referred to as diffusion. Diffusion rate is a measurement taken to characterize the property of diffusion. But diffusion does not appear to be an emergent property because it can be explained by random motion, i.e., as the probability distribution of individual gas molecules. In contrast, a truly emergent property is the "aquosity" (Mayr 1982: 63) or liquidity of water. This property cannot be deduced from an understanding of the properties of oxygen and hydrogen atoms. I have found great difficulty in indentifying a large number of emergent properties in ecology (see Pearson 1993, Andrén 1994); yet, the persuasive argument has been made that complexity cannot be understood strictly by reductionist approaches alone (Lidicker 1988, May 1994, Brown 1995), suggesting that emergent properties are present in nature.

Studies involving changing landscape patterns may be an appropriate place to look for emergent properties. For example, changes in habitat fragmentation result in changing characteristics of isolation and patch size; i.e., patch size, frequency, distribution and relative position in the landscape (isolation) change abruptly as a critical level of fragmentation is reached, demonstrating the non-linearity of the relationship (Turner 1989, Gardner and O'Neill 1991, Gustafson and Parker 1992, and Andrén 1994), although non-linearity in itself is not sufficient to infer the presence of an emergent property. To the extent that birds and mammals respond to patch size and isolation, the relationship cannot be understood completely by examining a single fragmentation level. Here, the composite property associated with landscape pattern is the explanatory variable predicting animal response and appears to fit the definition of an emergent property.

Is Persistence an Emergent Property or Just an Emergent Measurement?

In ecology, metapopulation theory has been considered as an essentially large-scale framework used for understanding the consequences of habitat fragmentation on predator/prey interactions and species persistence (Harrison 1994). As an example of the difficulty in identifying truly emergent properties, it is reasonable to examine whether persistence in this case is an emergent property under the rigorous definition provided earlier.

Metapopulations have been characterized as an assembly of several distinct populations occupying discrete positions across the landscape (see Levins 1970), but with more or less frequent exchange between the populations, to achieve some balance or trend between colonization and extinction. Harrison (1994) has critically evaluated this simplified "balance" view and its application in conservation biology and concluded that most populations do not appear to fit the classic metapopulation model. She identified two "non-classic" population patterns ("mainland-island" and "non-equilibrium") that bore superficial resemblance to the classic model, but exhibited significant differences. For this paper, the significance of her findings is that non-classic metapopulation dynamics are explainable at lower hierarchical levels than the classic model which, by definition, is explained by the extinction/colonization balance. Bighorn sheep (*Ovis canadensis*) populations appear to follow the metapopulation model (Bleich et al. 1989). Acorn woodpeckers (*Melanerpes formicivorous*) may be distributed as metapopulations across the landscape (Stacey and Taper 1992), as well as butterflies (Hanski 1991, Hanski and Gilpin 1991).

Predator/prey interactions are one aspect of metapopulation dynamics whose persistence is scale-dependent on spatial heterogeneity (May 1994). The scale of heterogeneity necessary to ensure persistence of any predator/prey interaction is not clear, but as May (1994) suggests, may be very large. In his classic study of predatory mites (*Typhlodromus occidentalis*) and prey mites (*Eotetranychus sexmaculatus*) in an "archipelago" of oranges, Huffaker (1958) was never able to model persistence at the scale of his experimental study. May (1994) suggested that few if any field studies provide enlightenment on the relevant spatial and temporal scales necessary for persistence of predator/prey or host/parasite interaction. The implications for modeling become apparent. Simulations of the relevant parameters can provide at least the range of solutions that may then be addressed specifically in field situations. Regardless of the approach, the relevant question remains whether persistence, if dependent on spatial heterogeneity rather than just a larger uniform universe, is an emergent property? One could argue that immigration and emigration, parameters understood at the population level, are the important responsible mechanisms that ensure persistence. If so, it would appear that reductionist explanations are sufficient and that sampling at the appropriate temporal and spatial scales is all that is required. The remainder of this paper is concerned with this cause of data uncertainty, i.e., making the necessary methodological adjustments in scale in ecological studies.

The Model

Figure 1 depicts an idealized match between time and spatial scale. As the spatial extent of the study is increased, so, too, does its concomitant temporal scale. Spatially, the *grain* of a study represents its lower level of resolution, usually set by the sampling unit or quadrat size; the *extent* is the area covered by a study (Wiens 1989). Holling (1992) has termed the equivalent temporal components as *resolution* and *horizon.* A strict match of the temporal horizon with the spatial extent for a forest stand, a community or landscape is not directly possible (Figure 1.); we seldom can conduct a study for multiples of 10 years or centuries. How then can one achieve a reasonable match of the relevant scales?

Most ecological research would appear to fall in the lower right of Figure 1; an area characterized by high *apparent* predictability (pseudo-predictability) (Wiens 1989). These studies usually are short term and conducted over larger spatial scales. Because local heterogeneity is averaged out over larger spatial scales (O'Neill et al. 1986, Wiens 1989), prediction in this region may seem reliable (Wiens 1989), but may not be. For example, responses of organisms that are sensitive to selection pressures operating at smaller spatial scales, i.e., localized food resources, may be lost when measurements are taken at larger scales, i.e., when spatial grain and temporal resolution are inappropriate. Similarly, organisms responding to larger-scale fragmentation may appear insensitive to smaller-scale mechanisms, unless the grain of the study is reduced to expose the causal mechanisms (C. Hargis and J.A. Bissonette unpublished data). Fewer ecological studies are conducted over very fine spatial scales for long periods of time, and these are characterized by low predictability (Wiens 1989). For example, the fast dynamics of stomatal gas exchange can be measured accurately over fine (second to second) time frames, but one still is unable to predict with great certainty what the relevant dynamics might be in the distant future, i.e., one year, two months, three days, six hours, or two minutes, hence, even if the study is long term. The reason is that the interplay of variables influencing stomatal gas exchange, i.e., ambient temperature, atmospheric gas concentrations, relative humidity, insolation, etc., is dominated by essentially rapid dynamics at lower hierarchical levels where state variables change from minute to minute. Predicting the interaction of three or more variables with short dynamics essentially is impossible (Lorenz 1963). Chaotic or stochastic dynamics may characterize the interaction.

Adjustment of Resolution and Grain

How then can one attain a better temporal/spatial match? The two most obvious ways to address the problem are either to change the spatial *extent* of the study area or to change the time *horizon* over which the study is conducted; however, the magnitude of adjustment possible would appear to be limited. The relevant temporal and spatial scales for landscapes are much larger than, for example, the scale domain for forest stand dynamics (Figure 1). I suggest that even though altering spatial extent and time horizon significantly may be difficult, it is possible to adjust spatial *grain* and temporal *resolution* to try to achieve a closer scale match. For example, increasing the number of sample replicates, the quadrat size of the sampling unit, changing the distribution of the existing sampling units across the landscape, and altering the temporal resolution of the sampling efforts can help achieve a closer match of temporal and spatial scales, thus, more accurately measuring the relevant dynamics of the problem under consideration. A caveat here: the range over which such alterations may help adjust the scales appears to be relatively small.

Figure 1 demonstrates two situations. The first (a) represents a hypothetical situation where the temporal scale of measurement is too long and not matched to the spatial scale, e.g., a leaf surface. If we are interested in leaf photosynthesis, the solution is simple; the sampling interval must be shortened to monitor the relevant variables. For illustration, stomata are capable of opening and closing within a few seconds. Taking one reading every hour, day or month is nonsensical. Hierarchically, stomatal gas exchange process rates are very fast and measurements must be designed to capture the relevant changes. Shortening the sampling interval effectively brings the time scale within the boundary that matches the spatial scale. If the objective of the study is to characterize differences in photosynthetic activity at different places within the foliage of a tree, then increasing the spatial extent of the sampling will be important. This example illustrates a fundamental tenet of the scale problem, i.e., the question asked must drive the selection of scale. There are few specific, *a priori* solutions to matching temporal and spatial scales.

Example (b) is perhaps the more common problem faced by wildlife biologists, i.e., a larger spatial scale relative to the temporal scale involved. The study of the home range dynamics of a particular species or interacting species might be an apt example. Alternatively, one might be interested in trying to relate the effects of a disturbance on some population response. For example, fragmentation has been shown to influence survivorship of core sensitive species, e.g., marten (*Martes americana*) (Bissonette et al. 1991, Brainerd 1990). However, logging does not directly result in marten mortality, rather, mortality is manifested as an increased risk of predation (Drew and J.A. Bissonette unpublished data) and decreased prey availability. The resultant mortality takes place over several years across the landscape. If the dynamics are such that it takes four to six years for the response to begin to be realized across the landscape, we almost certainly will miss the important consequences if our period of data collection is shorter, unless the system has reached equilibrium. However, equilibrium states are transitory in most landscapes where disturbance is frequent, widespread and anthropogenic (White and Pickett 1985, Pickett and White 1985, Botkin 1990).

Not all scaling problems are strictly biological. The time constraints of theses degree programs in general, (e.g., M. S. programs usually are two years in duration) mitigate against longer-term studies (May 1994). Additionally, the exigencies of crisis management on the part of state, andoften federal, resource management agencies mitigates against longer-term studies. These problems can only be solved with increased knowledge and appreciation of the important scale problems involved in wildlife research and a willingness to invest in the future with important research initiatives.

Summary and Conclusions

Failure to match spatial and temporal scales predisposes the scientist and manager to the problem that predictions from data collected at inappropriate scales may not be reliable. Lidicker (1995) provided a table of landscape-level measurements that he termed emergent properties. Wiens et al. (1993) provided a similar table but referred to the properties as "measurable features," rather than emergent properties. Bissonette (in press) argues, however, that not all properties specific to a domain of scale need be emergent. The concept of emergent properties is tied directly to the notion of whether or not ecology is more than just the sum of its parts. In turn, how one addresses the question is tied directly to one's philosophy of science. For those who believe that biological complexity can be understood by reducing all problems to their component parts, then, by definition, there is no such thing as an emergent property as defined above. If, on the other hand, one takes the view that complexity cannot be understood fully by reductionist methods alone (Allen and Starr 1982, O'Neill et al. 1986, Lidicker 1988, Wiens 1989, 1993, Brown 1995), then the concept of emergent properties takes on important meaning. Neither view is absolute, rather, ecology is both synergistic and composite, depending on the question of concern (Lidicker 1988). Cast in terms of the holism/reductionism dichotomy that was the subject of the "Forum Section" in the journal *Oikos* (Lidicker 1988), holism recognizes a hierarchical biological organization and embodies both a search inward for mechanisms and outward for context (Lidicker 1988). O'Neill et al. (1986) have suggested that problems in ecology can be thought of as middle number systems, i.e., as organized complexity, where the interactions are complex and multi-causal, and characterized by an intermediate number of components. If biology is hierarchically organized, then it may be possible to capitalize on that organization, and decompose middle number systems to the much more tractable small number systems, characterized by simple interactions and a small number of components. This is the essence of the triadic approach (O'Neill et al. 1986, Wiens et al. 1993) where mechanistic explanations for a phenomena are sought at one level lower, and context is provided at one level higher than the level of interest. It is clear that many problems in ecology can be explained by mechanistic approaches, using essentially small number systems, e.g., the metapopulation parameters of birth, death, emigration and immigration rates, operating in a given landscape, appear to be sufficient to explain or predict metapopulation persistence, even in heterogeneous environments if the appropriate temporal and spatial scales are selected for study. In these cases, there may be no relevant emergent properties of concern. In habitat-based studies, smaller landscapes may serve as "micro-landscape" (Wiens et al. 1993) analogs to the larger area, allowing reductionist methods to approximate the true state of nature. In other areas of biological complexity, properties emerge that require different scales of measurement to be understood, i.e., where there are no smaller scale micro-landscape analogs. If, in the metapopulation example, persistence could not be explained by population variables, but rather, with each different landscape mosaic, very different dynamics appeared that could only be understood as a cause/effect relationship dependent on landscape pattern alone, then an emergent property may be involved (Pearson 1993, Andrén 1994). The implications of emergent properties as general phenomena are startling. Scientists believe that there is pattern and prediction in ecology. Mechanistic approaches, based on a hierarchical perception of ecological systems, have been the foundation for theory and prediction. If emergent properties are common, and if reductionist methods cannot provide explanation, the implication is that the effect of each landscape pattern on its biota is novel, and that scientific investigation is reduced to a cataloguing of the effects, until a higher-scale theory can be put into place. Pickett and White (1985) have discussed the conceptual framework that they view as a prolegomenon for disturbance theory. My pragmatic reading of the issue is that a multiscale approach to resource problems, using both reductionist methods to answer the "how" question and a more holistic approach for context probably is required to understand ecological complexity fully.

Wildlife managers dealing with the conservation and management of predator and prey species work with management areas or landscapes of specified extent. Whether or not management actions, taken to ensure maintenance of predators and prey, will be effective would seem to be a direct function of the nature of the interaction itself, and the heterogeneity and extent of the landscape. With too small an area, persistence of either predator or prey well may track the dynamics of Huffaker's (1958) mite-orange experiment, with local extinctions occurring. The increasing efforts of game and fish departments to relocate species to areas of previous occupancy suggests that these are serious concerns.

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Managing Research as an Investment

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The theme of this year's Conference, "Facing Realities in Resource Management," is fitting and timely, especially with regard to natural resources research. Research and development in the United States and elsewhere is undergoing transition. The so-called science/society contract negotiated in the post-war optimism of the late 1940s is being challenged and requires renegotiation. The system of natural resources research in the U.S. is no exception; an overhaul is long overdue. I have a larger concern, however. The nation's attention span is getting shorter. People want immediate results for their money. Long-term research projects will be increasingly difficult to sell to our ultimate stakeholders, the public. For example, to maintain their visibility and viability, long-term projects must produce interim deliverables.

The realities for research are that budgets will be tighter, the workforce will be smaller, demands for relevant scientific information will increase and research, like other government sector services, will be subject to performance assessments. Over the long term, these realities may result in opportunities for the natural resource research community.

A more fundamental reality is the inherent tension between research and management. They are entirely different estates. Like politics, management aims at the responsible use of power and resources to accomplish desired outcomes. Science, on the other hand, aims at finding truths as defined by peer groups and as obtained from systematic observation and careful study. Scientists deal in data; managers want relevant information. Kai Lee (1993), author of *Compass and Gyroscope*, refers to this relationship as the power-truth spectrum. Because of their basic differences, science and management have difficulty communicating with one another. A common denominator is missing.

I propose that natural resources research be viewed and treated as an investment. As personal investors, most of us are willing to invest in stocks, bonds, maybe a little real estate and certainly in education for our children in hopes of realizing future returns on those investments. An investment approach applied to research requires that sponsors and stakeholders be willing to make hard investment choices, assume the risks associated with those investments and then have the patience to wait for the returns.

This is not a new concept. Callaham (1981), in discussing criteria for choosing among forestry research programs, considered scientific research to be a form of capital investment necessary for economic health. A link between investment in research and growth of productivity was demonstrated repeatedly in the agricultural, forestry and forest products sectors and in various industrial sectors (Bengston 1989). Economists have computed rather high yields from natural resources research "investments," including returns of between 9 and 111 percent for forest management research (Jakes and Risbrudt 1988). Expected returns from natural resources research take the form of improved land health, more efficient ways of managing resources, and improved policies, processes and decisions.

What is an appropriate level of investment for natural resources research? In the early '90s, the Forest Service was investing an amount equal to about 11 percent of its national forest systems budget. The Bureau of Land Management was committing roughly 3 percent of its wildlife and fisheries budget to research. The National Park Service's investment in research averaged 3 percent of its budget and the Fish and Wildlife Service spent the equivalent of 16 percent of its refuge budget on research. Considering both federal and state levels, wildlife research investment is about 6 percent of all national expenditures for wildlife management. Research on wildlife and fisheries constitutes only about 0.2 percent of total sportsmen expenditures for hunting and freshwater fishing. To put these numbers into perspective, the United States' total research and development budget each year averages about 2.5 percent of the Gross Domestic Product.

Managing Natural Resources Research Portfolios

What would a natural resources research portfolio look like and how would it be managed? Research portfolios might consist of a set of projects, locations or programs, depending on the level of analysis. I will use projects for sake of discussion. Research portfolios are multidimensional. The research organization's core functions and strategies, which hopefully reflect the expectations of the parent organization or sponsors, determine the dimensions and boundaries of the research portfolio. So, like snowflakes, every research portfolio is going to be unique. Natural resources research portfolios generally have three primary dimensions: time horizon, level of risk and research purpose (Figure 1).

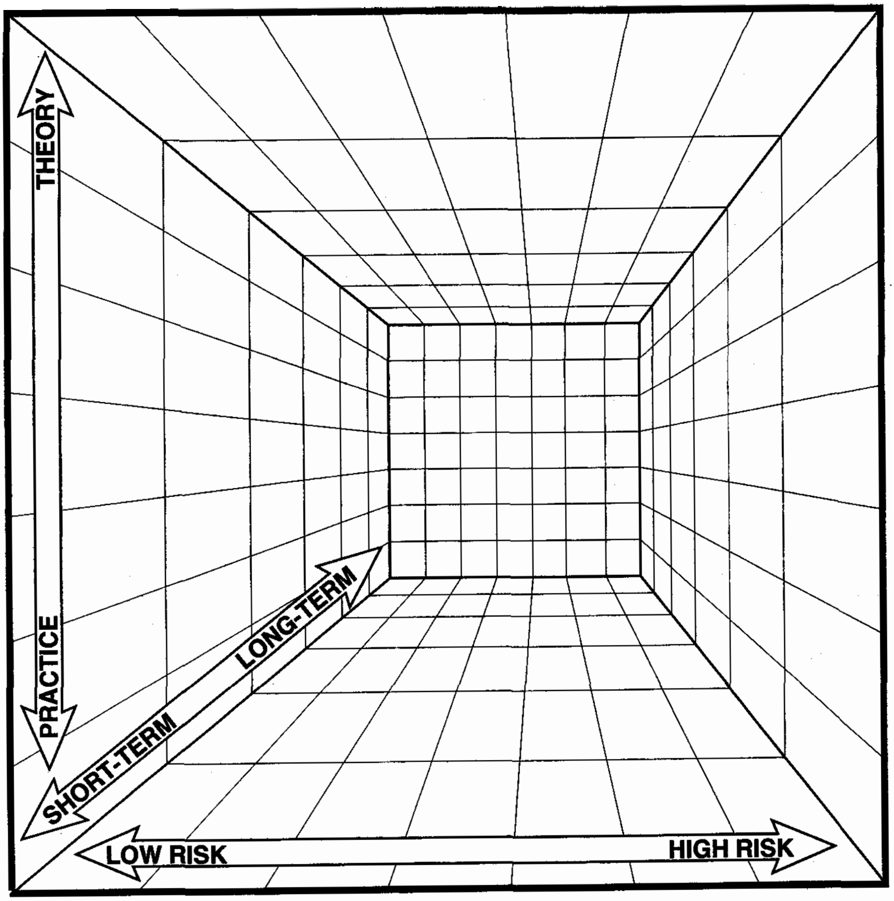

Figure 1. The three dimensions of natural resources research.

Time horizon is a function of the time required to work through the research approach, including data collection, and meet the project objectives. Martin and Irvine (1989) define short-term as 1 to 3 years, medium-term as 3 to 5 years and long-term research as 5 to 30 years. In its review of the Department of the Interior's proposal to create a National Biological Survey, the National Academy of Sciences (1993: 50) made a point to distinguish between short-term and long-term studies, suggesting that this is an important dimension of research investment planning.

Level of risk refers to the degree of certainty of research outcomes. Research that is undertaken to corroborate the findings of other investigations or to confirm a well-known and accepted hypothesis usually is less risky than pioneering research at the frontiers of science. I do not mean to infer that managers should avoid investing in high-risk research. Much of the science involved in advancing our understanding about natural ecosystems is, of necessity, both long-term and high-risk.

The third dimension is labeled Theory versus Practice. This is the purpose of the research. We also could call this dimension "fundamental understanding versus policy-relevant knowledge." Also included in this complex dimension is the development of new tools and methods. The research portfolio does not have to be limited to three dimensions. Other possible dimensions relevant to natural resources research include:

- *breadth of investigation* (narrow or penetrating versus broad or pioneering);
- *reduction versus synthesis;*
- *anticipatory/strategic versus goal-directed/tactical;*
- *intramural versus extramural;* and
- *small and focused versus large and comprehensive.*

Different investments yield returns in different ways and investors make choices according to the rate of return of alternative investments and their riskiness (Lee 1993). This is another way of saying that research portfolios are dynamic. For example, research managers make investment decisions when they initiate, expand or close research projects (Jakes and Risbrudt 1988). Therefore, we need adequate strategies and tools for managing research portfolios. A strategic approach to managing research requires that an organization understand where it is going and what its strengths and weaknesses are. A quadrant approach, depicted in Figure 2, is suggested as a tool for managing research portfolios.

Research portfolio analysis begins with a consideration of the existing strengths of the organization—essentially, the right skills in sufficient numbers of scientists and technicians. This is the internal dimension of the portfolio. Research projects also are judged to be either proven past performers or promising new opportunities. This is the external dimension, because research potential must be viewed from a client or sponsor perspective. Orthogonal portrayal of these two dimensions results in the four quadrants depicted in Figure 2. These quadrants are labeled, in counterclockwise fashion, as the α (alpha), β (beta), ω (omega) and δ (delta) quadrants.

The α quadrant is home to projects backed by substantial organizational strengths and representing promising new research directions. In other words, these are the future superstars of the portfolio. Projects in the β quadrant are the cash cows. They enjoy solid reputations as proven performers. However, success does not last forever and β-quadrant projects eventually will reach maturity and begin to decline in favor, if not in resources. The ω quadrant houses projects at the end of their productive life. These are research efforts which need to be terminated. They are maintained in the portfolio pending the completion of final project reports, publications and other information transfer activities.

Substantial management involvement is required in the δ quadrant. These are projects that require strategic changes because of critical organizational weaknesses and because they represent promising new research opportunities. Another way to view a research portfolio is to think of the four quadrants representing a life cycle of research initiatives. Research initiatives tend to begin in either the δ or α quadrants, progress over time into the β quadrant and eventually end up in the ω quadrant.

