TRANSACTIONS
of the
Forty-seventh North American Wildlife and Natural Resources Conference

Conference Theme:

Population Pressures and Natural Resource Management Needs

March 26–31, 1982
The Portland Hilton
Portland, Oregon

Edited by
Kenneth Sabol

Published by the
Wildlife Management Institute
Washington, D.C.
1982

Additional copies may be procured from the
WILDLIFE MANAGEMENT INSTITUTE
709 Wire Building, 1000 Vermont Ave.
Washington, D.C. 20005

Transactions of the Forty-seventh
North American Wildlife and Natural Resources Conference
ISSN 0078-1355

Printed in
U.S.A.
by
Automated Graphic Systems, Inc.
White Plains, MD 20695

Wildlife Management Institute

ROBERT L. HERBST, *Executive Director*
Trout Unlimited, Vienna, Virginia

A. ALAN HILL, *Chairman*
Council on Environmental Quality, Washington, D.C.

RUTH S. HINERFELD, *President*
League of Women Voters of the United States, Washington, D.C.

ROBERT A. JANTZEN,*Director*
U.S. Fish and Wildlife Service, Washington, D.C.

ROBERT D. MARCOTTE, *President*
Ducks Unlimited, Omaha, Nebraska

SHEILA L. LINK, *President*
Outdoor Writers Association of America, Bradley Beach, New Jersey

JACK LORENZ, *Executive Director*
Izaak Walton League of America, Arlington, Virginia

ALAN G. LOUGHREY, *Past Director-General*
Canadian Wildlife Service, Ottawa, Ontario, Canada

J. MICHAEL McCLOSKEY, *Executive Director*
Sierra Club, San Francisco, California

JOHN L. MERRILL, *President*
Society for Range Management, Crawley, Texas

WALTER N. PEECHATKA, *Executive Vice-President*
Soil Conservation Society of America, Ankeny, Iowa

R. MAX PETERSON, *Chief*
U.S. Forest Service, Washington, D.C.

RUSSELL W. PETERSON, *President*
National Audubon Society, New York, New York

PAUL C. PRITCHARD, *Executive Director*
National Parks and Conservation Association, Washington, D.C.

GILBERT C. RADONSKI, *Executive Vice-President*
Sport Fishing Institute, Washington, D.C.

EVERETT RANK, *Past Administrator*
Agricultural Stabilization and Conservation Service, Washington, D.C.

WILLIAM K. REILLY, *President*
The Conservation Foundation, and *Chairman,* Natural Resources Council of America, Washington, D.C.

REXFORD A. RESLER, *Executive Vice-President*
American Forestry Association, Washington, D.C.

IGN. JUAN JOSE REYES RODRIGUEZ, *Subdirector General*
Direccion General de la Fauna Silvestre, Mexico City, Mexico

DONALD H. ROSENBERG, *Director*
The Sea Grant Association, Fairbanks, Alaska

RICHARD A. RYDER, *Past-President*
American Fisheries Society, Thunder Bay, Ontario, Canada

IGN. AVELINO VILLA SALAS, *Subsecretario*
Forestal y de la Fauna, Mexico City, Mexico

R. NEIL SAMPSON, *Executive Vice-President*
National Association of Conservation Districts, Washington, D.C.

LOWELL V. SMITH, *President*
National Association of State Foresters, Carson City, Nevada

LEE M. TALBOT, *Director General*
International Union for Conservation of Nature and Natural Resources, Gland, Switzerland

RUSSELL E. TRAIN, *President*
World Wildlife Fund, Washington, D.C.

WILLIAM A. TURNAGE, *Executive-Director*
The Wilderness Society, Washington, D.C.

C. CLIFTON YOUNG, *President*
National Wildlife Federation, Reno, Nevada

Contents

Improving Resource Management

Habitat Classification—Assessments for Wildlife and Fish

Formal Education—Resource Career Development Relationships

Current Challenges in Resource Management

Western Riparian Habitats and Wetlands

Alaska: Resource Management Progress and Challenges

Human Dimensions in Wildlife Management

THE WHITE HOUSE

WASHINGTON

March 12, 1982

I am delighted to send my warm greetings to all those gathered for the 47th North American Wildlife and National Resources Conference.

This event provides a welcome opportunity to express my high regard for your work as professional resource managers, adminstrators, researchers, and conservationists. Your knowledge and experience are a valuable source of information in our efforts to manage resources thoughtfully and productively for all Americans.