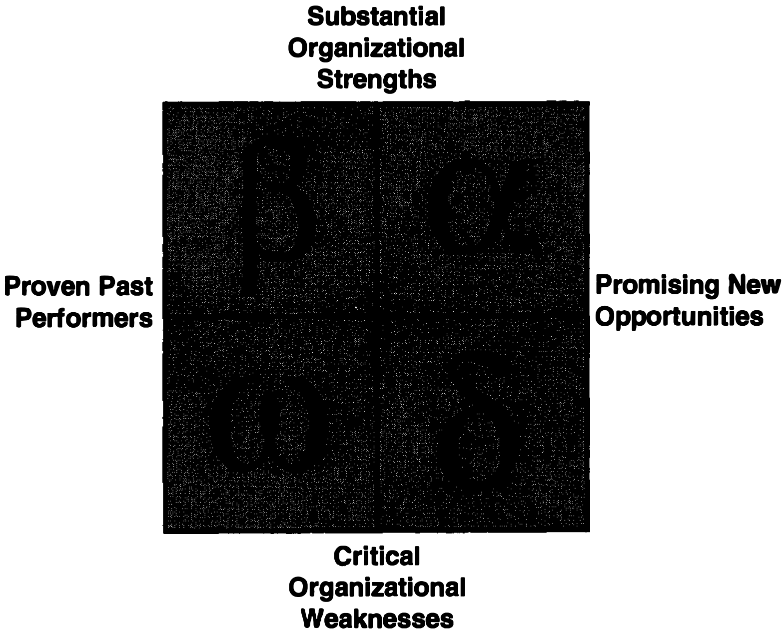

Figure 2. A quadrant approach to managing research portfolios.

Research Planning and Evaluation: Links to Management and Policy

I already have suggested that the link between long-term research and management include an investment orientation on the part of management and a client orientation on the part of research. As stated earlier, long-term research must involve interim products. We expect monthly or quarterly dividends from financial investments, so why not dividends from research investments? As indicated in Figure 3, collaborative research planning and research performance evaluation form the final links in the chain between long-term research and management. Research planning should be a truly collaborative exercise between researchers and managers, with managers identifying their short-term and long-term information needs. The goal is the construction of a research portfolio that suits the needs of all the stakeholders.

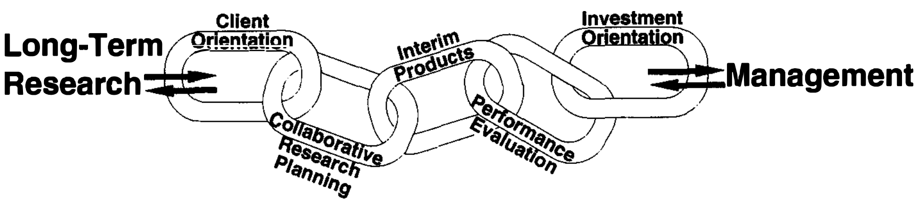

Figure 3. The connection between long-term research and management.

An Evaluation Model for Natural Resources Research

Research performance evaluation is a complex and very controversial topic. The issue revolves around what is to be evaluated and who will perform the evaluation. Long-term research is particularly hard to evaluate. More importantly, evaluation systems must recognize that research projects are different. This is evident in the concept of the research portfolio. One project may have the goal of advancing fundamental knowledge about ecosystem processes, whereas another project may be designed to provide a short-term answer to a management question about wildlife habitat. Whereas the former promises primarily "intrascientific" benefits, the latter results in primarily "extrascientific" benefits.

The evaluation model depicted in Figure 4 provides a framework for thinking about research performance evaluation. The framework can be applied to all projects in a research portfolio and it recognizes that there are both outputs and outcomes that accrue intrascientifically and extrascientifically. Finally, the bottom line of a research evaluation should be the determination of social-scientific value. Did the research have an impact on its target audience or did it just gather dust?

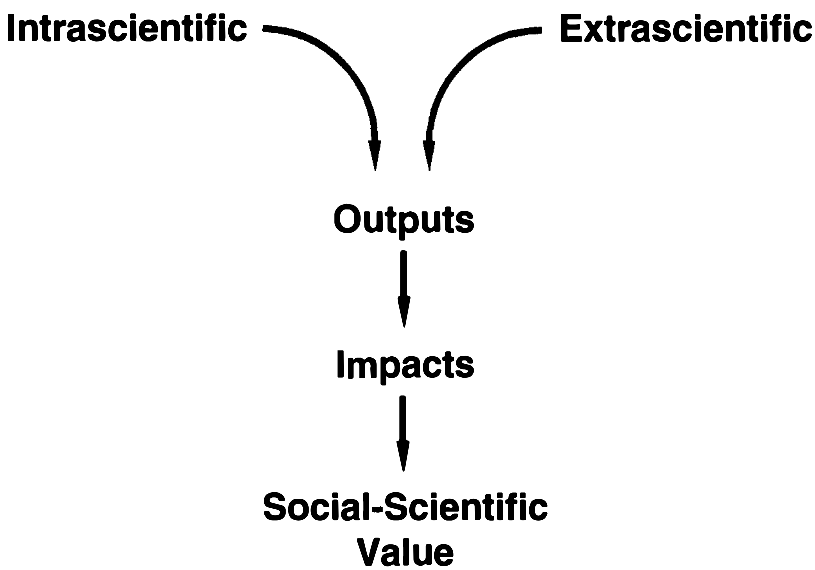

Figure 4. A research evaluation model that considers both intrascientific and extrascientific aspects of research output, impact and value to society.

In summary, I believe and would argue that the logical link between long-term research and management is one of investment. Like any other business or personal investment portfolio, resource managers must support an active investment strategy with reasonable goals and expectations, while the research community works to produce the expected returns from the investment.

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Special Session 7. *Issues and Ecological Dimensions of Forest Health*

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Forest Health and Biological Resources: Making the Connection

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When wildfires burned nearly 4 million acres in 1994 and federal firefighting costs mounted past $1 billion, the condition of western forest systems became a more visible public policy issue. Tragically, that attention was amplified by the publicity surrounding the lives lost in wildfire incidents that year. This raises legitimate questions as to whether those events were simply natural disasters, or whether people had allowed conditions to reach a point where natural events can more easily turn into disaster.

For those who have been studying these forests and their condition, 1994 looks like a modest harbinger of things to come rather than an unusual happening. For every acre hit by wildfire in 1994, there are 5 to 10 more acres, particularly on the public lands, where the fuels have built to the point that similarly intense fires are virtually assured (Sampson and Clark in press).

These natural events have become catastrophic in their effects, and the impacts are not limited to burned trees and endangered homes or towns. The impacts include potentially significant soil, watershed and biological changes. In one 1994 wildfire—the Thunderbolt fire on the Boise and Payette national forests—the post-fire environmental analysis indicated that 79 percent of the area had experienced moderate or high fire intensities (Boise National Forest 1995). Those intensities, which occur largely as a result of the fuel conditions that have been encouraged over decades of fire suppression-based management, make a significant difference in the environmental impact of the fires (Agee 1993).

To understand what is happening on these lands today, you have to combine history with ecology. Throughout much of the western United States, the main wave of settlement and development occurred in the mid- to late 19th Century. Most of us have read the stories—or seen the movies—of gold rushes, wagon trains, rough frontier towns, cattle and sheep wars, railroads and farmers. Some of that has happened fairly recently, in historical terms. Many areas of the West still were being settled in the early parts of the 20th century.

Settlement brought enormous change to the environments of the West. A land that formerly supported fairly low human populations, many of whom lived a nomadic lifestyle that moved across the land as seasons and food sources changed, was suddenly the home of growing numbers of people developing a settled lifestyle with fixed property boundaries. Where formerly there had been few large grazing animals, suddenly there were hundreds of thousands—cattle, sheep and horses—grazing the grasses and shrubs across all but the most remote regions (Covington et al. 1994). In the valley bottoms, meadow grasses gave way to hay and crop fields, while in the streams, diversion dams led water out to irrigate crops which could not otherwise survive in the dry climates.

In the forests, too, there were important changes. The late 19th century, as well as the early decades of the 20th century, featured an emerging industrial economy driven by wood as its energy source, as well as its main structural material. As these regions were settled, the demand for wood in all forms skyrocketed. Loggers penetrated deep into the forest, using railroads, river drives, flumes, steam donkeys, splash dams and other methods to extract the huge pines that dominated many of the forests. Their logs built roads and bridges, tied rails together on railroads, shored up mine tunnels, and built homes, businesses and factories. The wood they harvested also drove the steam engines that were a major power source and, in those areas without coal, provided the charcoal that smelted the ore. This was a wood-based industrial economy and its appetite was enormous (MacCleery 1993).

Two other changes in the forest, however, missed the attention of many historians. The removal of the Native American populations changed the wildfire situation dramatically. Native Americans used fire extensively in their land management, hunting and defense strategies (Pyne 1982). With the Indian populations decimated by imported diseases and the few remaining numbers restricted to reservations, the fire situation was altered dramatically.

Equally important, livestock grazing eliminated the sea of grass so that a fire could no longer burn for miles. The irrigation of the valleys kept a fire on one mountain from easily burning across to the next. In addition, settlers feared fires which could destroy their wooden homes and towns, so it was a civic duty to put out any fire as rapidly as possible. The fires that had been an integral part of these lands for millennia came to an abrupt halt as settlement occurred. Some people fault the USDA Forest Service for the elimination of all fire from these lands, but effective fire control in many of these forests began with settlement—50 to 100 years before Smokey the Bear.

Eliminating fire started a major change in the wildlands of the West. In the long-needled pine forests that were common from mid-Mexico to Canada, the fact that fires no longer occurred every 5 to 25 years meant that small trees could now thrive in great profusion (Covington et al. 1994). Research in Arizona has found sites where pines historically numbered about 25 to 40 per acre in an open savannah-type forest. Today, there are as many as 1,200 trees per acre—a dog-hair jungle of spindly, stressed plants fighting each other for limited water and nutrients (Covington and Moore 1994).

In the Boise National Forest of Idaho, one research plot where 27 to 30 pines existed from the 1500s until 1890 now has more than 550 trees per acre, with almost two-thirds being firs which were able to invade the site after fire was eliminated in 1890 (Boise National Forest 1994). Similar examples, with only the numbers and species mix changing a bit, can be found from the top of the coastal mountains—the Cascades and the Coastal Range—to the Great Plains, and from Mexico to Canada. On the vast grasslands, elimination of fire favored the invasion of huge areas by species such as sagebrush, juniper and other brush. Much of this land is now filled with old brush plants, many of which burn with high intensity and extreme fire behavior (National Commission on Wildfire Disasters 1994).

Today, millions of acres have fuel loads that are many times higher than the historic conditions. Ranging from sagebrush prairies through pinion-juniper woodlands to pine and fir forests high in the mountains, these lands are just waiting for a dry day and a spark. When that occurs, the resulting fire will, in many places, be hotter and more destructive than the fires that occurred over the millennia. On the drier forests, where historical fires usually were low-intensity, high-frequency events that burned through grass and fallen litter with very little damage to either topsoils or large trees, high-intensity fires now roar into intense crown fires that kill every tree, large and small (Clark and Sampson 1995).

Where fuel loads near the ground are heavy, the fire burns hotter and longer, driving heat deeper into the soil. The effects on soil biology, nutrients, organic matter and structure are highly variable, but one aspect is fairly clear—the extent of damage is proportional to the temperature and duration of the heat impact (Agee 1993). Soils that evolved under the impacts of high-frequency, low-intensity fires now are experiencing high-intensity fire effects. These effects are not the same and they should not be taken lightly. The damage from dry raveling, where the soil on steep slopes slides into ravines and streams like dry sugar, or from the sheet erosion that can occur when a water-repelling soil layer turns normal rain into a massive mud flow, is essentially permanent. The take-home lesson is that these are not normal fuel conditions, they are not normal fires, and the effects are well outside historic ranges. When you hear someone say, "Let it burn, that's nature at work; it will be just fine," don't believe it. That may be true in some places; on millions of acres today, it is a prescription for permanent environmental damage.

The public debates on this situation are bound to continue and get more controversial, long after the smoke from 1994 and the current round of fights over salvage logging have passed into history. The question of whether we now are required to manage these public lands in a more intensive and scientific manner, or whether we still have the option of letting nature take its course on them, will be bitterly debated. For many people, the science they learned at school, the folklore they learned from their parents and peers, and even the religious teachings they received support the idea that "nature knows best," and that if we leave these forests alone, that will be "natural" and "better" than if we change them with human efforts.

Modern ecological science, the history and condition of the forests of the West, and the escalating cost and damage we are experiencing argue the other case. Today, the most high-risk strategy available, both in terms of economic costs and losses, as well as long-term or even permanent environmental damage, is to do nothing on these lands and let nature take its course (Sampson et al. 1994).

The primary risk to biological resources in this situation is related to the likelihood of significant or permanent ecosystem changes, and those ecosystem changes are related directly to the intensity and landscape scale of the wildfires that occur. Avoiding wildfires that are significantly more intense and damaging than the historic fire regime, and restoring wildfires that burn within the historic ranges to replicate the ecological effect of fire are the primary management challenges on these lands.

Those challenges can be illustrated by two conditions that are common across the West. The first is the ponderosa pine, douglas-fir and mixed conifer forest where fires were frequent historically, usually burning at low intensities. Today's fuel conditions lead to fires with a high percentage of high-intensity fire, and the resulting ecosystem impacts are greater. Killing all the large trees within the burn area means, for example, that it will be 100 to 150 years before the ecosystem gets a large-tree component equivalent to what is lost in the fire. The plants and animals that thrive on large-area landscapes of early successional forest may do just fine as a result, but there will be a long-term lack of the older, larger structures that other species need.

If the topsoils are damaged seriously, either by high heats or subsequent erosion events, the sites may be degraded permanently. I inspected a 1995 soil erosion blowout on the North Fork of the Boise River that was the direct result of the 1994 Rabbit Creek wildfire. A roadless area that had never been logged so far as I could determine was burned very intensely in 1994. Sampling transects across intensely burned areas near the eroded area revealed a surface layer of about 2 to 3 centimeters. of ash and unconsolidated mineral soil. A water-repellent layer had been created about 4 to 10 centimeters. down, as the organic compounds volatilized by the fire had condensed and sealed the soil where they were driven by the heat into the cooler, lower layers.

Into that situation, a summer rain event caused enormous damage. Rainfall records were not available on the site, but estimates from nearby stations indicated about 1.2 inches of rainfall in a three-hour period, which would classify the storm as a one-in-three- to a one-in-five-year event. Sheet erosion could be seen at the very top of the ridges, and concentrated runoff moved enormous amounts of soil, rock and woody debris from the channels that dropped steeply from the top of the ridge to the river. The result was a major mud and debris flow that will significantly affect a 10- to 20-mile stretch of that river for years. Fisheries will be impacted long after the roads and other damages have been repaired.

On the high slopes where the soil erosion began, soils appear to be seriously degraded by the loss of all organic matter and much of the surface soil. Time will tell what kind of ecosystem can re-establish on that site, but it clearly will be less productive than what was there before the fire. In a climate where soil formation is very slow, that damage looks likely to persist for millennia.

Despite of the raw emotion that surrounds the salvage issue today, that particular ecosystem damage had nothing whatsoever to do with salvage—or even logging. It had two major causal factors—high-intensity wildfire and rainfall. In these systems, a high-intensity wildfire sets up the soil for serious damage if rainfall events follow. And they nearly always do, because these are normal climatic events that cause major impacts because of vulnerable conditions on fire-damaged soils. The only management recourse is to change the fuel conditions on the land before the inevitable wildfire occurs. Everything done after the fire probably is almost meaningless in terms of soil and watershed protection.

On the higher mountain sites where lodgepole pine and spruce/fir forests are common, low-frequency, high-intensity wildfires were the more common regime. In these areas, many of which have not missed their normal fire cycle too significantly, today's wildfires are a more normal event and create more normal impacts. Soil damage is much less of a threat in these situations.

The most worrisome thing in terms of the biological impact of wildfire in these situations is the unusual size of the contiguous areas with heavy fuel loads and uniform conditions. Satellite imagery of the lodgepole pine forests in the Selway-Bitterroot Wilderness Area indicate that future wildfires are almost certain to be significantly larger in area than the historic fires (Neuenschwander personal communication: 1995). Our fire suppression activities over the past 50 years have most effectively suppressed the small lightning-set fires that would have broken that landscape up into smaller patches had we let them burn. Now, unusually large areas are in condition to support intense fires. When those fires burn, the resulting landscape uniformity could have implications for habitat and biological diversity.

Unusual habitat uniformity can occur in two ways under the current fuel and wildfire condition. If, as the satellite imagery indicates, the patch size of uniform conditions is larger than the historic norm, then an ignition anywhere in a vulnerable fuel and weather situation quickly can become a very large wildfire that alters a significant area.

The other aspect of uniformity can occur within the boundaries of the fire area itself. Wildfire statistics normally indicate the area affected by a wildfire. But typically, within that perimeter, fire is very uneven in its intensity, ranging from patches of complete mortality to patches of no noticeable effect, with all ranges between. A recent example is the Yellowstone fire, where satellite imagery clearly illustrated a very diverse mixture of conditions within the fire perimeter (American Forests 1989).

Some of the recent wildfires, however, have been more uniformly intense within their perimeter. I flew virtually the entire Foothills fire near Boise, Idaho, a year after the event, and was amazed to see almost total tree mortality within the perimeter. This was a diverse landscape, with pockets of isolated ponderosa pine occupying north-facing pockets surrounded by grass or brush, grading into higher slopes of mixed conifers. The topography and vegetative pattern suggested a very diverse mix of conditions, but nothing within the perimeter appeared to escape that fire. Trees with dozens of prior fire scars were killed, indicating that this was a different kind of event (Sampson et al. 1994). The landscape diversity there has been greatly reduced, and only time will tell whether that is a temporary event or something that will last much longer.

Many believe that the answer to this situation does not lie in fighting over salvage logging following the fires. Instead, the challenge is to work ahead of the fire event to try and alter the fuel conditions. On ponderosa pine and similar sites, that means thinning small trees and removing ladder fuels from areas where the highest ignition risks exist. That can help some areas, at least, retain a large-tree component when fires affect the area. If it is done skillfully, it can break up large-area fuel conditions and help the resulting fires create a more diverse landscape (Monnig and Byler 1992).

On the high-elevation forests where lethal crown fires are the more normal disturbance, there needs to be more use of prescribed fire and other silvicultural tools to break up the large areas before they burn. That way, wildfires are more likely to give the diverse habitat results that were the historical pattern. Both of these situations have enormous implications for wildlife habitat conditions in the coming century, and wildlife professionals should be closely engaged as forest health discussions proceed and land-treatment decisions are made.

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Restoration of Forest Ecosystem Health: Western Long-needled Pines

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Semantic and philosophical confusion lies at the heart of much of the current controversy over restoration of forest ecosystem health (e.g., see Kolb et al. 1994). Nowhere are these controversies more heated than in the long-needled pine forests of western North America (Clark and Sampson 1995, Covington et al. 1994, Sampson et al. 1994, Williams et al. 1993). To some, the health of the forest is simply the health of the trees. To others, forest health implies the natural functioning of entire landscape ecosystems, including native diversity and natural disturbance regimes. In this paper we examine ecosystem health of western long-needled pine forests and draw conclusions regarding ecological restoration of this widespread forest type in an adaptive ecosystem management framework.

Our paper begins by defining ecosystem health, ecosystem restoration and the concept of the evolutionary environment. Next, we present an overview of the ecological context of ecosystem health declines in ponderosa pine ecosystems. Finally, we close with a discussion of ecosystem restoration in this important forest type.

Ecosystem Health

Ecosystem health (*sensu* Leopold 1949, Callicott 1994) is related to, but distinct from forest health as it often is used today. Although most foresters and others in the conservation professions generally have used the term "forest health" to connote the health of entire forest ecosystems, some in the lay public have used the term "forest health" in a much more restricted sense—all too often to mean merely tree or stand health and as a euphemism for the practice of salvaging trees, including old-growth trees, before they "go to waste" as food for bark beetles or fuel for infernos. We believe that it is important for conservation professionals to be clear on this point. When we refer to a "forest," we should refer to a forest ecosystem—a specified spatial entity—and all that exists, lives and occurs within that area. As used in this paper, the term "forest health" is synonymous with the term "ecosystem health," for those ecosystems that are, in fact, forests.

Ecosystem health refers to the health of ecosystems in their entirety, including humans as members of ecosystems. Taking this metaphor a bit farther, we can define ecosystem medicine as the science and art of dealing with the health of ecosystems, including the prevention, alleviation and cure of diseases, where disease is defined as dysfunctions, such that natural ecosystem structures and processes become disrupted. In this sense, ecosystem restoration as an ecosystem health discipline is analogous to general practice in the field of human medicine. Ecosystem management might be viewed as the science and art of maintaining well-being.

Ecosystem Restoration Defined

Ecosystem restoration is founded upon fundamental principles of evolutionary ecology and conservation biology. A central premise of ecological restoration is that restoration of natural systems to conditions consistent with their evolutionary environments will prevent their degradation, while simultaneously conserving their native plants and animals. Practitioners of ecological restoration recognize that a failure to include human interactions with wildlands is folly and that "pure" restoration goals are appropriate for only a subset of public lands (see below).

Ecosystem restoration consists of a broad variety of practices designed to restore natural ecosystem structure and function. For example, in southwestern ponderosa forests, ecosystem restoration might consist of preserving all of the old-growth trees (those which predate Euro-American settlement), removing most of the trees which postdate Euro-American settlement, raking heavy fuels from the base of the old-growth trees, burning under prescription, removing introduced plants and sowing with native herbaceous seeds.

However, ecosystem restoration should not be construed as a fixed set of procedures, nor as a simple recipe for land management. Rather, it is a broad intellectual and scientific framework for developing mutually beneficial human/wildland interactions compatible with the evolutionary history of native ecological systems. In other words, ecosystem restoration consists not only of restoring ecosystems, but also of developing mutualistic human uses of wildlands which are in harmony with the natural history of these complex ecological systems.

Evolutionary Environment Concept

The concept of the evolutionary environment is central to understanding ecosystem restoration. The term evolutionary environment is used to refer to the environment in which a species or groups of species evolved—the environment of speciation. Over evolutionary time, species not only adapt to their evolutionary environment, but they also may come to depend on those conditions for their continued survival.

The evolutionary environment of western forest ecosystems is dominated by natural disturbance regimes (e.g., fires, predation, defoliation), which have varied in kind, frequency, intensity and extent (Agee 1993). These disturbance regimes served as natural ecological checks and balances on populations and insured spatial and temporal habitat diversity.

Declining Ecosystem Health in Ponderosa Pine Forests

Short return-interval, fire-adapted ecosystems often are the first indicators of problems that are propagated across landscapes and throughout biomes (e.g., Williams et al. 1993, Covington et al. 1994). In the absence of periodic low-intensity fire, these ecosystems undergo rapid and striking changes in species composition and structure which, in turn, become predisposing factors to undesirable changes in ecosystem health, not only for indigenous biota, but for contemporary humans as well.

The sequence of these undesirable changes is becoming widely acknowledged but poorly documented. Fire exclusion leads to tree population irruptions (including conversion from fire-resistant species to fire-intolerant species), steadily accumulating forest floors, impoverishment of herbaceous and other non-arboreal vegetation, shifts away from indigenous wildlife diversity, epidemic insect and disease outbreaks, severe stand-replacing crown fires, degradation of human habitat values (e.g., esthetics, biodiversity, watershed condition and wood products), and threats to human life, health and property (Clark and Sampson 1995, Covington et al. 1994, Williams et al.

1993). To all of these other undesirable costs must be added the rapidly accelerating cost in firefighter life and health and the exponentially increasing direct costs of fire suppression. Continuation of these trends is intolerable.

Although there is an increasing consensus among ecologists and natural resource professionals that these undesirable changes have been and are occurring throughout North America's short-interval, fire-adapted ecosystems, many, including most of the lay public, are skeptical about the magnitude and extent of these changes in ecosystem conditions and disturbance regimes. Furthermore, even among natural resource scientists, debate is heated over what, if anything, can be done to alleviate these problems. Some argue that these systems will recover rapidly to natural conditions following insect, disease and crown fire epidemics. Others argue that these synchronous, large-scale catastrophic disturbance regimes will tend to be self-perpetuating. Still others argue that thinning alone can be used to restore ecosystem health or that prescribed burning without mechanical thinning can restore natural conditions. Currently, there is a great need for quantitative data to illuminate these debates.

Long-needled pine forests extend over more than 20 million hectares of western North America (Bailey 1995, Brown 1982), constituting the majority of the commercial pine forests of the continent. Ponderosa pine (*Pinus ponderosa*) alone accounts for more than 1.1 billion cubic meters of growing stock (Van Hooser and Keegan 1988). These forests are highly valuable as sources of wood products, water, livestock forage, wildlife habitat, recreation and conservation of biological diversity. However, a century or more of human-caused disruption of the frequent low-intensity fire regimes and elimination of the open, parklike forest structures characteristic of these ecosystems prior to Euro-American settlement has led to extensive ecological degradation, reduction in social and economic values, and the development of dense forest and fuel structures that are highly susceptible to insect outbreaks and high-intensity crown fires of unprecedented scale (Everett et al. 1994, Covington et al. 1994). Although Euro-American settlement occurred at varying times across North America, our functional definition is the time when long-term patterns of fire disturbance regimes were disrupted, often associated with major structural changes (e.g., grazing, harvesting). By this definition, some unharvested forests in northern Mexico are in presettlementlike condition due to the ongoing frequent fire regime, despite 400 or more years of Spanish colonization (Leopold 1937, Fulé and Covington 1994a, 1994b). To provide quantitative information essential to address the growing concern over sustainable management of these ecosystems, we propose to investigate the effects of high-intensity wildfire, prescribed fire, understory thinning and bark beetle-induced tree mortality "treatments" on key ecosystem and human resource characteristics of long-needled pine ecosystems of the cordilleran region of North America.

The long-needled pine forest and savannah ecosystems of western North America are dominated by an ecological group of closely related pines (*Pinus ponderosa, P. durangensis, P. engelmannii., P. arizonica, P. jeffreyi, P. washoensis*) in the section Ponderosae characterized by thick bark, insulated buds and other adaptations to frequent fire regimes (Conkle and Critchfield 1988, McCune 1988, Barton 1993). Frequent fire, recurring every 2 to 20 years in these forests prior to Euro-American settlement (Weaver 1943, Biswell 1972, Dorey 1979, Kilgore 1981, Arno 1985, Knight 1987, Mast 1993, Covington et al. 1994, Swetnam and Baisan in press), has played a key role in the evolution of the biota of these widespread ecosystems. In fact, Mutch (1970) hypothesized that natural selection in ponderosa pine has produced characteristics such as long needles with high resin content and exceptionally slow decomposition rates which function to encourage fires, thereby reducing establishment of and competition from other trees (e.g., *Abies* spp., *Picea* spp.) that are not adapted to frequent fires. Frequent fires appear to be essential for maintaining open, parklike forests, by controlling pine tree population irruptions and forest floor accumulations (Covington et al. 1994), and by maintaining a high level of nutrient availability (Covington and Sackett 1984, 1990).

Since Pliocene times, these forests have provided important evolutionary habitat for an exceptionally diverse biota, much of which appears to be dependent on frequent fire. For the past 10 to 30 thousand years these forests have been vital resources for numerous human cultures, most recently (1850 to present) for Euro-American industrialization. Early human cultures in North American forests supplemented lightning ignitions by using fire as a hunting, gathering and agricultural tool (Pyne 1982); however, soon after Euro-American settlement of the region, heavy livestock grazing broke the continuity of grass fuels and active fire suppression eliminated the presettlement fire regime. In the absence of frequent fires, striking changes occurred: tree species less adapted to frequent fire have invaded (at the expense of other plants), and pine tree biomass, both live and dead, has steadily accumulated, contributing to progressively declining biodiversity, increasing susceptibility to insect and disease epidemics, and supporting a shift from frequent, low intensity surface fires to larger and larger crown fires (Cooper 1960, Covington and Moore 1994a, Covington et al. 1994).

To a society with high demands for wood products, the increase in tree density at first seemed beneficial to many. However, after 50 to 70 years of fire exclusion, foresters and ecologists, beginning with Aldo Leopold in the 1930s, began sounding the alarm that fire exclusion in these long-needled pine forests was leading to rapidly accelerating ecological degradation. For example, in 1943, Harold Weaver summarized conditions in eastside Washington ponderosa pine: "Dense, even-aged stands of ponderosa-pine reproduction have developed...enormous areas are growing up to dense, even-aged stands of white-fir [sic], Douglas-fir, and incense-cedar [sic] reproduction under the merchantable ponderosa pines...for the past 20 years epidemics of the western pine beetle have killed and are continuing to kill billions of board feet of ponderosa pine worth many millions of dollars. Because of these ecological changes, which are continuing to take place, the fire hazard has increased tremendously. Fires, when they do occur, are exceedingly hot and destructive and are turning extensive areas of forest into brush fields."

Soon, other researchers pointed out additional undesirable consequences of fire exclusion in ponderosa pine forests. Studies in Utah (Madany and West 1983, Stein 1987), Montana (Gruell et al. 1982), Idaho (Steele et al. 1986, Barrett 1988), Washington (Weaver 1943, 1957), California (Laudenslayer et al. 1989) and the Southwest (Cooper 1960, Covington and Sackett 1984, 1992, Covington and Moore 1992, 1994) have shown that increased tree density, fuel loading and crown fire occurrence are common consequences of fire exclusion throughout the ponderosa pine type (Kilgore 1981).

Various authors (e.g., Leopold 1924, Arnold 1950, Cooper 1960, Biswell 1972, Weaver 1974, Kilgore 1981, Covington and Moore 1994a, 1994b) have inferred that associated with these increases in tree density, forest floor depth and fuel loading in ponderosa pine ecosystems have been: 1) decreases in soil moisture and nutrient availability; 2) decreases in net productivity and diversity of herbaceous plants and shrubs; 3) decreases in tree vigor, especially in the oldest age class of pine; 4) decreases in animal productivity; 5) decreases in stream and spring flows, particularly dry-season or base stream flows; 6) increases in susceptibility to pine bark beetles; 7) increases in fire severity and size; and 8) large homogenous landscapes that, in the absence of frequent fires, will tend toward large-stand replacing fires in perpetuity. In sum, the implication is that today's tree densities and fuel loads in ponderosa pine ecosystems are not sustainable, and that virtually every aspect of the ecosystem, not just the trees, is either adversely affected or placed at greater risk as a result. However, with few exceptions, these inferences have not been supported by intensive ecosystem management-oriented research.

Public recognition of the severity of these ecological changes has led to considerable debate over implications of various management scenarios (including no action) on ecosystem health and sustainability (e.g., Kolb et al. 1994, Salwasser 1994, Mutch 1994). Furthermore, researchers, other natural resource professionals and the lay public are embroiled in an often rancorous debate over what, if anything, should be done. Concerns about overcutting of old-growth trees (or, for some factions, practically any commodity uses of forestlands) has led some environmental groups and some scientists to argue against any role for mechanical treatments in restoration of ecosystem health. However, others point to evidence that, without mechanical treatment to reduce unnatural fuel loads, the ensuing fires, even under controlled conditions, can kill old-growth trees and other vegetation, and cause such intense soil heating that restoration of natural conditions is retarded, if not precluded, for the foreseeable future (see review by Covington et al. 1994).

Conclusions

Natural fire regimes were particularly important in shaping the communities present at the time of Euro-American settlement. Exclusion of natural fires in the forests and woodlands of the West, coupled with global climatic fluctuations and changes in atmospheric chemistry, has led to tree population explosions, dead fuel accumulations and landscape-level fuel continuity to such an extent that the niches of some species of plants, animals and microbes have become threatened. In many cases, the natural functioning (e.g., successional processes, recycling processes) of these ecosystems has been severely impaired. Parallel declines in resource conditions for humans have occurred to a greater or lesser extent in all types.

As a result of increased tree densities in the ponderosa pine type, the increase in late successional species in the mixed conifer climax type and the increasing landscape homogeneity in all types, catastrophic disruption of these systems by either large crown fires or large insect and disease epidemics is certain. And the resulting homogenous landscapes will tend to be self-perpetuating unless something is done to restore more nearly natural conditions.

The ongoing crash of old-growth tree populations is almost as great a concern as is the irruption of postsettlement trees. Although logging and "sanitation" cutting probably remain principal causes of old-growth mortality in some ponderosa forestlands, insects, diseases, drought and crown fire now predominate as sources of mortality. Given the severe population crash of old-growth trees and their importance to both biodiversity and esthetics, it is essential that we reinvigorate and protect them by thinning competing postsettlement trees and removing other fuels from around their bases.

These changes, in concert with ongoing global changes in atmospheric carbon dioxide and climate, imply the need for extensive ecosystem restoration and management to prevent wide-scale collapse of existing ecological systems. Ironically, this is especially true for wilderness areas and nature reserves where unnatural tree densities often exceed that of surrounding wildlands.

While some might quibble over the exact magnitude of the changes, the general trajectory seems unequivocal. Continued climate changes, coupled with fire regime disruption, are likely to lead to increased tree seedling establishment (especially of shade-tolerant species), intensified competition among established trees, further deterioration of tree vigor, and increased tree mortality from insects, disease and drought. Thus, we should anticipate an acceleration of historical changes in the West, including increased fuel accumulations, lengthened fire seasons and intensified burning conditions, all contributing to larger and more catastrophic wildfires. The threats to natural ecosystem structures and processes, human lives, and resource values are great. Given current trends, the consequences of inaction far exceed those of well-reasoned and scientifically based ecosystem restoration (Sampson et al. 1994). Nonetheless, we must be cautious that increased publicity and alarm cries about ecosystem health not lead to ill-conceived and haphazard solutions, with the possible result that the "cure" may be worse than the "disease." There has been a lot of wishful thinking from different quarters that there might be some simple solution to ecosystem health problems, that thinning, prescribed fire, wildfire, bark beetles or tree diseases alone will restore natural conditions. Today's severe crown fires are a far cry from an ecosystem restoration process. In fact, any disturbance (e.g., logging, bark beetle attack, tree diseases) which kills old-growth trees sets the system on a long path to recovery, one that will take at least as long as the time it takes to regrow the dead old growth (perhaps 300 to 700 years for ponderosa pine ecosystems).

Although uncontrolled disturbances may restore portions of ecosystems under specific circumstances of site, ecosystem condition and disturbance environment, it is likely that the more general case is that these individual disturbances, in isolation, will run contrary to comprehensive restoration goals. It is far more likely that some combination of management actions and natural recovery processes will be necessary. Integrated ecosystem management is essential.

Given the diversity of human needs and goals for western wildlands, it seems unlikely that vast areas will be restored to natural conditions. In fact, keeping some areas in a some-what artificial state may be desirable. Areas dedicated to wood fiber production, livestock grazing or human settlements might fall into this category, with the caveat that it is generally safer to manage in harmony with natural tendencies. Such departures from managing within the natural range of variability should be made judiciously.

Fortunately, recent calls for applied systems approaches for dealing with undesirable environmental changes are beginning to be heeded by both resource interest groups and governmental organizations (e.g., USDA Forest Service's recent policy change toward ecosystem management and the U.S. Department of the Interior's shift toward ecosystem approaches to conservation of biological diversity).

According to Callicott (1994), Aldo Leopold suggested several lines of evidence for a potential synergy between innovative commodity resource uses and restoration and maintenance of ecosystem health: "Accordingly, Leopold set out to define conservation in the following terms: as 'a universal symbiosis with land, economic and aesthetic, public and private;' as 'a protest against destructive land use;' as an effort 'to preserve both utility and beauty;' as 'a positive exercise of skill and insight, not merely a negative exercise of abstinence and caution;' and, finally, as 'a state of harmony between men and land.'"

Systematic adaptive ecosystem management can provide a sound scientific basis for evaluating the consequences of various ecosystem restoration options and help us to define innovative mutualistic roles for humans in wildland ecosystems.

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Forest Health and Spotted Owls in the Eastern Cascades of Washington

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The "forest health" hypothesis has been applied to the east side of the Cascade Mountains in Washington and the sustainability of these forests currently is a major management consideration (Agee 1993, Everett et al. 1994, Oliver et al. 1994). The "forest health" hypothesis is based on the following generalizations. Presettlement landscapes of this region have been described as open, park-like stands dominated by ponderosa pine (*Pinus ponderosa*) with an understory of grasses and sedges (*Calamagrostis* spp., *Carex* spp.) (Plummer 1902, Weaver 1943, 1961). This condition was maintained by frequent, low-intensity fires started by lightning and aboriginal peoples, coupled with relatively infrequent insect outbreaks (Weaver 1943, Agee 1993, Hessburg et al. 1994). These forces interacted to create even-aged patches (stands) that aggregated into a ponderosa pine forest with a variety of stand ages (Weaver 1961).

Due to fire suppression, insect control, heavy livestock grazing and high-grade logging, these areas now are composed of relatively dense stands of Douglas-fir (*Psuedotsuga menzesii*), grand fir (*Abies grandis*) and ponderosa pine. These forests have been labeled "unhealthy" because of their low vigor and growth, and susceptibility to stand-replacement fire, disease and insect damage (Weaver 1943, Agee 1993, Oliver et al. 1994).

Spotted owls (*Strix occidentalis*) nest in these stands (Buchanan et al. 1995), and owl productivity has been higher here than in any other region of Washington (mean = 0.67 young fledged/female/year) (Thomas et al. 1993, Irwin and Fleming 1995). The contribution these spotted owl populations could make to recovering the species would be significant. However, the "forest health" hypothesis suggests that: 1) spotted owls were relatively rare or non-existent in the eastern Cascades prior to settlement by Caucasians, and 2) the current levels of spotted owl habitat, density and, perhaps, productivity are not sustainable. Nevertheless, the eastern Cascades is a diverse area comprising a number of provinces, ecoregions (Franklin and Dyrness 1973, Bailey 1980, Omernik 1995) and variable landscapes. This diversity suggests that the "forest health" hypothesis may not apply everywhere and may be scale dependent. Furthermore, if the "forest health" hypothesis characterizes landscape changes in general, variation in disturbance regimes at finer scales may have produced suitable habitat for spotted owls in the past (Oliver et al. 1994).

Two landscapes (Entiat and North Blewett) have been proposed as Special Emphasis Areas (SEAs) under federal and state programs for spotted owl recovery (U.S. Fish and Wildlife Service 1995, Washington Forest Practices Board 1995). Longview Fibre Company is the major private landowner in these landscapes (12,417 and 23,325 acres [5,029 and 9,446 ha] in the Entiat and Blewett, respectively), which currently contain about 25 spotted owl sites. Our properties generally exist in a classic checkerboard pattern intermingled with USDA Forest Service parcels.

The objectives of this study were to assess the applicability of the "forest health" hypothesis with information specific to the Entiat and Blewett landscapes. Information about presettlement and current forest conditions, the extent and spatial arrangement of presettlement fire refugia, and historical and current fire regimes were reviewed and analyzed in relation to the characteristics of spotted owls and their habitat in these areas.

Study Area and Methods

Both the Entiat and Blewett landscapes are in Chelan County, Washington, and are topographically mature with deeply incised water courses and steep slopes. Both areas drain into the Wenatchee River with the Entiat to the north and Blewett to the south. Leavenworth, Washington, elevation 1,128 feet (344 m), is located along the Wenatchee River between the two areas. Temperatures at Leavenworth average 23 degrees Fahrenheit (-5° C) in January and 69 degrees Fahrenheit (20° C) in July, and annual precipitation averages 23 inches (59 cm) with 10 inches (25 cm) of snow (Franklin and Dyrness 1973). Primary elevational gradients in both areas encompass the *Pinus ponderosa/Psuedotsuga menziesii/Abies grandis* zones of Franklin and Dyrness (1973), and the ponderosa pine and mixed-conifer/mixed-evergreen forests of Agee (1993). In general, elevation increases from west to east in the Entiat area and north to south and east to west in the Blewett.

Presettlement and Current Forests

Two sources of data were used to estimate presettlement forest conditions in the Entiat and Blewett areas. From this information, tree species composition, distribution and density were estimated and mapped.

The original land surveys for these areas were conducted in 1880 through 1910. At each section corner, bearing trees were established in each quadrant. For each bearing tree, species was recorded along with diameter at breast height (dbh) and distance (in links = 0.66 feet) from the section corner. This procedure is analogous to the point-quarter sampling method (Cottam and Curtis 1956) if the assumptions are that the closest tree in each quadrant was selected and that the location of section corners is random in relation to tree distribution. An estimate of tree density at each corner was calculated following Pollard (1971). Average tree dbh by species also was estimated.

Plummer (1902) conducted a forest inventory in the late 1890s in the central Cascades that included the Entiat and Blewett areas. He produced coarse-grained maps showing average timber volumes per acre, species composition and areas burned or logged. We used mean dbh estimates for each species from the land survey records and form class/dbh/volume relationships in Girard and Bruce (1976) to estimate tree density from the volume estimates made by Plummer. Data from the land surveys and Plummer (1902) were entered into a geographic information system (GIS) for comparison and refinement of a presettlement forest type map for each landscape. The extent of each forest type was estimated from that map.

Current forest conditions were taken from Longview Fibre Company's inventory database. Estimates of species composition, average dbh and tree density were made for each landscape.

Fire Regimes and Refugia

Agee (1993) summarized the information on presettlement fire regimes for the eastern Cascades of Washington by forest type. R. Schellhaas (personal communication: 1995) also has determined fire histories for six spotted owl nest sites in or near our study areas based on six to eight fire-scarred trees per site.

Post-settlement fire regimes were developed based on the occurrence of wildfires over the last 25 years. These data were obtained from USDA Forest Service records.

Presettlement fire refugia were patches of forest that escaped most or all wildfires, embedded within a forest matrix that burned more frequently (Camp et al. 1995). Camp (1995) developed a classification model, based on topography, that was used to identify potential fire refugia in the Entiat and Blewett landscapes. Her study area overlapped the southern half of the Blewett area. Camp (1995) reported that elevation ($\geq$ 4,025 ft [1,228 m]) and aspect (260-100 degrees) were sufficient to identify areas that had a 50-percent probability of being a late-successional fire refugium. Areas less than 4,025 feet with northerly aspect, combined with other topographic features (upper-middle headwall, bench, valley bottom), had a 20-percent probability of being a fire refugium. We used the GIS to map fire refugium based on elevation and aspect, then refined the maps by manually delineating areas containing the other topographic features listed above.

Spotted Owl Habitat Characteristics

Information was collected from 13 spotted owl sites in the Entiat area and 12 sites in the Blewett area. Data on site occupancy and productivity of spotted owls on the study areas have been collected since 1987. Suitable spotted owl habitat was mapped in each landscape based on several iterations of habitat definitions resulting from state and federal regulatory efforts (Hanson et al. 1993, Buchanan et al. 1994) and local expertise. We compared the current distribution of spotted owls and the extent, distribution and characteristics of spotted owl habitat with presettlement forest conditions. Means reported in the text are followed by standard errors in parentheses or brackets.

Results and Discussion

Presettlement and Current Forest Conditions

Data from the original land surveys and Plummer (1902) indicated that the presettlement forests of both areas were dominated (80-88 percent of each area) by relatively low-volume stands ($\leq$ 5,000 board feet/acre, Table 1). The primary tree species in both areas were ponderosa pine (53[4] percent) and Douglas-fir (27[13] percent) (tables 2 and 3). Plummer (1902) reported that western hemlock and western red cedar (*Thuga plicata*) (1 percent) were the next most abundant tree species, while the land survey records indicated that western larch (*Larix occidentalis*) and Engelman spruce (*Picea engelmanii*) were more abundant. In addition, the survey data indicated a greater overall abundance of Douglas-fir than that reported by Plummer. However, both data sets were consistent in that the stands in the Entiat landscape had a smaller proportion of Douglas-fir than in the Blewett area, and that species richness was greater in the Entiat area (tables 2 and 3).

Estimates of species composition based on the land survey data were confounded by the use of common names and variation among survey parties in taxonomic skills (White no date). We assumed that "pine" referred primarily to ponderosa pine and "fir" to Douglas-fir. The largest discrepancy between Plummer's data and the land survey data was in the proportion of Douglas-fir in each landscape, and survey parties may have lumped grand fir and Douglas-fir more frequently than they did the pines.

Estimates of tree species diameters from the land survey records should be highly reliable, but may suffer from the same problems in species identification. Average dbh was 23.8(1.7)

Table 1. Acres of the Blewett and Entiat landscapes in merchantable timber volume categories, logged or burned (following Plummer 1902).

	Blewett	Entiat
Category	Acres (percentage)	Acres (percentage)
Burned	5,216 (5)	7,025 (5)
Logged/non-forest	14,872 (13)	1,625 (1)
0 to 2,000 board feet per acre	48,436 (44)	57,939 (43)
2,001 to 5,000 board feet per acre	40,416 (37)	62,246 (45)
5,001 to 10,000 board feet per acre	607 (1)	4,843 (4)
10,001 to 25,000 board feet per acre	0 (0)	2,431 (2)

Table 2. Mean (SE) density, percentage composition and board feet per acre for five conifer species in the Blewett and Entiat landscapes (derived from Plummer 1902).

	Blewett			Entiiat		
Species	Trees per acre	Percentage	Board feet per acre	Trees per acre	Percentage	Board feet per acre
Pinus ponderosa	10 (4)	48	1,292 (339)	6 (2)	63	5,389 (999)
Psuedotsuga menziesii	9 (2)	15	1,031 (197)	5 (2)	12	1,330 (257)
Thuga plicata	<1	<1	109 (40)	<1	1	222 (72)
Tsuga heterophylla	0	0	0	<1	<1	159 (52)
Picea engelmannii	<1	<1	76 (34)	<1	<1	89 (50)

Table 3. Mean (SE) density, diameter at breast height and percentage composition of trees in the Blewett and Entiat landscapes, estimated from the original land-survey records.