My Administration is committed to balancing intelligently the competing needs of economic growth and natural resource conservation in the 1980's. We gratefully acknowledge the major role natural resources have played not only as part of our nation's strength but also as a significant contribution to the quality of our lives. It is our goal to manage these resources in a manner that reflects the best in the American character.

You have my best wishes for a successful and productive conference and my hope that it may contribute to improved management of our nation's natural resources and wildlife.

Ronald Reagan

Improving Resource Management

Chairman:
ROBERT W. MacVICAR
President
Oregon State University
Corvallis
Cochairman:
LARRY R. GALE
Director
Missouri Department of Conservation
Jefferson City

Opening Remarks

Daniel A. Poole
President
Wildlife Management Institute
Washington, D.C.

At Conference time last year, the Reagan Administration had been in office only a few weeks. For the conservation/environmental community, it was a time of apprehension. That is a normal situation when any new Administration takes over the government. The backgrounds of some appointees and candidates for appointment raised questions about the conduct of natural resources programs over the next four years. Echoes of campaign rhetoric added to the anxiety.

There was concern about the management of public lands, national forests, wildlife refuges and parks, about surface mining and energy development, wilderness reviews and designations, clean water and air, wetland protection, liquidation of old-growth forests, acid rain, reauthorization of the marine mammals, endangered species and Sikes acts, and many others.

Since the last Conference, communication has been strained or severed between the Administration and some major elements of the conservation/environmental community. Name calling and finger pointing have been commonplace. Reasoned discussion has given way to charge and countercharge.

There always have been and there always will be differences in outlook between an Administration and elements of the heterogeneous conservation/environmental community. I say elements because the conservation/environmental community itself is by no means a sea of constant fraternal tranquility.

However, from my Washington experience, now spanning seven Presidents, it is clear that differences between this Administration and the conservation/environmental community are sharper than at any time since the early years of the Eisenhower Administration. The issues today are infinitely more complex. And they are being faced in a harsh environment of inflation, recession, unemployment, and fiscal and international uncertainty.

Today's dissension is unfortunate, because so much needs to be done to upgrade management of the country's natural resources and to assure their productivity for coming generations. Even under the best of circumstances, progress is uneven.

Today's frustrations arise for many reasons. There is the volatile matter of the national economy, and debate over ways for setting it right. Under the Administration's budget, reductions in staff and programs to manage renewable natural resources, to monitor water and air and to assess the impacts of development are made more startling by requests for substantial increases for resource exploration and extraction. There is grave concern that a lion would be loosed among the sheep.

Certainly, some conservation/environmental work can be slowed without serious short-term harm. But deliberate or mindless restriction of essential programs removes the tools needed to protect the environment and maintain resource productivity.

Nearly 2,000 years ago, the Greek biographer Plutarch noted that "Economy, which in things inanimate is but money making, when exercised over men becomes policy." Such is the effect of this Administration's budgetary approach. New initiatives will not be offered in the natural resource area except for a few that hold some promise of garnering receipts to offset costs. Others will seek to regain at least part of the cost of on-going activities.

Adding further to the conservation/environmental community's concern is the regulatory relief task force—a high-level group that is examining federal rules and regulations suggested by some to be frivolous, obstructive and needlessly expensive. Among the documents under review are regulations covering issuance of dredge and fill permits under Section 404 of the Clean Water Act and for implementing the important Endangered Species and Fish and Wildlife Coordination acts. Failure to apply these authorities promptly and even-handedly will have a serious impact on fish, wildlife and the general environment.

Another threat is seen in the Federal Property Review Board, created by the President last month. Among other things, it is charged with establishing annually the amount of each Executive agency's real property holdings "to be identified as excess." Target lands will be those properties "that are not utilized, are underutilized, or are not being put to optimum use." A companion document of the Office of Management and Budget focuses on Agriculture and Interior Department lands suitable for raising crops and timber. And lands around Corps of Engineers and Bureau of Reclamation lakes that "may have high value for private development."

Running along with all this are identical bills to "privatize"—as they say—public lands to reduce the federal deficit. According to a senior economist on the President's Council of Economic Advisers, "Until we begin to privatize the public lands, we will not have accomplished anything of real economic or moral value." So sayeth the sage.

President Nixon, in his 1969 land disposal executive order, specifically excluded national forests and parks, but inadvertently overlooked wildlife refuges. The new executive order covers the country, coast to coast.