	Blewett			Entiat		
Species	Trees per acre	Diameter at breast height	Percentage	Trees per acre	Diameter at breast height	Percentage
Pinus ponderosa	6 (0.1)	22 (1)	45	19 (1)	26 (1)	52
Psuedotsuga menziesii	12 (1)	18 (1)	42	26 (2)	20 (1)	38
Larix occidentalis	14 (0.4)	23 (2)	6	45 (4)	14 (3)	1
Picea engelmannii	18 (1)	20 (2)	5	28 (1)	19 (2)	3
Abies grandis	8 (3)	21 (2)	1	5 (3)	28 (11)	<1
Tsuga heterophyla	6 (3)	25 (1)	<1	9 (7)	16 (3)	1
Pinus contorta	3 (1)	24	<1	4 (2)	10 (1)	<1
Pinus monticola	2 (2)	34 (1)	<1	6 (8)	11 (2)	<1
Thuga plicata				8 (6)	12 (4)	<1
Populus trichocarpa				4 (1)	17 (6)	1
Acer macrophyllum	15 (2)	11 (6)	<1	61 (13)	8 (1)	<1
Salix spp.	62 (45)	5	<1	26 (5)	6 (1)	<1
Cornus spp.				8 (2)	7 (1)	<1

inches (60.4[4.3] cm) for ponderosa pine and 19.1(1.0) inches (48.5[2.5] cm) for Douglas-fir. Most other conifer species fell within this range (Table 3).

Estimates of coniferous tree density based on the land survey information averaged 18 (9) per acre (7[4]/ha) and 9(6) per acre (4[2]/ha) for the Entiat and Blewett areas, respectively. Density estimates by species for each area ranged from 2 per acre (0.8/ha) to 45 per acre (18/ha) (Table 3).

Estimates of tree density based on Plummer's volume estimates and form class/dbh/volume relationships averaged 8 per acre (3/ha) for Ponderosa pine, 7 per acre (3/ha) for Douglas-fir and 1 per acre (0.4/ha) for all others combined (Table 2).

Plummer's (1902) inventory was focused on merchantable timber, and trees with defects or below 10 inches (25 cm) dbh would not have been considered in his volume estimates. In addition, he presented data for only the most valuable and common species. Tree density estimates based on Plummer's data likely are low, but his data indicated that 87 and 50 percent of the Entiat and Blewett areas, respectively, were made up of stands where the featured species composed at least 75 percent of a stand.

A potential source of bias associated with the survey data would be the synchronization of a repeating feature of the landscape in the section corner grid, e.g., if all north aspects were 1 mile apart. There is no indication that this occurred for any feature. Another bias would occur if trees other than the closest in each quadrant were used as bearing trees. This would result in lower density estimates and may be applicable to the data for ponderosa pine if those trees were avoided for marking as bearing trees because of their thicker bark relative to Douglas-fir and grand fir.

These potential biases indicate that these data should not be viewed as accurate estimates of tree density and species composition. However, they do establish a range that likely encompasses average conditions and perhaps 80 to 90 percent of the variation in the forests of those landscapes.

Even if our presettlement species composition and density estimates were biased, they still are much different than generalized current conditions for the eastern Cascades (Agee 1993, Hessburg et al. 1994). Currently, average conifer density on our properties is 89(4) per acre (36[2]/ha) and 101(4) per acre (41[2]/ha) in the Entiat and Blewett areas, 11- and 5-fold increases, respectively (Table 4). In addition, species composition estimates have changed from a dominance of ponderosa pine and Douglas-fir to dominance of Douglas-fir, ponderosa pine and grand fir.

Table 4. Mean (SE) density, diameter at breast height and percentage composition of conifer species for Longview Fibre Company properties in the Blewett and Entiat landscapes.

	Blewett			Entiat		
Species	Trees per acre	Diameter at breast height	Percentage	Trees per acre	Diameter at breast height	Percentage
Pinus ponderosa	23 (2)	16 (0.2)	23	21 (2)	16 (0.4)	24
Psuedotsuga menziesii	44 (1)	14 (1)	48	41 (2)	14 (0.2)	47
Larix occidentalis	5 (1)	10 (0.4)	5	2 (1)	10 (1)	2
Abies grandis	15 (2)	11 (0.2)	15	16 (2)	11 (0.2)	18
Tsuga heterophyla	1 (0.1)	10 (0.1)	1	<1	10 (0.1)	<1
Pinus contorta	6 (1)	9 (0.3)	6	6 (2)	9 (1)	6
Thuga plicata	7 (1)	2 (0.4)	7	3 (1)	5 (2)	3

Fire Regimes and Refugia

Generalized descriptions of the presettlement fire regime for the forests of the eastern Cascades indicated that frequent, low-intensity burns were the norm (Agee 1993). The primary ignition sources were indigenous people and lightning strikes. However, there was substantial variation associated with that general trend. Estimates of fire-free intervals for ponderosa pine forests ranged from 3 to 36 years, for Douglas-fir forests from 8 to 18 years and for the grand fir series from 33 to 100 years. Agee (1993) cited two studies in the Douglas-fir zone that occurred in or near our study areas. Fire-free intervals in the Wenatchee Valley ranged from 7 to 11 years and in the lower Entiat Valley from 8 to 18 years.

The data collected by R. Schellhaas (personal communication: 1995) for six spotted owl nest sites in the grand fir zone in the Entiat and Blewett landscapes is consistent with the above information. Fire-free intervals at these sites averaged 14(1) years and ranged from 4 to 30 years between 1750 and 1900.

High-intensity, stand-replacement fires also occurred in these areas prior to settlement (Agee 1993), but little information is available on their frequency or extent. Plummer (1902) mapped areas in which stand-replacement type fires recently had occurred. Five percent of both the Entiat and Blewett areas (7,025 acres [2,845 ha] and 5,216 acres [2,112 ha], respectively) had burned at that time. Burn size was highly variable with 3 areas in the Entiat averaging 2,342 (1,074) acres (948 [435] ha) and 10 areas in the Blewett averaging 522 (225) acres (211 [91] ha).

Camp's (1995) model estimated that about 10 percent of the Entiat area and 15 percent of the Blewett area had a 50-percent probability of supporting a high-elevation (≥ 4,025 feet [1,228 m]), late-successional fire refugium. However, refinement of those areas indicated that only 3 and 4 percent of the Entiat and Blewett areas, respectively, had a greater probability of containing late-successional fire refugia habitat. Nine and 12 percent of the Entiat and Blewett areas, respectively, had a 20-percent likelihood of containing low-elevation (< 4,025 feet [1,228 m]) fire refugia. Fire refugium occurred in discrete patches averaging 48, 90 and 37 acres (19, 36 and 15 ha) for the 20-percent low-elevation, 50-percent high-elevation and greater than 50-percent high-elevation categories, respectively. There were 542, 496 and 226 patches in these categories, respectively, in both landscapes. Most of the low-elevation fire refugia were narrow, linear patches in valley bottoms.

Since the early 1900s, fire-suppression policies have altered the fire regime of these areas. In general, fires were quickly contained and of small extent. However, since the 1970s, following years of fuel accumulation and the beginning of a regional drought period, fires that were not quickly extinguished became high-intensity, large-extent, stand-replacement events.

From 1970 to 1995, 248 fires were recorded in the Entiat area and 134 in the Blewett, averaging eight (2) and five (1) fires per year, respectively. Acres burned per year averaged 1,675 (1,434) (678[581] ha) in the Entiat area and 516(276) (209[112] ha) in the Blewett area, and the mean acres burned per fire per year was 460(367) (186[149] ha) and 123(63) (50[25] ha), respectively.

Significant fire events (> 100 acres burned/year) occurred at 3.7- and 4.8-year intervals in the Entiat and Blewett areas, respectively. Large fires occurred in the Entiat area in the 1970s and 1980s, with the latest occurring in 1994. Three different fires in 1994 burned more than 32,175 acres (14,479 ha), or 24 percent, of the Entiat study area, primarily in the northeast quarter. Large fires occurred in 1976 and 1985 in the Blewett area and in 1994, when 16,825 acres (6,814 ha) or 15 percent of the total area were burned. The 1994 fires were high-intensity, stand-replacement events and burned five spotted owl sites; two in the Entiat and three in the Blewett area.

The post-settlement fire regime of these areas appears to have two components: fires that are quickly suppressed and of small extent, or fires that escape containment and quickly become high-intensity, large-extent events.

Spotted Owl Habitat

Suitable spotted owl habitat currently occurs in discrete patches averaging 69(12) and 40(5) acres (28[5] and 16[2] ha) in the Entiat and Blewett areas, respectively. About 20 to 30 percent of each landscape currently is classified as spotted owl habitat. Sixty-six percent of owl habitat in the Entiat area and 82 percent in the Blewett area occurs on northeast aspects.

Buchanan et al. (1995: Table 4) reported that 62 spotted owl nest sites and associated random sites on the Wenatchee National Forest of the eastern Cascades were composed primarily of grand fir (41 percent), Douglas-fir (40 percent) and western hemlock (17 percent). Total tree densities averaged 170(9) per acre (419 [23]/ha) between nest and random sites, with the majority of trees in the 4- to 12-inch (10-34 cm) dbh class. They also noted that 89 percent of the nest sites examined showed evidence of past fire, but did not give more details.

No known owl sites occurred in the high-elevation fire refugia, and only one site in each of the Entiat and Blewett areas occurred in the low-elevation refugia. About 8 percent of the mapped spotted owl habitat overlapped with low-elevation refugia, 7 percent with the 50-percent high-elevation refugia and 2 percent with the greater than 50-percent high-elevation refugia.

In presettlement forests, fire refugia were likely to develop suitable spotted owl habitat at some point (Oliver et al. 1994, Camp 1995). It would be logical to expect a close relationship between spotted owl site occupancy and the distribution or amount of fire refugia, but this was not the case. There are two hypotheses that may explain this result: 1) forest succession in fire refugia may have advanced to the point that the habitat no longer is optimum; or 2) high-elevation fire refugia never provided high-quality spotted owl habitat. A number of studies have concluded that forests above 3,500 to 5,500 feet (1,050-1,650 m) are low-quality habitat for spotted owls (Hanson et al. 1993). Lower elevation sites will have a lower probability (20 percent) (Camp 1995) of supporting fire refugia type forest, but refugia stands at these elevations are higher-quality habitat.

Conclusions

This study confirms the applicability of the regional "forest health" hypothesis to both the Entiat and Blewett spotted owl SEAs. In general, presettlement forests of these areas were dominated by stands of ponderosa pine and Douglas-fir. These trees were of large diameter and stands ranged from 2 to 45 trees per acre. Frequent, low-intensity fires sustained these conditions over a majority of these landscapes. However, 3 to 15 percent of these landscapes also was potential fire refugia, where development of late-successional forests was possible. The composition and structure of these refugia forests probably were similar to the forests that now dominate the area (Oliver et al. 1994, Camp 1995). Stands in fire refugia probably were suitable spotted owl habitat, but whether owls were present in these landscapes in presettlement times is unknown. Spotted owls occasionally make long-distance movements (Thomas et al. 1990) and it is likely that some individuals were present in the eastern Cascades, particularly toward the crest in lower elevation passes. The small extent and fragmented distribution of fire refugia in the Blewett and Entiat landscapes raises questions about owl survival rates and productivity, in relation to the current paradigms of spotted owl habitat requirements and habitat quality (Bart and Forsman 1990). However, the current size and distribution of suitable owl habitat in these landscapes also are inconsistent with these generalizations.

Our data suggests the following working hypothesis for the Blewett and Entiat landscapes. Suitable spotted owl habitat always existed, but was confined to fire refugia (Oliver et al. 1994, Camp 1995) prior to settlement, which occurred on approximately 11 percent of each landscape at any point in time. This is approximately 40 percent of current habitat levels and could have supported a maximum of 10 spotted owl sites. Forest management over the last 70 to 90 years resulted in a tripling of suitable habitat in these areas, which now are fully occupied, or nearly so, by spotted owls. However, much of this habitat and the resident spotted owls are at risk, as demonstrated by the 1994 fires.

These fires alone burned an area equivalent to 95 percent of the mapped spotted owl habitat in the Entiat area and 90 percent in the Blewett area. The patchy distribution of owl habitat and fire suppression efforts likely will assure that not all spotted owl habitat will be lost in a single event. Nevertheless, the data indicate that this amount and distribution of habitat is not sustainable, but predicting the rate, extent and type of habitat conversion process is fraught with uncertainty.

Under current conditions, areas identified as fire refugia also are at risk. In the past, the probability that these areas would burn was a function of the characteristics of fires that occurred in the surrounding forests. The low-intensity fires of the presettlement landscapes were not hot enough to carry the fire into these areas. However, fire refugia occasionally did burn during extreme fire conditions (Oliver et al. 1994). Currently, fires that are not immediately extinguished quickly become extreme events and are likely to carry into areas of fire refugia, as was the case in the 1994 fires.

The forest health/spotted owl predicament in the eastern Cascades creates difficult policy choices. Options include doing nothing, attempting to maintain the status quo or restoration of some semblance of presettlement forest conditions (MacCracken 1996). Clawson (1975) emphasized that the primary test of any natural resource policy was its biological feasibility. Policies that advocate a hands-off approach or attempt to maintain current conditions put spotted owls, as well as a variety of other resources and amenities, at the greatest risk. Spotted owl habitat can be maintained at high-elevation fire refugia sites with a relatively high probability of persistence. However, spotted owl occupancy rates and productivity likely will be low in these areas. Lower-elevation fire refugia had only a 20-percent probability of persistence under presettlement conditions, but owl occupancy and productivity will be much higher. These low-elevation areas should be the focus of management plans for owls in these landscapes, recognizing that forest structure alone is not driving spotted owl occupancy or productivity patterns in these areas (Irwin and Fleming 1995). Spotted owls are probably at the least risk from carefully designed and implemented habitat management that focuses on reducing the risk of high-intensity, stand-replacement fires occurring within and surrounding these sites, while maintaining forest characteristics preferred by owls and their prey (e.g., see Oliver et al. 1994).

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Special Session 8. Commissions, Compacts and Councils: Strengthening State-based Institutions

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North American Waterfowl Management Program: State Action to Protect Migratory Resources

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It is likely that greater responsibility for a variety of environmental and resource programs will, of necessity, devolve to the states over the next decade as Congress and the Administration seek a balanced budget. During the past decade, states, provinces and the private sector assumed a strengthened role in waterfowl habitat programs through implementation of the North American Waterfowl Management Plan. This paper will familiarize you with the financial situation at that time (1986), the actions taken and results achieved, and suggest other applications.

In May 1986, the Canadian Minister of Environment and the U.S. Secretary of the Interior signed the North American Waterfowl Management Plan. The Plan had been developed with heavy state and provincial involvement. It presented what wildlife managers in both Canada and the United States believed to be appropriate waterfowl population goals and recommended actions necessary to achieve those goals. The Plan established acreage targets for priority habitat areas in the United States and Canada over a 15-year period from 1986 to 2000 and estimated that $1.5 billion would be required to accomplish objectives.

The following is a quote from the last paragraph of the signature page: "The total cost of achieving the goals stated here is clearly too great to be borne by the national governments of the two signatory countries. It must be understood that this plan is not a commitment by either signatory government to expend funds beyond its borders or to bear the total cost or responsibility for its execution; rather, it is a challenge to all those who enjoy and benefit from waterfowl to contribute their share toward its attainment."

The body of the Plan pointed out that the costs of achieving the Plan greatly exceeded the levels currently budgeted by the governments of both countries for waterfowl management. "Major governmental budget increases for waterfowl management, especially in the United States, should not be anticipated in the near future, given competing demands and projected budget levels. Therefore, the primary source of increased funding for this plan must be private organizations and individuals."

The Plan recommended establishing joint ventures as a means for governments and private organizations to cooperate in the planning, funding and implementation of projects to preserve or enhance waterfowl habitat, and looked to states, provinces and conservation organizations for participation and leadership.

Elsewhere in the Plan was a recommendation that 75 percent of the $1 billion needed for work in Prairie Canada be raised by U.S. interests. This was not to be construed as a commitment by the government of the United States to finance activities in Canada, but recognition of the interests of U.S. citizens in wetland conservation in Canada. It also pointed out that specific authorization and appropriation of funds by the respective legislative bodies would be required before the two governments could participate in a joint venture.

That was the stage, as it was set in 1986 by the U.S. and Canadian governments, representing many conservation organizations and agencies, for delivery of the North American Waterfowl Management Plan. There were sound quantified goals, an estimated price tag and a time line of 15 years which both governments agreed to, but without binding financial commitment. What next?

The U.S. Fish and Wildlife Service established a scoping committee to address implementation. States, Ducks Unlimited, the Wildlife Management Institute and other conservation organizations were represented. This committee recommended that the International Association of Fish and Wildlife Agencies (IAFWA) establish an Implementation Committee to involve the states and provinces. That Committee was established and continues to promote implementation of the Plan.

The IAFWA worked with the Scoping Committee and the U. S. Fish and Wildlife Service, National Fish and Wildlife Foundation, and other key partners. An innovative plan evolved to raise $1 million state dollars, match that with $1 million from Ducks Unlimited, match that with $2 million from the National Fish and Wildlife Foundation and match that with $4 million from Canada. Given prevailing exchange rates, this equated to approximately $10 million Canadian to begin work.

There were several major problems with this unusual idea. Problem number one: What laws governed the movement of money to Canada for Plan work? To find out, New York State provided $100,000 and the Executive Committee of the IAFWA directed the Implementation Committee to move the money to Canada and work out whatever problems occurred in that process along the way.

Problems number two and three: The National Fish and Wildlife Foundation did not have clear authority to fund projects in Canada and there was a cap which prevented the Foundation from spending more than $1 million. The cap would have to be raised and the law would have to be changed to allow the Foundation to fund Canadian projects.

Problem number four: The Foundation did not have money for the match. Federal money would have to be found.

A less significant problem was that state money was being solicited after states' budgets were in place—not at the beginning of normal budget cycles. Federal money needed to be appropriated for work that Congress had not yet authorized by a Foundation with a cap in place and laws which might make it illegal for the Foundation to spend the money if appropriated.

While people in the U.S. dealt with these problems, the provinces were figuring out how to provide a $4 million (U.S.) match for the $4 million (U.S.) dollars they would receive. And the provinces needed to develop project proposals to spend $10 million (Canadian) they might never see.

I mention these things to point out that the government climate for funding the Plan was not good; the idea for launching the Plan was unique and the obstacles which had to be overcome were significant.

What happened? The states found $1 million in the middle of their budget cycle; Ducks Unlimited matched that $1 million making it $2 million. The National Fish and Wildlife Foundation was authorized to fund Canadian projects; the cap was raised and the Foundation received a foreign appropriation of $2 million, giving them $4 million (U.S.) total for Canadian projects. Canada matched this with $4 million (U.S.). Projects were developed to spend the imaginary money received, about $10 million (Canadian), and work began—all within two years of the ink drying on the Plan document!

The International Association of Fish and Wildlife Agencies continued working with key people in Washington, D.C. to increase political awareness of Plan activities and, in 1989, Senator Mitchell came forward with the North American Wetlands Conservation Act that emphasized funding for Plan projects. At the same time, Plan partners encouraged all federal agencies to seek funding for projects and programs within their purview which would advance goals of the North American Waterfowl Management Plan. In simple terms, those who cared about waterfowl "scrounged" money wherever they could find it, and discovered many commonalities with agencies and nongovernmental organizations.

Since the Plan was signed in 1986, about $1 billion has been spent. In Canada, more than 1 million acres have been secured and more than a half million acres enhanced. In the United States, more than 1 million acres have been protected, 420,000 acres restored and more than 1.5 million acres enhanced. Waterfowl populations rebounded, partially because of the Plan, partly because precipitation improved water conditions in the prairies and partially because of complementary programs, such as the Conservation Reserve Program and Wetland Reserve Program.

A critical analysis of Plan programs would show significant habitat accomplishments in some lower priority areas and slower progress in some higher priority areas, particularly in the Prairies. It is not that habitat conservation in the Prairies has been dragging as much as habitat work in some other areas has ignited. For example, conservation work along the coastlines of the U.S. is fueled by higher population densities, numerous conservation groups and dedicated funding sources. Moving state money to Canada has been well below the IAFWA goal of $10 million per year, with 37 of the 50 states sending $20.3 million through the North American Wetlands Conservation Act since 1990. Accelerated work in the United States, in some cases, utilized federal funds which might otherwise have been used in Canada. However, most U.S. work used funding that either was technically or politically not transferable. U.S. funding for the Canadian Prairies has been less than needed to fund 75 percent of the work there. Taking the fiscal condition of states, provinces and federal governments into account, understanding political realities, and respecting priorities and constraints of Plan partners, Plan implementation is a huge success. Results certainly exceeded all expectations. In 1986, none of the key players involved in implementation expected that $1 billion would be spent, or that several million acres would have been conserved by 1996.

That brings us to the present. President Clinton indicates that the days of big government are over. Republicans in Congress are seeking to balance the budget in seven years. The Canadian government has taken drastic cuts to balance their budget. Some provinces have cut expenditures by almost 50 percent and some states are having trouble making ends meet. Sustaining adequate funding for wildlife programs in this climate will not be easy.

Can lessons learned in the North American Waterfowl Management Plan implementation process be applied in today's world of scarce funding? Yes! It is logical that wildlife programs packaged best will sell best. Wildlife programs composed of parts which advance other important programs have increased appeal and additional support. Programs which leverage federal dollars with nonfederal dollars should compete better than those which do not. Programs supported by federal and state governments, and the private sector should fare better than programs without broad base support. Programs crafted by groups of recognized experts should withstand criticism better than those developed by individuals. Programs that address international, national and regional needs logically would be funded ahead of those which do not. Programs having strong economic justification should be addressed ahead of those which do not. Such logic may not always prevail in the political world, but ability to compete for scarce funds clearly is enhanced where projects possess the criteria mentioned.

Federal, state and private interests joined together to address the needs of neotropical birds through Partners In Flight in 1990. The group is following in the footsteps of the North American Waterfowl Management Plan in their development of a North American Plan for neotropical birds. A large body of experts eventually will reach consensus on the habitat needs of neotropical birds across our nation, and eventually in Canada, Mexico, South and Central America. Already, those experts are folding songbird habitat work into the Lower Mississippi Valley waterfowl joint venture. A common goal for songbirds and waterfowl is the reforestation of thousands of acres of bottomland hardwood. Thus, an important component of one plan is also part of another, creating additional support for action. Bottomland hardwood reforestation also benefits game species leading toward partnerships with the National Wild Turkey Federation, Audubon and Ducks Unlimited to leverage state and federal dollars. These types of activities are occurring now. In fact, shorebird experts are proposing a course of action similar to that taken by Partners In Flight.

Efforts are underway to bring fish into the equation in the Lower Mississippi Valley through the Mississippi Interstate Cooperative Research Association (MICRA). It is likely that flooded bottomland hardwoods serve as rich nursery areas for fish from the Mississippi River. It is no secret that ducks also thrive in flooded bottomland hardwoods along the Mississippi River. These are the same forests that songbirds, turkey, deer and squirrel frequent, providing additional opportunity for support and funding.

Fish habitat restoration work progresses into flood plain restoration, and possibly into the budget of the U.S. Army Corps of Engineers. The role for the U.S. Department of Agriculture, with their Wetland Reserve, Conservation Reserve and Forest Stewardship programs of the Forest Service, also is critically important.

Over time, strengthened migratory bird partnerships will facilitate the eventual development of an International Migratory Bird Management Plan. Partnerships developed through that plan, MICRA and others will evolve into biodiversity initiatives, watershed management programs and, ultimately, impact ecosystem management. This evolution opens new doors for funding, partnerships and leveraging, and should lead to support from those interested in clean water, protection of riparian zones and wetland functions, and should strengthen ties with the Environmental Protection Agency and others. But that is down the road.

How will state fish and wildlife agencies deal with these developments? Emphasis in the Tennessee Wildlife Resources Agency (TWRA) has been on game species. TWRA has a deer biologist, small game biologist, turkey biologist, waterfowl biologist, etc. State wildlife agencies employed experts to work with a few species. For example, TWRA has done their own thing with their own people in their own state, almost game species by game species. In the future, state wildlife agencies will be attempting to manipulate habitat in large watersheds within huge ecosystems and, hopefully, influence habitat protection even in other countries to meet the minimum needs of all wildlife, including mammals, birds, reptiles, amphibians, fish and mussels. Much work will occur on land we don't own, in water we don't control, and it will be dictated by blueprints developed through processes like the North American Waterfowl Management Plan.

TWRA presently is working with adjacent states to determine land ownership, present and anticipated land use, land cover, species occurrence, and distribution in physiographic regions that stretch beyond our state border. There are about 1,200 nongame species that TWRA must look after that live in those physiographic regions. TWRA cannot afford to hire an expert for each species or even each species assemblage. Instead, they must utilize experts outside their agency to provide program direction. TWRA is doing this through technical partnerships involving the best experts within a several-states area without regard for whom these experts work for, as was done with the North American Waterfowl Management Plan. Research partnerships are needed to monitor population responses to habitat work within ecosystems and to provide management with essential information, again, as is occurring with waterfowl. These partnerships include university people, the private sector, federal employees, etc. The only real problem states have moving down this path is money.

States must continue working through the IAFWA to protect priority federal programs from critical budget cuts throughout the federal budget process—something states have done for years. States also must press, through the IAFWA, for passage of the Teaming With Wildlife funding initiative to secure $350 million in new, dependable money annually for non-game programs. That user-pay/user-benefit program, having no impact on the federal deficit, is critical to state involvement in a broad spectrum of fish and wildlife programs of regional and national significance.

Increased funding for the North American Wetlands Conservation Act and the National Fish and Wildlife Foundation also is essential to facilitate expanded partnerships and for leveraging.

Given funding in these critical areas, many of the lessons learned in the North American Waterfowl Management Plan process will be applied to move us into the next century at an accelerated pace in an otherwise austere budget situation. It won't be easy, but in 2006, we will look back and be amazed by our progress, just as we were with the North American Waterfowl Management Plan.

MICRA—From Dream to Reality

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The Mississippi Interstate Cooperative Resource Agreement (Agreement) and its vision to develop cooperative programs for interjurisdictional river fisheries in the Mississippi River Basin are becoming reality. The Agreement, spawned on September 1, 1989 by several state fishery chiefs, resulted from a shared concern for the welfare of the ancient paddlefish and how interstate management of this important species could be coordinated and implemented better.

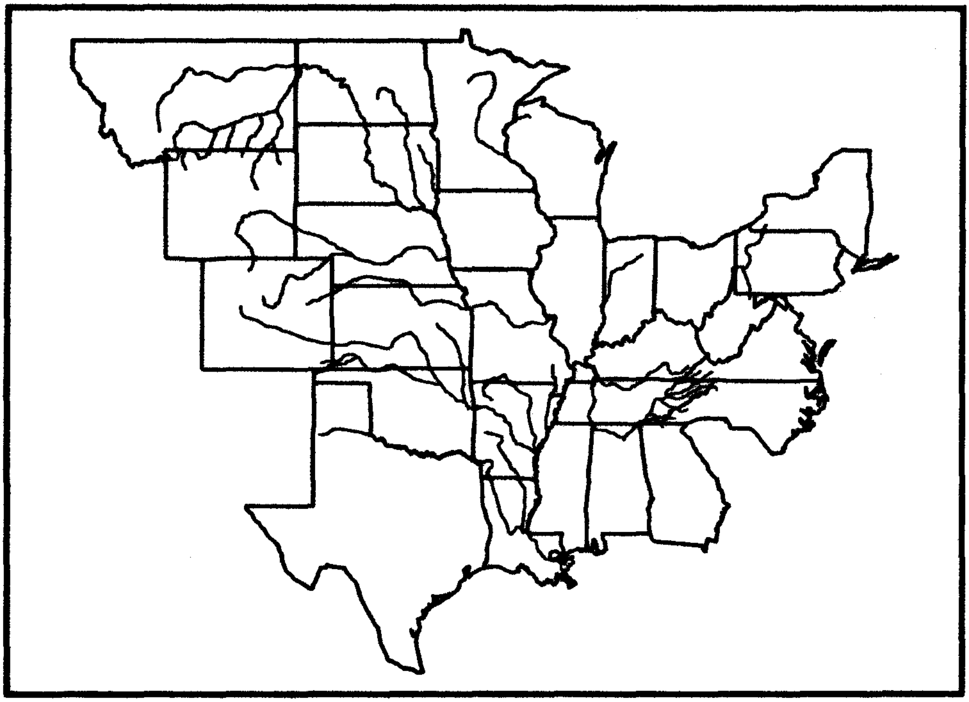

Figure 1. Some of the interjurisdictional rivers of the Mississippi Basin.

During 1989 and 1990, 28 of the Basin's state fish and wildlife agency directors signed on to the Agreement. The states invited the U.S. Fish and Wildlife Service to sign on in January 1991, and requested that they begin supplying office space and funding for a MICRA Coordinator. That position was established and has been maintained by the U.S. Fish and Wildlife Service since March 1991.

By August 1991, through assistance of the American Fisheries Society and a federal grant using "Sport Fisheries Restoration Funds," the states had developed and adopted a Comprehensive Strategic Plan (Rasmussen 1991). That Plan included 10 major goals and identified 93 rivers and streams and 98 fish species as coming under the umbrella of interjurisdictional management. By the following spring, tasks within that Plan had been prioritized.

The states began inviting other federal agencies, commissions, interstate groups, power companies and Indian tribes to sign on in October 1991. To date, the Tennessee Valley Authority, U.S. Bureau of Reclamation, U.S. Geological Survey/National Biological Service and two Indian tribes (Chickasaw Nation in Oklahoma and Chippewa-Cree Tribe in Montana) all have signed on in support.

The organization, the Mississippi Interstate Cooperative Resource Association (MICRA), is composed of one representative from each member state and entity, each having an equal vote in the MICRA decision-making process. Members are required to be senior agency or entity officials, with decision-making authority and a strong interest in river management. The Association establishes subcommittees, as needed, to conduct its technical business. Subcommittee members are appointed from the Association's member agencies and entities having an interest in subcommittee activities. MICRA currently maintains a Paddlefish/Sturgeon Subcommittee (formed in 1992) and an Exotic Species Subcommittee (formed in 1994).

Since 1992, MICRA has published a bimonthly newsletter, "River Crossings," as its primary information exchange and communication mechanism. MICRA also has adopted a formal Constitution and Bylaws to guide future implementation and decision-making processes. A voluntary dues structure was established in 1994 with states paying $1,500 per year and federal agencies paying $5,000 per year. To date, all member federal agencies and 22 member states are full dues payers.

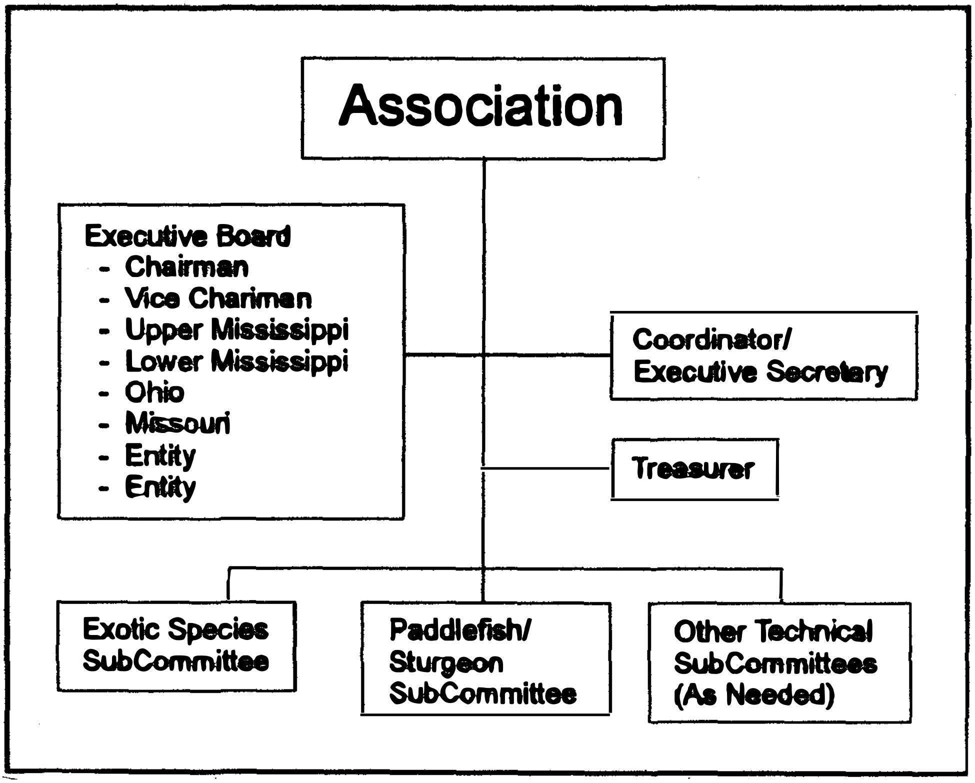

Figure 2. MICRA organizational chart.

In addition to collection of dues, MICRA also has been actively pursuing various outside funding sources, including special legislation. In that regard, Congressman Steve Gunderson (R/WI) has recommended a Congressionally authorized evaluation of MICRA in his "Mississippi Interstate Cooperative Resource Agreement Act of 1996" (H.R. 2939), introduced on February 1, 1996. Congressmen Doug Bereuter (R/NE) and Jim Leach (R/IA) signed on early in support of that bill. Gunderson, a leader in Upper Mississippi River planning and management issues, sees MICRA as a potential model for the development of long-range strategic plans for the basinwide management of interjurisdictional rivers' fishery resources.

Interjurisdictional rivers are defined as those rivers that flow between or are common to two or more state boundaries, or that flow between two or more land-management jurisdictions. Interjurisdictional species are defined as those fish that depend on interjurisdictional rivers during some part of their life cycle and, therefore, come under the management of two or more governmental entities. Interjurisdictional species are not necessarily migratory, but can move either short or long distances between political jurisdictions in the completion of their life cycles. Even species as common as bass and bluegill, in the right setting, can come under the umbrella of interjurisdictional management.

Major Accomplishments

In 1994, MICRA played major roles in the response to 1993 flooding in the Midwest. MICRA's Coordinator/Executive Secretary was assigned to serve on the White House Floodplain Management Review Committee, many MICRA members served on the various floodplain management technical committees in the field, and MICRA used its newsletter as an important mechanism for information transfer regarding flooding and floodplain management issues.

MICRA's Paddlefish/Sturgeon Subcommittee presently is focussing on the needs of paddlefish and sturgeon through development of two projects. The first, funded through a National Fish and Wildlife Foundation Challenge Grant, will complete a basinwide survey of all existing information on paddlefish and all sturgeon species and their management throughout North America.

The second project is implementing a multi-year, basinwide paddlefish stock assessment. Information also is being collected on paddlefish movement, exploitation, age and growth, and reproduction. Internal coded wire tags are being used to mark captured and hatchery-reared paddlefish. The project, endorsed by the International Association of Fish and Wildlife Agencies in September 1994, was funded in 1995 through year-end Federal Aid administrative funds. Twenty-two of MICRA's 28 member states are involved in the tagging survey. Each participating state is collecting paddlefish through field surveys and/or work with commercial fishermen. As many adult fish as possible are being tagged, and all state, federal and private hatcheries are being encouraged to use MICRA tags to mark paddlefish (slated for release within the Basin). At the end of 1995, we had tagged and released more than 2,000 wild fish and more than 200,000 hatchery fish in the Basin's rivers.

Data for the survey is being provided through field recaptures, as well as through tag returns from sport and commercial fisherman. Since fishermen are unable to identify tagged fish, return of the entire rostrum from both tagged and untagged fish is required. Recovery of tagged and untagged fish will increase the statistical power of data recovered and give MICRA the ability to complete an unbiased, basinwide assessment of paddlefish populations. A reward system is being used to enhance fishermen participation and tag recovery, with numerous private vendors contributing prizes. The project data base is being developed under contract with Tennessee Technological University. Our goal is to have the data available for public use through our own Homepage on the Internet.

This project is precedent setting in that nothing of this magnitude ever has been attempted on an inland, freshwater fishery. When completed, MICRA feels its results will rival that of major salmon and striped bass tagging projects on the coasts. After a number of years, very accurate estimates of the impact of harvest and stocking on native paddlefish populations should be possible.

In 1995, MICRA began participating in several other smaller, multi-year projects through funding provided by grants from the U.S. Fish and Wildlife Service's Endangered Species and Ecological Services programs. MICRA's facilitation mechanism provides a convenient bridge between its members to reduce overhead costs and fund projects that otherwise may be difficult to complete.

Lingering Concerns

In a relatively short period of time, MICRA has developed a strong organizational structure, effective planning documents and communication mechanisms, and begun implementing field projects. However, despite our progress, we are not without a few lingering problems and growing pains. Most important among these, from my perspective as Coordinator/Executive Secretary, is the fact that some of our state members seem to continue to question the need for MICRA and be confused over MICRA's relationship to the other interstate groups within the Basin (i.e., Upper Mississippi River Conservation Committee (UMRCC), Lower Mississippi River Conservation Committee (LMRCC), Missouri River Natural Resources Committee (MRNRC) and Ohio River Fish Management Team [ORFMT]). This problem has its roots in basic parochialism. It should be obvious that non of these sub-basin groups can focus on the basinwide issues that MICRA can, so there is no overlap or duplication of effort. MICRA is a logical coordination point that the sub-basin groups should use to address basinwide issues. This problem needs to be resolved because it is very counterproductive. In fact, this sort of issue probably prevented completion of a habitat classification project on the lower Mississippi River in 1995.

Second, there seem to be two factions within MICRA. One group would like the Coordinator to do everything and another group gets very nervous when he does. As recently as this past autumn, some of our members were critical of MICRA because, from their perception, the Coordinator was running everything. While MICRA does a pretty good job of creating the illusion of a much larger organization, some MICRA members forget that the Coordinator's office essentially is a part-time, one-person operation, and everything else that MICRA does is done under contract or through part-time volunteer support. We need more of our members to become volunteer leaders and ambassadors for MICRA. Then the Coordinator wouldn't have to be the "front person" for all of MICRA's activities. Our members have to realize that MICRA is us, all of us, and we all must be a part of it. If MICRA succeeds or fails, we, as its members and participants, must all do it together, and do so in the best interest of the resource, not ourselves.

Third, many of our members see MICRA as a funding source rather than a funding mechanism. By funding mechanism, I mean that we have found very efficient ways to channel money into the resource, with very little being lost to overhead. Unfortunately, MICRA has very little discretionary money of its own. We receive between $50,000 and $60,000 annually in member dues. Out of that, we pay our expenses and help fund our larger projects. All of our contract money is targeted to specific projects, so those funds are mostly obligated up-front. I think MICRA has the potential to be a very effective tool in leveraging money from outside sources, but we're not there yet. If we're really serious about MICRA's future, all of our members need to invest in it at some level beyond their current dues. When this happens, it will become obvious to others that we are serious about MICRA, and then, and only then, will outside sources be inclined to agree and readily jump on board with their support.

Fourth, we have made significant strides with our basinwide paddlefish stock assessment. With it, we have proven that we can all work together for a common cause. The enthusiasm shown by the 22 states involved in the study has been tremendous. It is surprising that we haven't yet found solid funding to cover the second year of the project. We can't allow our failure to get simple grant funding for a project extension to disrupt such an important project. We must find a way to keep it going, even if it means dipping deeper into our own state and agency pockets.

Finally, and most importantly, we need to look at our overall long-term financial status. Virtually all of our contract money has come from the U.S. Fish and Wildlife Service's Federal Aid and Endangered Species accounts, and the possibility of additional funding from either source in 1996 looks pretty bleak and probably is nonexistent. So, if we are serious about MICRA, we need to find more reliable ways of funding our work.

Conclusion

Probably the most important aspect of MICRA is that it was conceived and developed by and for the states. Second, it is a natural mechanism to address resource issues from the ecosystem or basinwide perspective—an approach that currently is very popular at the federal level. Third, MICRA provides the opportunity for the tribes and other land-management groups to participate in the management process.

MICRA is what ecosystem management is all about. It is partnering: efficient sharing of resources and cooperating to achieve common goals. We finally have a mechanism to address basinwide ecosystem issues that no one state or agency has been able to tackle alone in the past. If MICRA survives, our large interjurisdictional rivers and their resources now can get the attention they long have deserved.

MICRA's long-term future, however, will depend on the continued strong support of its members. If MICRA fails, responsibility for that failure likely will lie with encroaching apathy among its own members, traditional parochial attitudes related mostly to states' rights issues, "Big Brother Fed" attitudes, and our collective failure to recognize that we all have a shared stake in the future of these important rivers and that the only way we can get the job done is to work together through some form of ecosystem management.

MICRA is a new way of doing business and I think it shows great promise for the future. The Baby Boomer generation came into its own with the election of President Clinton in 1992. Many of us belong to that generation and we have witnessed some of the greatest technological changes in history, especially with regard to widespread environmental degradation and possible climate change.

Past generations could get by without thinking of such things as ecosystem management, because there always was another resource for them to exploit and somewhere else for them to go to get away from it all. But, more and more, we are losing those options. Today, there are just too many of us and we are impacting too many resources, and those impacts are far too significant and complex to ignore. Despite our greed, our various religious and spiritual beliefs, and our parochial attitudes, our society must recognize that, if we are to survive on this planet, in any kind of a quality way, we must start addressing these major resource issues from more of an ecosystem perspective.

MICRA has the capability of addressing major aquatic resource issues across the entire Mississippi River Basin, the largest river basin in the country. Our challenge is to be smart enough to use it and take whatever actions are necessary to make it work. If that means something as simple as using some of our state Wallop-Breaux funds to get the job done, then so be it. That is our greatest challenge—will our members be willing to step up to the plate and share the economic burden? The states must realize that along with the increased responsibilities that many of them say they want, comes the responsibility to put up the economic resources necessary to address important interjurisdictional issues that reach beyond their state borders.

The bottom line is that if everyone chips in a little, together we can make big things happen. I hope we can count on enhanced support of all of our members (states, agencies and groups) and the public to help MICRA be all it can be. I stand ready and my agency stands ready to help in whatever way we can because species and rivers that have long been ignored because of their complexity and magnitude, finally can be addressed through the truly cooperative efforts being conducted under MICRA. MICRA belongs to everyone in the Mississippi River Basin who cares about aquatic ecosystems, and it deserves their non-partisan support.

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Developing the Tools of Cooperative Interjurisdictional Programs—The Experience of Statistics and Fisheries-independent Data Gathering in Southeastern Marine Fisheries

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Catch and effort statistics are fundamental for assessing the effects of fishing on stocks of living marine resources. Information on total catch, fishing effort, and seasonal and geographical distribution of the catch and effort is required to develop rational management policies and plans. Accurate and timely catch statistics, along with associated biological, social and economic data, are required to provide management agencies with the information necessary to plan for the wise use of fishery resources. Statistics are essential to management agencies for assessing the status of stocks and developing and monitoring fishery management plans. Statistical data and information are necessary to achieve optimal benefits from the use of fishery resources and to reduce the risk of overharvesting. Recreational and commercial catch and effort statistics have been of fundamental importance to state fishery management agencies in assessing the influence of fishing and making decisions on appropriate management measures to maintain and enhance fishery resources. Inseason regulatory changes and catch quotas have become common fishery management strategies. Timely, accurate and precise harvest information for both recreational and commercial fisheries is required to determine the need for and effects of these management measures. The Gulf States Marine Fisheries Commission (GSMFC) is interested in and, therefore, has developed programs to assist the states with the improvement of the collection, management, coordination and dissemination of vital marine fisheries data.

Historical Data Collection Programs

Individual management agencies have conducted numerous statistical surveys over the years to provide information for the management of fisheries within their jurisdictions. The collection of statistics for commercial fishing in the United States began in the late 1800s under the auspices of the Bureau of Commercial Fisheries. These early statistics were comprised mostly of monthly landings for broad market categories of marine and some freshwater species. In the mid-1950s, a program was initiated to collect detailed data on the amount and value of shrimp landings by species and size for individual fishing trips in the Gulf of Mexico. In the late 1970s, the concept of cooperative data collection programs was discussed and, in the early 1980s, formal agreements were signed by the National Marine Fisheries Service (NMFS) and all states, commonwealths and territories in the Southeast Region (Region) to collect and manage commercial fishery statistics under the Cooperative Statistics Program (CSP). The CSP currently includes four separate data collection activities: 1) monthly landings that provide monthly data on the amount and value of all marine resources landed and sold through commercial markets in the United States. These data are combined with similar data that are collected from other regions within the NMFS and are used to provide information on the amount that commercial fisheries contribute to the national income; 2)

South Atlantic shrimp data that determine the contribution to national income provided by these resources as well as data on fishing effort to support management of the shrimp resources in the South Atlantic area; 3) Gulf of Mexico shrimp data that provide information on fishing effort and location for individual fishing trips; and 4) the Trip Interview Program that provides size information for stock assessments of federal-, interstate- and state-managed species, as well as information on the species composition, quantity and price for market categories, age information and catch-per-unit effort for trips that are sampled (Southeast Cooperative Statistics Committee 1994).

Programs to collect statistical information on marine recreational fisheries began in the 1950s with local creel surveys and were followed by saltwater angling surveys conducted every five years since 1960 to the present by the U.S. Department of the Interior through its National Survey of Hunting, Fishing, and Associated Outdoor Recreational Activities (U.S. Fish and Wildlife Service [USFWS] 1988). The survey estimates the number of anglers, hunters and nonconsumptive recreation participants (those who enjoy photographing, observing and feeding wildlife) nationwide. In addition, the survey estimates how often they participate and how much money they spend on these activities. Data elements collected include the number of participants in different types of hunting, fishing and wildlife-associated recreation activities; days of participation and trips; species hunted and fished; types of expenditures; and selected socioeconomic characteristics of participants.