Some of the difficulty the conservation/environmental community is experiencing is spurred by the Administration's tendency to view resources through the myopia of the traditional disciplines—forests, water, air, grazing, wildlife, parks, environmental protection and so forth. There appears to be a reluctance to look beyond the more obvious cause-and-effect relationships. Or the fact, for example, that timbering, done in an improper way, place or time, has a lasting impact on water, soil, wildlife and grazing. Or that commercial and sport fishes, marine mammals, birds and beaches enter into the off-shore energy development equation. Or that biotic diversity of the coastal Northwest's old-growth forests—centuries in the making—can be destroyed in a few decades.

The conservation/environmental community winces when the President tells legislators of Indiana, as he did, that had there been a federal government "when the Creator was putting a hand to this state," it would not exist because they would still be waiting for an environmental impact statement. Or when he joked to White House dinner guests that he would have preferred an outdoor barbecue in the Rose Garden but feared that smoke from the grills might have violated the Clean Air Act.

These are unsettling comments to those who have worked for many years to get environmental protection programs into place. And who are well-acquainted with the improved conditions the environmental laws have brought. Or who are familiar with the severe implications of problems not being faced, such as acid rain. Or the U.S. Department of Agriculture's recent contention that air pollution has prevented improvement in cotton yields since the mid-1960s despite new technology and better plant varieties. We are seeing merely the tip of an iceberg.

The Administration's economic recovery equation glosses over the fact that commodity extraction—which it emphasizes—can significantly curtail productivity of a related resource. Livestock grazing, mining, coal, oil and gas development, and timbering can be disproportionately detrimental to fish and wildlife if not planned and conducted in a sensitive manner. That means biologists sitting down with range conservationists, mining engineers, geologists and foresters to design developments in ways to minimize disruptive features. But when the federal budget significantly increases funding and personnel for commodity production and decreases funding and personnel for fish and wildlife management, the outcome is clear. Fish and wildlife will lose.

Fish and wildlife-related recreation generated expenditures of nearly $40 billion in 1980, as we heard yesterday from the U.S. Fish and Wildlife Service. To provide some scale, $40 billion is equal to the dividends paid by all U.S. corporations in 1979; equal to the costs of U.S. oil imports; more than the assets of General Motors; and equal to the annual sales of Sears Roebuck, K Mart and J. C. Penney combined.

Much of the money being spent for fish and wildlife-related recreation is collected by thousands of businesses and industries that service the 100 million people 16 years of age and older who participate in fish and wildlife-related recreation. Some is directed to the local, state and federal governments in the form of fees from the users, and taxes from the businesses and industries. Think of that—one of every two adults in the United States in 1980 indulged in some form of recreation involving fish and wildlife.

No one has analyzed the long-term economic impact of sacrificing fish and wildlife resources for relatively short-term economic gains, to say nothing of the recreational and other values foregone. The economic future of this country is not in the ledgers of the Office of Management and Budget. It is in the land and what the land produces.

There are other roots of concern. The livestock industry is heavily represented on a committee to review the fees charged for grazing public lands. Public interest representatives, a news release advises, are to be named later. A 21-member public lands advisory council, created under the hard-won authority of the Federal Land Policy and Management Act, is loaded with mining, grazing, energy, real estate and timber spokespersons. The entire public lands outdoor interest is represented by a respected but retired newspaper columnist.

In the area of western water policy, the Department of the Interior has done an about-face. On the 200 million acres of public range, ranchers now may own or cohold the rights to water developed for livestock. Western state fish and wildlife agencies long have been concerned about single-interest control of water rights on the western range where water is life.

There are hopes that renewable resource programs will weather these times without lasting injury. The Land and Water Conservation Fund can help federal land management considerably if Congress sees fit to appropriate significant amounts. The Reclamation Fund, made up of 40 percent of the receipts from on-shore mineral leases and royalties, and national forest and public lands sales, is a potential source, if Congress would redirect that money to resource management on the lands that are being exploited. Currently, that money is used for the unrelated purposes of irrigation and reclamation, which often degrade other natural resources. Last year, the Reclamation Fund gained nearly $360 million from this source. Estimates are that it will receive more than $1.2 billion in the next two years.

Coming months promise to test the resolve and imagination of all persons interested in natural resources. The ages-old admonition of making do with what one has will be sorely tried. Given the present mix of circumstances—and recognizing that many are beyond the capability of the conservation/environmental community to influence—merely holding the line may represent a substantial achievement over the near term.

These are, in truth, unreasonable times for reasonable persons.

Status and Future of Wilderness Designations and Management

Honorable James A. McClure
United States Senator, Idaho

I'm sorry that my time is so constrained. Let me make three or four very general and brief remarks and then respond to questions.