Since 1979, the NMFS has conducted the Marine Recreational Fishery Statistics Survey (MRFSS) that produces annual estimates of total fishing effort and catch by species. The survey permits catch and effort estimates to be calculated for distinct sectors of the recreational fishery. Information produced by the MRFSS is used by stock assessment scientists to estimate population sizes, mortality rates and other parameters, make allocation decisions, and predict the effects of various management regulations. Management agencies have conducted numerous other surveys, either as enhancements to the MRFSS or as independent surveys (Van Voorhees et al. 1992).

Need for Cooperative State/Federal Programs

The major fishery resources of the southeastern United States require interjurisdictional management because of their transboundary distributions. Stocks of fish routinely cross interjurisdictional boundaries, and commercial and recreational fishermen and other harvesters cross these same boundaries in pursuit of those resources. Because of these movements, information on fisheries in one jurisdiction is useful to adjacent jurisdictions. Adequate information about fishing and other resource uses also is needed by state, territorial and local government agencies to determine the biological and economic impacts of land- and water-use decisions. Although there have been many state and federal data collection programs, vital information needed to meet minimum management needs is lacking for many important fishery resources in the Region. While considerable progress has been made in collection of fishery statistics, continuing changes in the nature and status of marine commercial and recreational fisheries and increasingly complex management regimes require more comprehensive, accurate, precise and timely data. The essential need for comprehensive programs to cooperatively collect and manage statistics on marine commercial and recreational fisheries was and is the driving force behind the GSMFC data coordination programs. A long-standing partnership exists among fishery management organizations that have similar or related mandates to conserve and manage living marine resources in their respective jurisdictions. Such programs can assist managers in avoiding duplication of effort, reducing overall data collection costs, providing a better base of information for formulating management policies, strategies and tactics, as well as reducing the risks of overharvesting, rebuilding depleted stocks and achieving optimal use of fisheries resources.

Overview of Current Cooperative State/Federal Programs

The Gulf States Marine Fisheries Commission has been involved in development, coordination and administration of cooperative state/federal programs for collecting and managing fishery data since the early 1980s. Two major programs have been the Southeast Area Monitoring and Assessment Program (SEAMAP) that collects fishery-independent data and Fisheries Information Network (FIN) that consists of the Commercial Fisheries Information Network (ComFIN) and Southeastern Recreational Fisheries Information Network (RecFIN[SE]) that collect, manage and disseminate marine commercial and recreational fisheries data in the southeastern United States.

SEAMAP

SEAMAP is a state/federal/university program for collection, management and dissemination of fishery-independent data and information in the southeastern United States (Stephan 1990). The program presently consists of three operational components: SEAMAP-Gulf of Mexico, which began in 1981; SEAMAP-South Atlantic, implemented in 1983; and SEAMAP-Caribbean, formed in 1988. Each SEAMAP component operates independently, planning and conducting surveys and information dissemination.

The structure of SEAMAP is divided into three parts: management agencies, management bodies and participating agencies. The management agencies provide administrative services for each component, such as coordinating and scheduling of committee and work group meetings, administration of funds for publications, meeting costs, personnel costs, travel, etc., and supervision and guidance of coordinators and clerical personnel. The roles of the management bodies include review and approval of component operations plans, review of annual reports, and approval of actions taken by SEAMAP committees. The participating agencies include the NMFS, the state fisheries management agencies and the fishery management councils in the Region.

Data collection from resource surveys has been continuous and, most importantly, has been coordinated for 13 consecutive years. Surveys by each program component allow reflection of distinct regional needs and priorities. The major surveys for SEAMAP include Spring Plankton Survey, Caribbean Reef Fish Survey, Gulf Reef Fish Survey, Shallow Water Trawl Survey, Summer Shrimp/Groundfish Survey, Fall Plankton Survey, Fall Shrimp/Groundfish Survey and Louisiana Seasonal Day/Night Surveys. In addition to the regularly scheduled surveys, SEAMAP participates in a variety of other projects, such as the Winter Trawling and Fish Tagging Cruise and the bycatch estimates project.

Information from SEAMAP activities is provided to user groups through three complementary systems: the SEAMAP Information System, which includes all of the biological and environmental data from SEAMAP surveys; the SEAMAP Archiving Center, which contains larval fish and fish egg samples sorted to the lowest taxonomic level possible; and SEAMAP Invertebrate Plankton Archiving Center, which archives and manages the collection of SEAMAP plankton samples and obtains specimens and/or data on selected invertebrate larval stages from those samples.

Some of the uses of SEAMAP data include, but are not limited to, the evaluation of the abundance and size distribution of penaeid shrimp in federal and state waters to assist in determining opening and closing dates for commercial fisheries; evaluation of shrimp fishery bycatch and weakfish stock assessment; assessment of shrimp and groundfish abundance and distribution and their relationship to such environmental parameters as temperature, salinity and dissolved oxygen; identification of environmental parameters associated with concentrations of larval finfish; compilation of the 1993 SEAMAP Biological and Environmental Atlas; comparison of catches of shrimp and groundfish captured by 40- versus 20-foot trawl nets; stock assessment of striped bass, Spanish mackerel, bluefish, spot and croaker; species differentiation of various menhaden species; and differentiation of shark DNA.

FIN

FIN is a marine commercial and recreational fishery statistics program for the Region of the United States. There are two distinct programs under the overall FIN mantle: the ComFIN and RecFIN(SE). The goal of FIN is to provide sound scientific information on catch, effort and participation that managers need to prudently conserve and manage marine commercial and recreational fisheries resources in the Region. FIN was established to provide a forum for discussion and resolution of issues and activities that affect both commercial and recreational fisheries data programs. FIN provides a unifying focus for fishery-dependent data collection and management activities in the Region.

ComFIN/RecFIN(SE). The mission of ComFIN is to collect, manage and disseminate marine commercial and anadromous fishery data and information cooperatively for the conservation and management of fishery resources in the Region, and to support the development of an inter-regional program. The four goals of ComFIN include to plan, manage and evaluate a cooperative commercial fishery data-collection program; implement a state/federal marine commercial fishery data-collection program; establish and maintain an integrated commercial fishery data-management system; and support the development of an inter-regional program. The mission of RecFIN(SE) is to collect, manage and disseminate marine recreational fisheries statistical data and information cooperatively for the conservation and management of fishery resources in the Region, and to support the development and operation of a national program. The four goals of RecFIN(SE) include to plan, manage and evaluate marine recreational fisheries data-collection and management activities; implement data-collection activities; establish and maintain a marine recreational fisheries data-management system; and support the establishment of a national program.

The structure of the FIN Committee was established to provide the optimum organization by including all major players in the Region's data collection and management activities. This structure includes the ComFIN and RecFIN(SE) Committees, three geographic subcommittees (Caribbean, Gulf and South Atlantic), standing and ad hoc subcommittees, technical work groups, and administrative support. Involvement of all program participants in planning and implementation through FIN, ComFIN and RecFIN(SE) Committees, geographical subcommittees and technical work groups ensures the development of a program strategy that will meet the fishery management needs best.

ComFIN and RecFIN(SE) are comprehensive programs comprised of coordinated data collection activities, an integrated data management and retrieval system, and procedures for information dissemination. These three program components are directed by the ComFIN and RecFIN(SE) Committees.

Conclusions

Cooperative state/federal programs, such as SEAMAP and ComFIN and RecFIN(SE), are totally integrated programs that address deficiencies, such as insufficient funding; lack of database compatibility; shortage of essential biological and environmental data; a needed infrastructure to plan, coordinate and evaluate commercial and recreational data-collection and management activities; among others. They provide coordination and integration of diverse state and federal projects and objectives through cooperative planning, innovative uses of statistical theory and design, and consolidation of appropriate data into a useful data base system. Coordination of these activities provides better data for management decisions, while controlling costs and avoiding duplication of effort. These programs provide a unifying focus for continued efforts in this direction. History has documented the positive aspects of fishery-independent sampling under SEAMAP. The GSMFC and its member states firmly believe coordination of fishery-dependent data collection for commercial and recreational statistics under ComFIN and RecFIN(SE) will prove to be just as positive to the improvement of that body of data collection.

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Cooperative State Action to Address Research Needs—The Experience of the Southeastern Cooperative Wildlife Disease Study

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It is indeed a privilege to be invited to speak to you about the Southeastern Cooperative Wildlife Disease Study (SCWDS). It is an honor that the SCWDS was selected as one of the showcase programs that have been successful in strengthening state-based institutions. In this brief presentation, we would like to give you an overview of the history, organizational oversight and goals, staff structure, activities, and achievements of SCWDS. In doing so, we are not here to applaud ourselves, but to show what can be accomplished through a cooperative effort and perhaps to help plan the future for others, including those concerned with wildlife health.

General History of SCWDS

SCWDS was founded in 1957 by the Southeastern Association of Game and Fish Commissioners, now the Southeastern Association of Fish and Wildlife Agencies (SEAFWA), in response to several dramatic die-offs of white-tailed deer (*Odocoileus virginianus*) that occurred between 1949 and 1955 (Hayes 1981). In reaction to the mysterious deer deaths, the Southeastern Association made inquiries among the various state universities and found willing partners in The University of Georgia's College of Veterinary Medicine and the founding SCWDS Director, Frank A. Hayes, a dynamic veterinarian who was co-inventor of the Capchur™ gun. The Cooperative was first called the Southeastern Cooperative Deer Disease Study (SCDDS), but the project's mission soon was broadened to include all wildlife, and a name change was made accordingly. Eleven southeastern state fish and wildlife agencies were original members of the Cooperative, and two more quickly joined so that the following states were represented: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia. Puerto Rico and Missouri became members in 1989 and 1991, respectively. Arrangements were made with The University of Georgia for each state to pay an equal share via an annual research contract with no overhead cost. The state fish and wildlife agencies have consistently used the Federal Aid in Wildlife Restoration (Pittman-Robertson) Act to help fund their share of SCWDS.

In the early 1960s, SCWDS supporters went to Congress and obtained a $200,000 appropriation for SCWDS to conduct wildlife disease research in the southeastern United States. This appropriation was placed in the budget of the U.S. Department of the Interior (USDI) and was administered by the Bureau of Sport Fisheries and Wildlife, which, in time, became the U.S. Fish and Wildlife Service (FWS). An administrative charge of approximately 7.5 percent was deducted each year. The National Biological Service (NBS) was formed in 1993, and administration of SCWDS funding was transferred there in calendar year 1994. On several occasions, SCWDS was eliminated from the Administration's federal budget when USDI was directed to reduce funding. In each instance, funding was restored due to strong support throughout the nation, and SCWDS's appropriation has been increased twice to the current level of $250,000 annually.

In 1979, another major cooperator joined SCWDS. Veterinary Services (VS), Animal and Plant Health Inspection Service (APHIS), U.S. Department of Agriculture (USDA), entered into a Cooperative Agreement with SCWDS with the primary mission being to assist Emergency Programs, VS, APHIS, in matters pertaining to wildlife in regard to foreign animal diseases. Subsequently, this mission has been expanded to include wildlife involvement in endemic domestic animal disease problems. Geographically, the USDA activities have covered much of the United States and several foreign countries. This is in contrast to the state and USDI programs that have focused on the southeastern region. Initially, the USDA funding level was $300,000 annually, but this gradually has been reduced and fluctuates between $200,000 and $260,000.

In overview, baseline support for SCWDS is composed of the three previously mentioned components: (1) annual research contracts with 15 state fish and wildlife agencies as a group; (2) a Congressionally directed Grant Agreement with NBS; and (3) a Cooperative Agreement with VS. But there is a fourth component—The University of Georgia also makes a substantial contribution to SCWDS through salaries of senior personnel and graduate students, plus a favorable attitude toward overhead charges. Supplemental funding through small annual or short multi-year contracts and awards from other sponsors has been another increasingly important source of support for SCWDS.

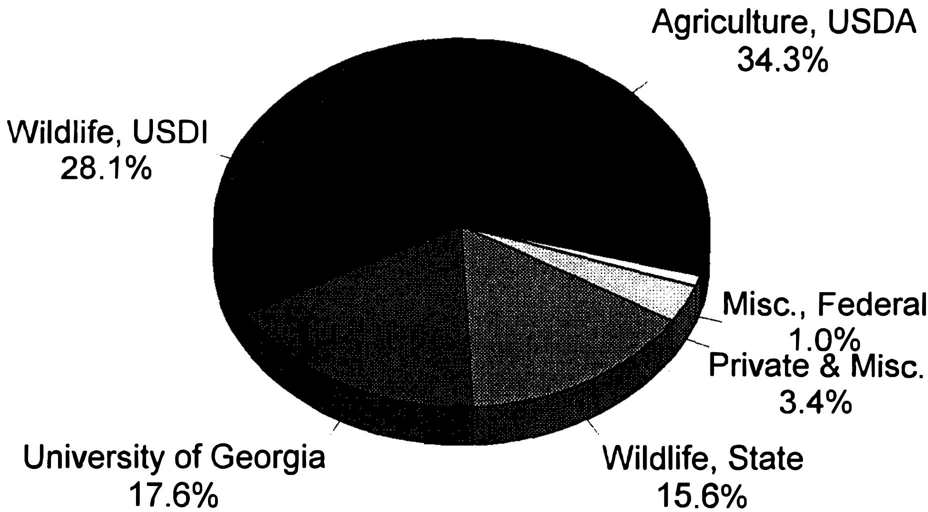

Figure 1. Multisectoral support of SCWDS (1984-1996). Miscellaneous funding sources include: Tall Timbers Research Station, Centers for Disease Control and Prevention, Miles/Mobay, Inc., National Wild Turkey Federation, Callaway Gardens, National Institutes of Health, National Pork Producers Council, Rockefeller Foundation, Wistar Institute, Southeastern Poultry and Egg Association, Lake Blackshear Watershed Authority, University of Kentucky, Colorado Wildlife Division, International Paper Company, General Electric, Shadwell Farms, Inc., Boone and Crockett Club, Syntrovet, Champion International, Westvaco, and private individuals.

Organizational Oversight

When the Congressional appropriation began in 1963, a SCWDS Steering Committee was formalized. This Steering Committee is a standing committee of the Southeastern Association of Fish and Wildlife Agencies, and its Chairman and members are designated by the Association's President. Membership includes a person representing each state agency, a representative from NBS, a representative from Region Four of the FWS, a member from the Wildlife Management Institute, the Dean of the College of Veterinary Medicine at The University of Georgia and the SCWDS Director. This Steering Committee meets twice annually to review SCWDS activities and give direction. Attendance at these meetings is exceptionally high.

Basic SCWDS objectives have remained the same for several decades. Briefly, they are: (1) to detect causes of sickness and death in wildlife; (2) to define the impact of diseases and parasites on wildlife populations; (3) to delineate disease interrelationships among wildlife and domestic livestock and poultry; and (4) to determine the role of wildlife in transmission of human diseases. Our basic philosophy is to work for the benefit of wildlife resources and animal health. We believe that by adhering to this philosophy, we will be serving the current and future needs of our sponsors and providing benefits to each cooperator far beyond what could be purchased with any member's individual contribution.

The Steering Committee assists SCWDS in identifying which activities should have priority on an annual basis. This year's priorities are set as follows:

1. Respond to requests for immediate diagnostic, consultative or field assistance in regard to wildlife health matters as problems arise. In addition to state and federal conservation agencies that support SCWDS, services will be provided to state and federal animal health authorities, public health officials, wildlife researchers, and other organizations when it is in the interests of wildlife conservation and SCWDS resources are available.
2. Prepare informational materials on salient wildlife diseases to increase understanding of disease biology among wildlife managers and to help wildlife agencies communicate with the public and the news media.
3. Provide disease evaluation services on translocated wildlife in order to assess potentials for introduction and dissemination of diseases and parasites to existing populations of wildlife, domestic livestock, poultry or humans.
4. Monitor major selected wildlife diseases to determine their impact on the populations and search for epidemiologic features that could be used by wildlife managers to predict and avoid problems.
5. Provide abomasal parasite count (APC) training and consultation services to any wildlife conservation organization wishing to use this tool to evaluate deer herd health.
6. Conduct or assist with the development and field testing of methods for disease prevention and control in wildlife populations.

Staff Structure

SCWDS has been established as a separate unit administered by the Associate Dean for Services in the College of Veterinary Medicine. The SCWDS Director, Victor F. Nettles, is a Professor in the Department of Parasitology. The Associate Director, W.R. "Randy" Davidson, is an Associate Professor based academically in the D.B. Warnell School of Forest Resources, but he also has an academic base in the College of Veterinary Medicine in Parasitology. SCWDS currently has 21 staff members. Included are five veterinarians, four of whom have doctorate degrees and one of whom is enrolled in a Ph.D. program; four scientists with doctorates in biological sciences; and two biologists with M.S. degrees in wildlife management. Of the 21 people, three are part-time and two are graduate students. All of the aforementioned people except the Director and Associate Director are on "soft money" positions funded by annual contracts.

Activities of SCWDS

Many small organizations begin with a narrowly focused mission; those which are successful recognize broader opportunities and expand their activities accordingly. To use an ecological analogy, they adapt and evolve to fill available niches. SCWDS followed such a course, evolving from a small program focusing on a specific disease in a single species into a multifaceted wildlife disease diagnostic, research and service organization. To accomplish this evolution, SCWDS had to expand its activities to meet a broader array of needs on wildlife health issues. Perhaps this process is best addressed by providing some examples of SCWDS activities and how they have changed as the organization has grown.

Diagnostic Services

The sole activity of the original SCDDS was to provide diagnostic services on the mystery deer disease to state wildlife agencies. However, demand for broader diagnostic services encompassing all wildlife species almost immediately led to changes in the mission and name to SCWDS. Provision of diagnostic services to sponsoring state wildlife agencies has remained a key activity of SCWDS and, over time, this service was made accessible to the entire wildlife conservation community in the Southeast and, when feasible, outside of the region. The species composition of diagnostic cases also changed over time, from almost exclusively game species to a representative mix of most wildlife species in the region. Although most diagnostic case accessions represent individual animals or localized mortality events, some diagnostic work is in response to large epizootics, such as hemorrhagic disease in deer, canine distemper and rabies in carnivores, or *Mycoplasma* conjunctivitis in house finches. With these larger problems, the multi-state structure of the SCWDS program has proven extremely beneficial in gaining accurate assessments of problems which span state boundaries. SCWDS diagnostic services emphasize obtaining a rapid, accurate diagnosis and providing the submitting agency an assessment of the significance of the particular disease, along with recommendations for any appropriate disease management strategies.

Research Activities

The earliest research efforts were mission-oriented projects to delineate the role, if any, that deer might play as reservoirs of important livestock disease problems such as bovine brucellosis, leptospirosis and cattle fever ticks. Work in this area still continues as illustrated by more recent studies on anaplasmosis in deer, pseudorabies in wild swine and avian cholera in non-game species around poultry houses. Following the expansion of the SCWDS mission to include all wildlife and the acquisition of federal funding through the USDI, much of the initial research effort focused on routine disease and parasite surveys of different species. Species included were white-tailed deer, cottontail rabbits, gray squirrels, raccoons, black bears, wild swine, mourning doves, bobwhite quail, wild turkeys, woodcock, brown pelicans, clapper rails, wood ducks and ruffed grouse. This work provided insight on major disease problems and delineated the "normal" baseline levels for diseases and parasites that are essential when evaluating diagnostic cases. Later, as specific diseases were identified as being important either through diagnostic cases or routine surveys, research projects were developed to focus on these problems. Some examples are hemorrhagic disease, toxoplasmosis, elaeophorosis and haemonchosis among deer; histomoniasis among galliform birds; and vesicular stomatitis among wild swine.

Another common theme for applied research was evaluation of the health risks posed to wildlife, domestic animals or humans by indiscriminate translocation of wild animals. Examples include translocation raccoons, foxes, coyotes and pen-raised game birds. Recently, SCWDS has become active in conducting research on zoonoses (diseases transmissible from animals to humans), especially vector-borne diseases which have wildlife reservoirs, such as Lyme disease and ehrlichiosis. Finally, SCWDS has assumed a greater role in research on ways to limit existing disease problems among wildlife, including a series of projects to develop and field test baits for delivering oral vaccines or medications, a field evaluation of pseudorabies vaccination in wild swine and application of prescribed burning to reduce lone star tick populations.

Other SCWDS Service Activities

In addition to the aforementioned diagnostic service, SCWDS developed other service activities that help sponsoring agencies and the conservation community deal with wildlife health issues. A long-standing service has been deer herd health checks that are available upon request to sponsoring agencies when concern develops for the health of particular deer populations. Another service activity emphasized by SCWDS has been the dissemination of important wildlife health information to the wildlife and animal health professions. This has been accomplished through a variety of means, including distributing memoranda or mimeographed booklets, producing high-quality color brochures, publishing a high quality field manual on wildlife diseases and distributing a quarterly newsletter, the *SCWDS BRIEFS*. SCWDS also has contributed to in-service training of personnel with other agencies or organizations by conducting wildlife disease workshops in numerous states throughout the nation.

During the three-year emergency campaign to eradicate exotic Newcastle disease from the U.S. poultry industry in the early 1970s, SCWDS was recruited to determine the role of wild birds as reservoirs or disseminators of the disease. Similar services were provided at the request of USDA during subsequent programs to eliminate lethal avian influenza virus from the U.S. and African swine fever from the Caribbean. The goal of enhancing emergency disease preparedness has been further enhanced by providing annual in-service training for USDA's foreign animal disease diagnosticians on critical wildlife issues typical of such events. SCWDS staff also have assisted many professional associations and organizations by serving on key committees and advisory panels charged with addressing wildlife health issues.

Academic Instructional Activities

Because SCWDS is based in an academic institution, senior personnel with faculty status are expected to participate in some fashion in academic instruction. These obligations are met through an active graduate education program leading to M.S. and Ph.D. degrees either in veterinary medicine or natural resources management; teaching of upper-level graduate courses in wildlife diseases; instruction of senior veterinary students in wildlife population health; and externships in wildlife population health for veterinary students from other institutions. Graduate student instructional activities provide a cost-effective way to gain research information that benefits the state and federal agency sponsors. In addition, these instructional activities represent an investment that ultimately pays dividends in training future conservation agency employees in wildlife health and veterinarians who can assist agencies on wildlife health issues.

Achievements and Noteworthy Accomplishments

Today, SCWDS is even more than what its founders could have hoped for...an action-oriented, cooperative organization providing continuous service for the welfare of this nation's wildlife resources, domestic livestock interests and human health. Noteworthy accomplishments can be described as follows:

- SCWDS has provided thousands of diagnostic investigations to determine the causes of sickness or death in wildlife populations, involving more than 180 species of wild animals.
- SCWDS has contributed a significant amount of the knowledge on wildlife health in North America, probably more than any comparable laboratory, through more than 400 scientific journal articles or book chapters that have been published or are in press, and the publication of two highly respected books.
- SCWDS has been a vital source of wildlife health information for state and federal agencies and private organizations by actively serving as an advisor when questions arose and by routinely distributing the SCWDS newsletter, special advisories and other informational materials.
- SCWDS was the pioneer organization for promoting cooperation and teamwork between wildlife and agricultural interests in regard to disease problems of mutual concern and has continued to provide a strong liaison force between conservation agencies and domestic animal health officials.
- SCWDS has been the clear leader in creating an awareness of foreign animal disease threats to wildlife and has enhanced emergency disease preparedness by training hundreds of state and federal wildlife biologists and veterinarians.
- SCWDS has become a primary source of information on the disease hazards associated with indiscriminate relocation of wildlife by private citizens and has worked diligently to prevent repetition of problems resulting from animal translocation, as exemplified by the mid-Atlantic raccoon rabies epizootic.
- SCWDS has developed a high-quality wildlife health educational program for both graduate and veterinary students, thereby improving the abilities of the wildlife conservation and animal health professions to address wildlife health issues.

Compliments

The compliments and awards given to SCWDS and its employees provide an indication of value placed on this cooperative program by its supporters and a way to gauge the quality of services provided to wildlife resources and animal health. The Southeastern Association of Fish and Wildlife Agencies, the founding organization of SCWDS, has gone on record with their support through resolution (SEAFWA 1981). Furthermore, the Southeastern Association has conferred its highest award, the C.W. Watson Award, to SCWDS staff members on three occasions. The Southeastern Section of the Wildlife Society has awarded SCWDS their Best Book Award twice, plus awards for Best Journal Article and Best Scientific Presentation. In 1983, the Wildlife Society bestowed its Group Achievement Award to SCWDS. The Wildlife Disease Association, the lead organization for the study of wildlife health, has honored two SCWDS members with the Distinguished Service Award and seven SCWDS students with first prizes for their research presentations.

Our Federal supporters have been complimentary as well. *Restoring America's Wildlife*, a book which was published by the U.S. Fish and Wildlife Service to highlight the accomplishments obtained through the Pittman-Robertson Act, presents SCWDS as an organization that "exemplifies a highly successful cooperative program that was developed under the Pittman-Robertson Act" and "another example of professional standards at work" (Meslow et al. 1987). In reporting to the Office International des Epizooties, a global association of nations that monitors animal health, Dr. James Glosser, then Administrator of APHIS, stated that, "The relationship of APHIS and the SCWDS has greatly advanced the knowledge of animal health in the United States and illustrates the recognition of common interests which characterizes the US approach to wildlife disease services" (Glosser et al. 1988).

Looking Forward

When invited to prepare this presentation, we were asked to work under the precept that the federal government is going to diminish support for environmental programs and that states will have to take on greater responsibility. The concept that this is yet to come is frightening. SCWDS already has gone through significant cut-backs through flat-line budgets on the federal side. There has not been an increase in the USDI portion of our funding since 1987, and the USDA support has been base-lined at $200,000 since 1987. In contrast, contributions from our member state fish and wildlife agencies have increased 61 percent in the last 10 years, and The University of Georgia's component, another state funding source, has increased 34 percent. What others are predicting *already has happened*! It is imperative that SCWDS continue to receive financial participation from our federal cooperators if the current level of service is to be enjoyed. The key to this happening is the willingness of the wildlife resource agencies and all other SCWDS constituents to maintain their solid support for SCWDS in the political arena. And, on behalf of SCWDS, we would like to publicly acknowledge the state fish and wildlife agency Directors, the International Association of Fish and Wildlife Agencies, and many others who have helped in the past to keep the program solvent.

Looking forward, a few observations can be made. First, it may be necessary for the member state agencies to contribute a larger share. The current contract is $10,785 per state. That is not much compared with the value of total services returned to their wildlife resources, particularly when compared with what those dollars would yield by themselves. A second thought is to convince state agriculture and public health departments to become cooperators. Although these agencies are supportive and complimentary to the program, they have been getting a "free ride" on the benefits of SCWDS for many years. Through the generosity of our sponsors, other government agencies in the Southeast that have used our services without cost on occasion include wildlife agencies of nonmember SEAFWA states, the Department of Defense, USDA Forest Service, Tennessee Valley Authority, Corps of Engineers, and the Centers for Disease Control and Prevention.

Today, whenever research funding is discussed in a university setting, the conclusion is reached that more support must be obtained from the private sector. SCWDS already has moved in this direction through the formation of the Southeastern Wildlife Health Development Fund. In addition to the private funding initiatives associated with The University of Georgia, we believe that our state supporters will be willing to help promote gifts, because indirectly, they will become the ultimate recipients. Our first Development Fund project is to obtain gifts to produce a *Revised Edition of the Field Manual of Wildlife Diseases in the Southeastern United States*. International Paper Company, Boone and Crockett Club, National Wild Turkey Federation, Champion International Corporation, and Westvaco already have made donations. These donors are advocates of wildlife management and long-time friends of our cooperative; however, it has been our experience that we are going to have a much harder time with the general public in soliciting gifts. The public perceives wildlife health work as synonymous with rehabilitation or rescue, and there already are well-established programs that generate large sums of money to focus on the welfare of individual wild animals as opposed to management of wildlife population health. This is a strong competing interest.

Our purpose in presenting information about our funding outlook is not to whine. We are optimists! Instead, we are trying to identify the problems and issues for others who may wish to start or build on the SCWDS model. We are strong advocates of the cooperative approach and believe that comparable regional programs with multiple sponsors would be a tremendous asset to wildlife resources managers, animal and public health officials, and the wildlife conservation effort.

What exists outside the Southeast? The Northeastern Research Center for Wildlife Diseases, located at the University of Connecticut, has shared funding from several state fish and wildlife agencies, but it lacks full participation by the agencies in the region and has no cooperators on the federal side. In 1993, states in the Western Association of Fish and Wildlife Agencies formed a Western Wildlife Health Cooperative; however, this group has no budget and exists as a network of wildlife health veterinarians and biologists working for many different employers. The Canadian Cooperative Wildlife Health Centre was formed in 1992 as a partnership among Canada's four colleges of veterinary medicine, Environment Canada and the governments of all provinces and territories. Start-up funds also were obtained from two foundations. Their headquarters are in Saskatoon, but they have effectively regionalized their organization through branch offices in Charlottetown, Montreal and Guelph.

Many people have told us they want a wildlife health cooperative "like SCWDS." Can wildlife health cooperatives be developed or enhanced in the other regions of the United States? Yes...but it will be difficult. There are two major impediments—turf and funding. SCWDS had an advantage because it was formed in a vacuum. To paraphrase a country song, "we were wildlife health when it wasn't cool." Science and expertise in wildlife health have advanced dramatically since 1957 and, today, anyone charged with locating a multi-state wildlife health cooperative is going to be faced with a difficult choice among some highly capable institutions and people.

The resolution of this problem will be a nationally driven program and the money to fund it. The wildlife diversity initiative, known as "Teaming With Wildlife," represents a window of opportunity to form regional cooperative wildlife health programs. The concept calls for Congress to enact a small user fee on various goods that frequently are purchased by people involved in both consumptive and non-consumptive outdoor recreation. The funds will be distributed to the states on a formula basis similar to the Pittman-Robertson, Dingell-Johnson and Wallop-Breaux programs, and the target amount will be $350 million. The program is intended to support wildlife species not covered by other means, i.e., "non-game." Do not let this discourage the effort. Our experience at SCWDS demonstrates that a wildlife health cooperative will spend a minimum of 38 percent of its time with non-game species, and we could do more if funds were available.

If Congress passes a wildlife diversity act, there are many reasons that wildlife health research and service should be included in the programs it would support. We encourage the state and federal wildlife resource managers to start planning now to use this new source of funding for programs that will be cost-efficient, which, we submit, in the case of wildlife health, will be the cooperative approach.

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Cooperative Fish Therapeutic Funding Initiative: States in Partnership with Federal Agencies to Ensure the Future of Public Fish Culture

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The impetus for the Cooperative Fish Therapeutic Funding Initiative was and is the lack of properly approved drugs to reduce disease-related mortality and improve production efficiency and product quality on public aquaculture facilities. This crisis requires more cost-effective methods to gain approval of drugs for use in public aquaculture. Public concerns about human food safety, human health and environmental impacts have resulted in increasingly strict interpretation and enforcement of regulations by the U.S. Food and Drug Administration (FDA). Such actions have drastically curtailed the availability and use of drugs essential to maintain fish health in hatcheries. Drug and chemical manufacturers are reluctant to undertake any significant efforts to gain approval of aquaculture drugs because the market potential for these products is below the potential sales target for research investment (estimated to be $3.5 million for one fish species and one disease).

The approval of a drug by FDA can only be obtained with the development of required safety and efficacy data that leads to a new animal drug application (NADA) that is submitted to FDA for review and approval. The process to generate all the data and have the NADA approved by FDA may take 5 to 10 years. Only three therapeutants and one anesthetic are currently approved and available to hatchery managers.

It became apparent to a number of individuals, agencies and organizations that a massive, coordinated and cooperative effort was needed to resolve this crisis. This is the story of how various groups have joined together to meet this awesome responsibility.

Approach

The Upper Mississippi Science Center (UMSC, formerly the National Fisheries Research Center, La Crosse, Wisconsin) has been aware of the crisis since the 1970s and alerted the public and private aquaculture industry to the issues and potential solutions. UMSC was designated in 1972 as the lead facility in the U.S. Fish and Wildlife Service (FWS) to gain approvals for aquaculture drugs. Several attempts were made to increase the drug registration budget of the UMSC in the 1980s and early 1990s, but with little success, except for an increase from approximately $100,000 to $420,000 in an annual drug registration budget in the late 1980s.

The Joint Subcommittee on Aquaculture (JSA) formed the Task Force on Therapeutic Compounds in 1987 to develop a list of priority drugs and funding strategy that would benefit the aquaculture industry. The Task Force developed a report in 1988 that was submitted to Congress for funding, but no action was taken. In November 1990, JSA formed the Working Group on Quality Assurance in Aquaculture Production to address aquaculture drug issues, including funding initiatives that have not succeeded thus far.

UMSC sought advice on how to develop a joint effort and was encouraged to pursue the use of Federal Aid Administrative Funds in January 1992. Contact was made with state Federal Aid personnel, state hatchery chiefs, FWS officials, as well as the American Fisheries Society (AFS) to determine the feasibility of a federal/state partnership to fund and generate the data needed for drugs considered to be of high priority to public fish production. A proposal sponsored by 11 states was submitted to the FWS Division of Federal Aid before June 1, 1992. It was rejected by FWS because of the broad scope of the problem, large amount of funding needed and excessive length of time required for the approval process. Instead, FWS advocated that everyone needing aquaculture drugs should share in funding the cost of approval activities. FWS suggested that funding could include the use of state Sport Fish Restoration Federal Aid matching funds either on an individual basis, or with the states working together through the International Association of Fish and Wildlife Agencies (IAFWA) or through Memoranda of Agreements developed among states on drug approval projects. Several meetings were held in August and September 1992 with representatives of AFS, IAFWA, National Aquaculture Association, National Fisheries Institute, FWS, FDA and the U.S. Department of Agriculture to determine a course of action based on the recommendations of FWS.

The Ad Hoc Committee on Aquaculture (Ad Hoc Committee), established in 1992 by IAFWA as a forum for dialogue and action on aquaculture issues of importance to state fish and wildlife agencies, reviewed several related aquaculture health issues, focused only on means of solving the drug approval issue and reported their decision to the IAFWA Executive Committee. The IAFWA Executive Committee concurred with the assessment and directed the Ad Hoc Committee to: (1) gather information on the aquaculture drug needs of each state; and (2) investigate funding possibilities. On November 18, 1992, the Ad Hoc Committee sent a letter and questionnaire to all 50 states and Guam setting funding goals and urging the need for state cooperation to address this issue. The states were to have their responses back by December 14, 1992. Based on the tremendous and positive responses by the states to question # 1 (42 states and Guam) and question # 2 (38 states and Guam, with 32 states agreeing to help fund the project), the Ad Hoc Committee requested and obtained approval from the IAFWA Executive Committee to pursue a funding mechanism for a state partnership in a cooperative effort. The mechanism selected was a multi-state federal aid project with funding also coming from the federal government.

The Ad Hoc Committee then requested a technical proposal from UMSC that would include the efforts of the Fish Farming Experimental Laboratory, Stuttgart, Arkansas (FFEL). The preliminary proposal was submitted to the Ad Hoc Committee on September 7, 1993, finalized and accepted by the Ad Hoc Committee in March 1994. A Memorandum of Agreement was signed by the heads of FWS, IAFWA and the National Biological Service (NBS, now the research agency where UMSC and FFEL were administered) on March 21, 1994 at the 59th North American Wildlife and Natural Resources Conference held in Anchorage, Alaska.

The project has been administered by NBS and FWS contract, administrative and Federal Aid personnel who developed the agreements for the various state participants. Each state has the option to fund the project with reimbursable Federal Aid funds or with base funds. All participating states (currently, 37) will contribute $20,000 per year for a five-year period that began July 1, 1994 and ends June 30, 1999. The final contribution agreed on by the federal government was $867,000 in base budget funds at UMSC (increase of $447,000 authorized for fiscal year 1994) and some base funding at FFEL. As of February 1996, the UMSC base budget for this project was reduced by $100,000 to $767,000. Further reductions to the UMSC base budget funds may jeopardize the federal commitment to this project.

Description of the Project

The federal/state drug registration partnership is based on priority state aquaculture drug needs identified by consensus with UMSC and FFEL. Originally, the top 10 drugs to be approved for fish production, in priority order, and their uses as chosen by 42 state agencies and Guam in the 1992 IAFWA survey, are listed below.

1. Chloramine-T: control of bacterial gill disease in salmonids and control of flexibacteriosis in all publicly cultured species.
2. Formalin: control of fungi on eggs of cool- and warmwater species not currently on the existing label, control of external parasitic infestations on cool- and warmwater species not on the existing label, and control of fungal infections on all publicly cultured species.
3. Human chorionic gonadotropin: control of spawning in broodfish.
4. Oxytetracycline: extension of the feed additive formulation to control gram negative bacterial diseases in cool- and warmwater species not included on the existing label, use as a marking agent on cool- and warmwater species not included on the existing label, and control of gram negative bacterial diseases with injectable and immersible formulations in cold-, cool- and warmwater species.
5. Copper sulfate: control of external parasitic infestations and bacterial infections on all publicly cultured species.
6. Potassium permanganate: control of external parasitic infestations and bacterial infections on all publicly cultured species.
7. Diquat dibromide: control of flexibacteriosis on coolwater species.
8. Tricaine: use as an anesthetic with a reduced 21-day withdrawal time.
9. Romet: control of gram negative bacterial diseases in cool- and warmwater fish species not on the label.
10. Sarafloxacin hydrochloride: control of gram negative bacterial diseases in cold-, cool- and warmwater fish species.

In the initial IAFWA proposal, UMSC and FFEL considered the priorities of the 42 states and Guam that responded to the IAFWA survey and the benefits to public fish production as compared with the anticipated or projected ease of gaining approval from FDA. UMSC and FFEL reprioritized and updated this list based on recent rulings made by FDA and comments on the proposal made by the Center for Veterinary Medicine (CVM) and other sources. The new priority list of drugs was as follows: formalin (extension to other species), oxytetracycline (extension and expansion to other diseases), copper sulfate, chloramine-T, sarafloxacin, potassium permanganate, benzocaine (substitute for Tricaine), hydrogen peroxide (added), human chorionic gonadotropin (deleted), diquat dibromide (deleted) and Romet-30 (deleted).

The FWS produced and distributed 54 fish species in 1991; some states produce as many as 20 different species of fish. At least 40 fish species are produced commercially in the United States for food fish, fee fishing or stocking. All species would have benefitted from treatment with drugs being developed with funds provided in this proposal. Regulatory requirements of FDA dictate that residue chemistry studies be completed on each species that is to be included on the label of each approved drug. To develop residue chemistry data for each species cultured in public aquaculture would be prohibitive. The development and implementation of a crop-grouping plan would significantly reduce the data requirements for each drug, in that the FDA would require complete data packages for only a few representative species; the label could be easily extended to other species with demonstration of similarities between cultured species. At the suggestion of CVM scientists, UMSC identified work in this proposal to specifically address the crop-grouping concept.

The number and type of studies conducted on each drug annually depends on availability of funds from participating states and other sources, FDA's specific data requirements, data available from other sources, results of the crop-grouping research, a willing pharmaceutical sponsor, and availability of in-house research personnel and qualified contractors. The sequence of studies to be conducted will depend on the study sequence suggested by FDA and indications of data requirements from FDA. Other groups working on developing data for approvals will be consulted on a regular basis. Adjustments are made to the studies to be conducted as new information becomes available from any source, resulting in a flexible approach. Funds from other sources will be used in addition to those available through this project that will result in partnerships to gain approvals through the assembly and submission of NADAs for each drug under study.

Expected Results and Benefits

The development of data under this project that would result in NADA approvals will provide public and private aquaculture with certain essential drugs that will be legal to use. These drugs will reduce disease-related mortality and improve production efficiency and product quality. Under the current regulatory climate, almost no drug or chemical will be allowed for any routine non-investigational use. With the funds made available under this proposal, UMSC and FFEL plan to: (1) extend the approval of formalin as a therapeutant to control fungal infections on eggs and fish produced in public aquaculture facilities that currently are not on the label; (2) expand the oxytetracycline feed additive formulation for control of flexibacteriosis on cold-, cool- and warmwater fishes, and extend the treatment of certain bacterial diseases on fish produced in public aquaculture facilities that currently are not on the label, and for marking cultured cool- and warmwater fish species; (3) either obtain classification of copper sulfate and potassium permanganate as low regulatory priority (LRP) drugs or develop data toward their approval for use on cultured fishes to control external parasitic infestations and external bacterial infections; (4) gain approval of chloramine-T as a therapeutant to control bacterial gill disease on salmonid species raised in public aquaculture facilities and then expand and extend the label for control of flexibacteriosis on all freshwater fishes cultured in public hatcheries; (5) gain approval of sarafloxacin as a therapeutant to control flexibacteriosis and furunculosis in freshwater fish (development held in reserve until issues related to fluoroquinolones are resolved by CVM); (6) develop data that will allow benzocaine to be approved as an anesthetic and sedative with a low withdrawal period to replace tricaine methane sulfonate (MS-222); and (7) develop information to support the crop-grouping concept so that fewer species can be used for regulatory testing and drug approval. With the data generated under the initial studies, extensions of the labels to other cultured species should be much easier to obtain.

Additional efficacy and safety data were needed to expand the LRP status of hydrogen peroxide. On January 11, 1994, FDA declared that hydrogen peroxide is considered a LRP drug when used as a fungicide on all fish species and all life stages, including eggs. UMSC needed to delineate the safe and efficacious concentrations of hydrogen peroxide as a fungicide on both freshwater fish and their eggs. Hydrogen peroxide also may have applicability as an external parasiticide and external antibacterial. UMSC planned to develop data that will determine whether hydrogen peroxide is efficacious at safe concentrations against external parasitic infestations and external bacterial infections. Since this project was initiated, FDA has indicated that a NADA will be required for any expansion of its use beyond a fungicide and encouraged the development of a NADA even for its use as a fungicide. Efforts are underway by a pharmaceutical sponsor to obtain an approved NADA for its use as a fungicide.

The development of the crop-grouping concept will significantly reduce the data requirements for each chemical considered a drug by FDA because a complete data package would be required only for a few representative fish species.

Conclusions

This type of funding initiative was made possible because there was a defined need, obtainable goals, organizational structure, willing state agencies, support from other groups, matching federal funding and research facilities capable of generating the needed data. The states, by working through the IAFWA and in cooperation with NBS and FWS, have taken their responsibilities seriously and have provided the framework and funding for the potential approval of eight aquaculture drugs and the verification of the crop-grouping concept that would save millions of dollars in investment costs for aquaculture drugs.

State Action to Conserve Endangered Species: Bull Trout Restoration in Montana

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Strong state-based institutions are needed in management of endangered species and their role is growing. Historic federal responsibility is being shifted to states by, among other things, current political sentiment to reduce "big government" (Clinton 1996), failures of federal conservation institutions (Yaffee 1994), and initiatives taken by private people and organizations (Schildwachter 1996). In addition, states have been asking for a greater role in managing endangered species (Graham 1993). Although many states already support endangered species programs, these generally resemble the federal program, and the federal program appears incapable of efficiently resolving major conflicts (Fischer 1995, Yaffee 1994). To find out how state action can be strengthened as it takes a larger role, we should examine what states are doing and evaluate new approaches by demonstrated success in the field.

One example of state-based innovation is the restoration team convened by Montana's Governor, Marc Racicot, for a species that has been determined as warranted but precluded from listing: the bull trout (*Salvilinus confluentis*). The Bull Trout Restoration Team (BTRT) was envisioned as a planning body of diverse stakeholders who would plan and find a way to implement restoration of the fish. In chartering BTRT, Racicot believed that "progressive governments in states can play a crucial role as a catalyst in preventing the needless loss of precious resources like the bull trout" (BTRT Charter 1994: 1). How well BTRT supports the Governor's assertion can be examined by what this team accomplishes and where it stumbles and struggles.

The opportunity to learn from BTRT is limited because it is a single case of an experimental strategy. Strategies are qualitatively described and single cases are not generalizable; therefore, an analytical approach that uses methods for collecting and analyzing qualitative data is necessary. Toward that end, this report relies on ethnographic interviews to document what many BTRT members refer to as "the process" being developed, which is in its infancy. The next several years will reveal lessons as the process matures or dies young. My objectives are to: (1) describe the different perspectives in BTRT for its own use as a self-study; (2) provide an explicit empirical analysis of conservation planning and implementation; and (3) look for factors that enable us to reach voluntary agreements more often and more effectively.

This report presents views of BTRT members on their planning process and concludes with a few analytical conclusions. I attempt to represent members' views faithfully by quoting them as frequently as possible, stringing together multiple quotations when meaningful, and limiting my interpretation to the selection and organization of quotations from the interviews. The outline of this paper separates my report of the members' perspectives from my conclusions. Following the "Approach" section, which describes my methodology for interviewing, the next two sections report results: "The Process" and its subsections describe the BTRT process from members' viewpoints, and "Key Factors" describes influences affecting the process. In the conclusion, I offer a few analytical comments. This report is one product of a continuing study that will amend and specify these results.

Approach

This is an ethnographic case study because I have relied on ethnographic methods in the collection and analysis of data describing a single event. Case studies are empirical investigations that draw on multiple sources of evidence to describe phenomena occurring in real life (Yin 1989). The data which make this study empirical are the words of the participants. Published methods of qualitative data analysis describe how words can be collected as data, analyzed systematically and reviewed for observer bias (Strauss and Corbin 1990, Miles and Huberman 1984, Schatzman and Strauss 1973, Glaser and Strauss 1967). The methods do not control bias perfectly, but neither does "normal science" (Kuhn 1970: 10) and, after all, science always is limited by the nature of available data. In case studies, words are part of the available data.

I gathered data by recording interviews with BTRT members and reviewing official documents. I transcribed the interviews and classified statements according to the concepts they represented, which I labeled and defined in the words of BTRT members. By comparing and contrasting the concepts and their operational definitions, I proposed a model that relates the concepts to one another. These relationships are provisional and will be refined (or thrown out) as they are reviewed by participants, inspected by colleagues and tested in additional interviews for faithfulness to members' perspectives.

This approach assumes that BTRT is a community (Gold 1985), and this assumption shaped my methods. I assumed that by establishing relationships of mutual trust and respect with people in the community, I would learn its way of life. Interviews based on trust and respect reveal glimpses of the community's fundamental, private rules of conduct. This "inner structure" (Gold 1985: 8) explains cooperation and must be described in order to improve cooperative processes. Describing the inside of a group is delicate work. The inner structure is "vulnerable to...disruption because its great, inherent strengths are the human bonds of sentiment, trust, and reliability of familiar surroundings" (Gold 1985: 8). These are fragile strengths. Given this view of the "study site," and in the interest of trust and respect, I guaranteed anonymity to all participants and quote them without attribution.

Process

Documents and interviews revealed different parts of BTRT. Documents illustrated the arrangement of players and the sequence of events that have transpired. Interviews described relationships and interactions among players and showed how events were brought about. These two descriptions, respectively, presented the obvious milestones and inner structure of BTRT, so I have organized them in subsections accordingly.

Obvious Milestones

BTRT was formed following the Governor's Bull Trout Roundtable, a conference held in Missoula, Montana on December 1-2, 1993. Preceding the Roundtable, status reviews of bull trout were conducted by a contractor for the Montana Department of Fish, Wildlife and Parks (FWP), and also by the U.S. Fish and Wildlife Service in response to a petition to list the bull trout on the Endangered Species List (50 CFR 17.11-12). FWP biologists had begun working on a restoration plan by the time Montana Governor Marc Racicot convened the Roundtable. According to BTRT Charter (1994), presentations delivered on the first day of the Roundtable made it clear that bull trout populations had declined, the species range had diminished and further threats were imminent. The second day of the Roundtable began the discussion of how "a broad spectrum of experience, expertise and management authority [could] work together to maintain and restore bull trout populations in Montana" (BTRT Charter 1994: 2).

Signatories to the charter (Table 1) agreed to "work in a cooperative fashion to produce a plan that maintains, protects and increases bull trout populations" (BTRT Charter 1994: 2). Main elements of the agreement were: that the "complex and diverse problems" required the collaboration of many parties and the use of "a public participation process which works closely with various public segments impacted by, and interested in, bull trout restoration."

Table 1. Signatories to the Charter for the Bull Trout Restoration Team in Montana.

American Fisheries Society, Montana Chapter	National Wildlife Federation
Bonneville Power Administration	Plum Creek Timber Company, L.P.
Confederated Salish and Kootenai Tribes	USDA Forest Service
Montana Department of Fish, Wildlife and Parks	U.S. Fish and Wildlife Service
Montana Department of State Lands	

Since its charter, BTRT has set up its own structure, coordinated its activities with applicable state and federal law, and begun its work of maintaining, protecting and increasing bull trout populations. The internal organizational structure of BTRT is implied as circular, where each member has equal authority within the group. FWP assumed the administrative role of arranging meeting places, recording minutes and distributing other paperwork. An external structure was formed of groups and ad hoc committees invited by BTRT to help with particular needs. These needs have included: (1) information, which has been served by the Scientific Group and Independent Scientific Review Board; (2) public accountability, which is met through recommendations of an ad hoc committee in accord with the Montana Environmental Policy Act and the National Environmental Policy Act; and (3) field work toward restoration, which is underway voluntarily by members and will be continued by watershed groups (Figure 1). A summary of events up to December 1994 indicates that BTRT spent the balance of its first year identifying actions that are underway or could be initiated immediately, and discussing its funding (FWP 1994). The Scientific Group began by identifying key scientific issues for the recovery plan by meeting with colleagues from neighboring states and exploring issues of genetics, hatcheries, and suppression and

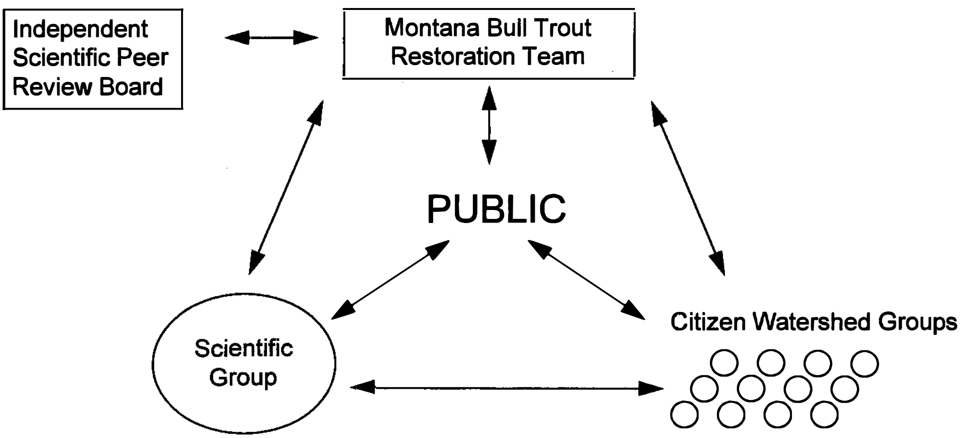

Figure 1. Participants in Montana Bull Trout Restoration Planning Process, indicating lines of communication.

removal of non-native fish. During 1995, BTRT pursued its discussions with potential watershed groups and continued voluntary activities. Also during 1995, FWP appointed a staff person as full-time coordinator for BTRT.

External structure has been and apparently will continue to be flexible. In addition to the ad hoc committee that advised BTRT on compliance with public accountability standards, the other groups were formed for specific purposes and may dissolve when those purposes are accomplished or at least advanced. The Scientific Group was convened by an invitation from BTRT to several scientists who were willing and able to add bull trout studies to their current activities. At the most recent BTRT meeting (March 7, 1996), the Scientific Group reported that, because of primary work responsibilities, several of its members would need to withdraw their participation upon completion of the reports now in preparation. The discussion following this report suggested that a list of interested scientists would be maintained so future Scientific Groups can be formed as needed. Watershed groups also are envisioned as voluntary teams; these will be comprised of local residents from within basins where bull trout occur and will implement restoration guidelines provided to them by BTRT based on the reports of the Scientific Group.

Inner Structure

Based on statements from BTRT members, the process can be seen as moving through overlapping stages which comprise multiple subprocesses (Figure 2). In the members' language, the stages are described as places; that is, members see their activities as occurring "on the table" and "on the ground." The interviews did not cover formation of Restoration Team, so I have labeled this stage in my own words as the approach to the table. Members are explicit in describing the current situation as an interim between activities on the table and on the ground. One member said, "[we're at the] end of the formative process stage, entering the 'doing' stage." This view belies the functioning of several simultaneous subprocesses pertaining to information, negotiation, relationships, ownership and responsibility. "Subprocess" is my terminology, and the flow chart of the process (Figure 2) is my attempt to describe something that at least one member considers indescribable. "Anyone looking for a cookbook will be disappointed...[this process] is amorphous."

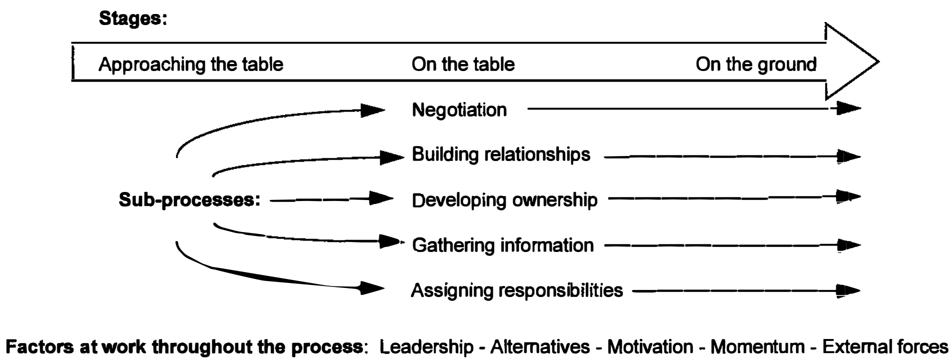

Figure 2. Propositional stages, subprocesses and factors of the Bull Trout Restoration Team process.

Information. Scientific Group reports are expected to provide information necessary for guiding land management, but how BTRT will handle the ambiguity of science is not yet established.

There is strong consensus that "the delay right now has been to wait for the Scientific Group [to answer] What do we mean by recovery? And how do we get there?" Also, members agree that BTRT has the job of fitting "the Scientific Group reports into the politics." Furthermore, there is some recognition that the team needs to agree on a common base of information before action on the ground can begin; the information must, in the words of one member, "become truth" for the group: "the information [produced by the Scientific Group review process] will become truth for further talks in the Restoration Team." This discussion will be difficult because: (1) members have "saved the sticky issues for last"; (2) "nobody has time or money to be sure" of all decisions; and (3) "science is not pure and absolute, players interpret science differently and derive standards and guidelines differently." The upshot of this situation was summarized by one member, "We'll either have to deal with these issues or come out and say that we're not going to."

Several members believe the most important lessons about the process of gathering and using information have been discovered by the Scientific Group. The members of the Scientific Group, who have not yet been interviewed, developed a process that not only has functioned routinely, but also resolved a critical situation. A particular disagreement might have forestalled agreement had not "the Scientific Group decided to review the data in detail and decide by a 'jury of peers'." The only insight to this process given to me was that the Group members made their goal: "to identify the differences in interpretation [of the data]."

Negotiation. The sense in which negotiation was discussed in these interviews was of disclosure and determining commitment (i.e., each interest determining its own commitment and gauging that of others). "There's a lot of caution people use at those meetings; they are careful about what they expose regarding what they'll support: it's a negotiation, it's frustrating at one level, but it's understandable." Along the same line, another member said, "The group has been a process of getting things out on the table—[it's been] a coordination mechanism of all the entities' duties, inclinations, and responsibilities, [so these] are all available at once—it makes them more evident." The bottom line of these negotiations for most members was how strongly their teammates were committed; in fact, the importance of knowing this has moved the issue from discussions at meetings into writing: the most recent memorandum from FWP proposed that "individual representatives from organizations participating in the Restoration Team be prepared to discuss [at the next meeting] and eventually write down a brief statement of their agency mandate or organization/industry commitment" (Spalding 1996). I do not yet know how the members explain the fact that these commitments were not discussed at that meeting, but it may not matter. A separate comment reflects the general feeling that commitments will be known fully only when the process moves down to the ground: "the real tale will be told when it comes to doing."

Building relationships. Another key element of activities at the table is building relationships among the members and between the state and federal agencies involved. One member noted, "As we interact, we get on a first-name basis...." During the process, some understanding developed about others' perspectives: "One day, someone said they now appreciate what the Forest Service goes through in managing for multiple use...." Several rivalries were mentioned, but the most obvious was between the state wildlife agency and the U.S. Fish and Wildlife Service. The implication was that reconciliation of this rivalry was key to the outcome: "...it will be interesting to see how the State and the Fish and Wildlife Service tip-toe through this without getting sideways of each other." At least one member saw the outcome optimistically: "The bull trout is not listed now because the Fish and Wildlife Service is bending over backwards to let the state try to manage it."

Ownership. The development of ownership, also referred to as "buy-in," is another process underway at the table. These words describe the sense among owners that the plan resulting from their work is theirs, and, therefore, they will use it and care for it well. One member claimed that this feeling is enhanced by including more "local knowledge": "the more you localize, the more potential buy-in, the better the solution, and longer lasting." Ownership also is affected by the lack of regulatory authority; a process free of regulatory authority "creates more ownership," said one member. Some suggested that the furthering of this subprocess may be the chief accomplishment of meetings that appear to accomplish nothing. Related to ownership is the concept of accountability. When people are "bought in," there is "a peer pressure thing...if a player is blatantly resisting, it might actually make things worse for them...you have to think hard about the long-term repercussions of your actions today." "When everybody's at the table, you don't have many s.o.b.'s who will say, 'This is my position and I'm sticking to it.'"

Responsibility. There was wide agreement that lack of resources—time, labor, materials, equipment and money—is a fundamental limitation at all levels of decision making, and that supplying resources was a matter of responsibility. This responsibility is being distributed among the parties to the BTRT effort. As one member said, "the limitation on strength of state-based institutions is finances, just like at the federal level...'precluded' is a workload analysis." This refers to the "warranted but precluded" decision by which U.S. Fish and Wildlife Service passed up its opportunity to take authority for bull trout and passed on responsibility to Montana: "When bull trout became warranted for listing politically and biologically, the state stepped forward." Montana's creation of BTRT recognizes that "the problem is bigger than any one interest," because it allows players "to pool resources." Now that BTRT has initiated some research and other activity, the group is "approaching the hand-off to the watershed groups." The watershed groups will shift responsibilities within agencies and groups to "field people [who] will be assigned the additional duty of sitting in on the watershed groups." Other members of the watershed groups will be citizens who will participate as their schedules and resources allow.

Some responsibilities have been funded ("we took a lot of projects and pieced together enough funding"), but many have been added to "full time" responsibilities. Not only are the "field people" dealing with "additional duty," but BTRT members themselves have squeezed these meetings into their schedules. The same problem has been recognized for members of the public who will be asked to join watershed groups, or who are trying to find time to participate in the process. These people, it was noted, "have jobs too" and already may be involved in other citizen advisory groups and, therefore, "may be burnt out."

Key Factors

The preceding discussion described the members' views of the BTRT process as series of stages and subprocesses (Figure 2). This provisional model did not accommodate factors that appeared to affect the process generally, without a particular point of influence. These factors are, in no significant order: (1) leadership; (2) alternatives to the BTRT process; (3) motivation for joining; (4) momentum; and (5) external forces.

Leadership

Leadership generally was described as the ability and willingness among participants to "commit [their group's] interests or policy to matters affecting bull trout." Often, the Governor's leadership was recognized: "...Governor [Racicot] is an outstanding individual. He is willing to deal with conflict and is interested in the gamut of resources." "With this Governor, Montana has a strong record of these kinds of processes." Several members listed a governor's commitment as necessary for success in any state-based effort, and especially because this leadership would draw the state wildlife agency into a "willingness to budget for it" and to maintain the necessary "viewpoint, number of people, and the qualifications" to succeed. Less often than the need for gubernatorial leadership, but also present, was the view that BTRT members must lead. One supervisor considered it his "job to bring field people in on the goal."

A particular description of leadership pertained to the state/federal rivalry for wildlife management authority. Several members referred or alluded to the "history [of rivalry in] state management versus federal management." Particular to Montana, "the struggle is long and deep" over management of grizzly bears (*Ursus arctos*) and grey wolves (*Canis lupus*). In this light, the formation of BTRT was seen by some as an attempt by Governor Racicot to establish a conservation effort that could forestall listing. One member saw the reconciliation of this state/federal rivalry as requiring "leadership...from the State and [the U.S.] Fish and Wildlife Service."

Alternatives

BTRT members are aware that their collaborative process is only one of several means of reconciling land-management practices with restoration of bull trout. The main alternative recognized by members is the regulatory approach, which could be accomplished through the Endangered Species Act or through state-level legislation that provided a regulatory "tool." "[This process is] another path," said one member, "the recovery plan may turn out as good as what the [U.S.] Fish and Wildlife Service might have done, but I'm not sure we have the tools [to implement it] that the Fish and Wildlife Service might. There are tools we don't have because there is no [Endangered Species Act]." An opposing view described regulatory alternatives as limiting possibilities and thereby encouraging participation in BTRT: "What makes these solutions possible is that they're non-regulatory. Federal law creates authority that casts a chilling effect." "If people can agree to a middle course, then each entity can advance at least part of their agenda...you can waste your time in the legislature, or you can collaborate."

Motivation

Members of BTRT came to the table for different specific reasons, and most of them acknowledged prospects for bull trout becoming an endangered species as a general motivation. At least one party at the table does not see a particular need for BTRT because they "felt the listing proposal was a good idea"; nevertheless, they are participating because they are open to alternative plans and "if you're not there, you don't know what's going on." Other members are involved because "I believe in it" or because "it's different, it's new, it's commendable and interesting, that's why [I'm involved]." Others came out of basic duty: "[bull trout management] is one issue that affects [my area of responsibility], so it's worth my time." Beside their individual specific motivations, several members recognized the overall motivation as "clearly...the threat of [bull trout] becoming a federal case." It stands to reason then that at least one member thought "the warranted but precluded decision may have taken a little steam [away from the process]"—meaning that when a decision to list the bull trout was forestalled, the members lost some sense of urgency that they may have brought to the table.

Momentum

Momentum is the pace at which the process moves toward its goals; members talked about its sources and effects. In the view of some members, momentum creates an effect like inertia that encourages the efforts already in motion to stay in motion: "Once a process gets going, the feeling develops that you don't want to fail. Once momentum is going, you don't want to see it fail." The degree of momentum is seen to reflect the legitimacy of the process: "a certain amount of progress is necessary to maintain credibility." A less encouraging assessment of momentum placed its source in "fear [of the Endangered Species Act]—that's what's driving the bull trout case." The process of gathering information also was associated to momentum by a member who described the Scientific Group as "the movers and shakers of this whole thing."

External Forces

Three primary external forces were described: (1) possibility of lawsuits challenging the process; (2) effect of publicity on the discussion; and (3) frustration from the Governor's office. At a recent BTRT meeting, a citizen brought a video- and sound-recording team. One BTRT member explained that "some people are concerned about the trustworthiness of this process." "What you saw here today probably was preparation for a lawsuit." Members were not equally concerned about lawsuits, some saw them as unavoidable possibilities, others expected that they would "reel from that" and measured their words accordingly.

One member described routine public attendance at meetings as also affecting the process: "When it's a public forum, it's uncomfortable and stifles [discussion] somewhat...it's the cost of public accountability." On the other hand, some members see greater publicity as an important objective of the process—they want to "get bull trout in the news."

Opposing the inhibiting effect of potential legal challenges and routine public scrutiny is pressure for faster results coming from "the Governor's office [which is] expressing some frustration with the slowness." This factor was described as if "the Governor is saying, 'I've held back the feds [by convening BTRT], but we got to get something done.'"

Conclusion

The lessons this case holds for strengthening state-based institutions do not teach a new, fast and effective way to recover endangered species, but they illustrate a strategy, identify its critical objective and cast a new light on the role of incentives. The strategy is to involve people at all levels of decision making, from local to federal. The crucial objective or milestone on the way to the restoration goal is agreement on a basis of information despite inevitable uncertainties. The new view of incentives shows that they are not only specific programs, but also byproducts of combining laws, regulations, organizations and customs. We can learn these things from BTRT, but, as BTRT members are quick to point out, "the jury is still out" on whether this state-based institution can restore bull trout or whether efforts modeled after it will effectively conserve endangered species.

Involving people from local to federal levels is a strategy for gathering the necessary labor, materials and money for conserving endangered species. By vertically integrating, so to speak, BTRT distributes the cost of planning and implementation across public agencies, private companies, interest groups, communities and landowners. With all these people fitting bull trout concerns into their existing full-time responsibilities, BTRT amasses many small bits of resources into a labor force.

Before this labor force, or any other, can agree on a sound course of action, its members must agree to the basic information that defines soundness. Earlier, I quoted a member who said that the group will "either have to deal with...issues [of uncertain science] or come out and say [they're] not going to." What this means is not exactly clear, but the prospects for agreement on actions appear dim to me if the parties cannot first agree on characteristics of the problem and the mechanisms by which remedies might work. Based on the sketchy evidence I received about a jury-type approach to uncertainty used by the Scientific Group, it seems that state-based institutions will need to handle reasonable doubt differently than the judicial system does. Unlike a jury, a restoration team will need to choose a corrective action despite reasonable doubt. To make this possible, the team probably will need to ensure that these unavoidably dubious actions do not unduly burden a particular member or set of members.

The important concept of incentives seldom was mentioned explicitly, but was embedded in most of what members said. Incentives, in common conservation parlance, are specific policies or programs that provide financial benefits, but, in the dictionary, an incentive is something that stimulates action. In this study, stimuli for action were byproducts of interacting laws, rivalries and established decision-making processes. According to BTRT members, Montana was stimulated to manage bull trout by the prospect that a federal agency would take jurisdiction over this species. The Endangered Species Act makes it possible for the federal government to assume jurisdiction (Ernst 1991, Bean 1983), and a history of rivalry that is "long and deep" colors this legal fact with emotional drive; therefore, the incentive felt by the state is created by law and feud. Similarly, the stimulus for private parties to come to the table results from multiple factors: interplay between the Endangered Species Act and the Montana Legislature as an alternative means of restoring bull trout. Because the Endangered Species Act holds "staggering implications" for land management if the bull trout were listed and, because legislative strategies to change land management are seen as ineffective by some BTRT members, an incentive exists for alternative planning processes that preempt the Endangered Species Act and accomplish more than lobbying.

These lessons will be refined and amended as the future of BTRT unfolds. The immediate future of BTRT will focus on finishing the Scientific Group reports and establishing the watershed groups. The questions that will be answered in these next phases include whether the Scientific Group reports supply sufficient information for the watershed groups to act on and whether the process is challenged in court as it moves toward action on the ground.

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Robert Anthony, Bradley Bales, Hugh Black, Brian Cox, Ron Escano, Erik K. Fritzell, Gordon Haugen, Jerry P. McIlwain, E. Charles Meslow, Richard J. Pedersen, Rudolph A. Rosen, Phillip Schneider, Mike Spear, Sara Vickerman, Robert W. Williams

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Puerto Rico
Jose Mentalvo

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Tennessee
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Texas
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Vermont
Allen Elser, Donna L.Parrish

Virgin Islands
David Nellis

Virginia
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West Virginia
Scott Hartman, Sue Haseltine, Paul R. Johansen, Sue A. Perry, Bert Pierce, Gordon C. Robertson, Michael Tome, Petra Bohall Wood

Wisconsin
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Wyoming
John Baughman, Pete Cimellaro, Chris Madson, Bill Noblitt, Art Reese, Reg Rothwell, Thomas Smith, Glen Titus, Oleta Titus, John Talbott, Karen Werbelow

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Japan
Christopher White

Panama
Tara Wiskowski