The topic that I was asked to discuss was that of wilderness legislation. I suspect you were waiting to hear from somebody who knows what is about to occur on wilderness legislation, because whatever we may have been thinking about earlier, the format and context have been radically changed by Secretary Watt's announcement of his intention to seek legislation withdrawing wilderness areas from mineral exploration during the balance of this century. And I say that, recognizing full well the import of both the statement that he made and the fact that it may change the context of the discussions.

There are three major issues before us now, in my judgment, that the Congress must decide. One was the old problem of the resolution of RARE II, which includes both national and state-by-state issues regarding wildnerness designations. For the last couple of years, it has been my hope that we would be able to resolve the RARE II dilemma by a national bill. And for the last 12–15 months, we have been trying to determine whether or not there is a consensus in a number of states, with respect to recommendations made by the U.S. Forest Service to the Administration and Congress on RARE II.

Some states are developing that consensus; others are not. And I have to say that I am disappointed that we have not been able to move more rapidly with respect to those recommendations.

The second issue with which we must deal is the issue of congressional determination of state-by-state issues if they are not in the context of a national bill.

And, finally, the third issue, which is now the important new element, is acceleration of the decision with respect to limitation on mineral exploration that was embedded in the 1964 Wilderness Act.

So those three issues are superimposed upon each other with respect to the specific and general questions the Congress must resolve. I am still hopeful that, before the end of this year, we will have come to such resolution. But, as you must know, economic conditions in this country certainly are the overriding legislative concerns of Congress and the Administration, and they quite properly have the legislative priority. Whenever there is something that must be done to improve the overall economic conditions of this country, that effort will have the green light. Whatever else that is on the legislative agenda will be temporarily set aside to accommodate the time necessary to discuss and hopefully to determine the economic issues.

With that very general overview, I think it might be constructive if, for the next few minutes, I try to respond to questions on the wilderness issue that may be of primary concern to you.

MR. RUPERT CUTLER (National Audubon Society, New York, N.Y.): I'd just like to ask if your committee intends to consider the bills that might be passed by the House committee, by Mr. Seiberling's subcommittee, that come along on a state-by-state basis, or whether the decision has been made in the Senate committee that a national approach will be taken and, therefore, your committee will wait until you can aggregate the state-by-state bills?

SENATOR McCLURE: That is a good question, Rupe, and I am not certain that I am prepared to answer it, because it will depend on both the progress that we are able to make on a national approach, as well as the conflicts, apparent or real, between the two positions.

If we are close enough to any kind of a consensus on some national program, I would not want to hold it up just for the sake of one or two particular areas, or maybe even three or four particular areas. But if we are widely divergent and it looks like it is totally impossible this year and unlikely that we would be able to resolve it in that manner next year, I think there are matters of sufficient urgency to justify moving on separate pieces of legislation, if that is what it requires.

MR. CUTLER: I am glad to hear you say that, because I think the matter can be resolved on a state-by-state basis, as you have in the past with Colorado and the central Idaho bill and so forth.

SENATOR McCLURE: I might again state what I have stated many times before that, while I looked at RARE II at the beginning with a great deal of skepticism about the ability of the Administration to do its job, and with a great deal more skepticism about the ability of the Congress to do its, Secretary Cutler and others in the Carter Administration did do their job. Congress simply has not done its part.

MR. JIM STRATTON (Juneau, Alaska). Don't you feel that congressionally mandating no more wilderness takes away a valuable wildlife and land management option from the natural resource managers who are the ones best prepared to make those decisions?

SENATOR McCLURE: First of all, I don't think Congress is going to mandate "no more wilderness." They might well say, however, that until Congress makes a further decision, that the land managers will manage under the other statutory mandates without managing to preserve the wilderness aspects during that period of time.

You know, 17 years ought to be long enough even for the Congress to make up its mind.

I don't mean to belabor the issue. As a matter of fact, I suspect by the size of the turnout today that there is a great deal of interest in this subject, and I know that it's a diverse interest. There is no unanimity in this room or anywhere else across our land as to what the federal policy should be in the management of these public lands.

I think those of you who know me know that I am very interested in these issues and have been for many years. Those who know Idaho well know that we have wilderness, and that we use our public lands in a variety of different ways. Part of that variety has been, is, and will continue to be wilderness management.

MR. CHARLES CALLISON (Public Lands Institute and the Natural Resources Defense Council, Washington, D.C.): There is pending in the Senate Committee on Governmental Affairs a resolution introduced by Senator Percy of Illinois that could have a tremendous detrimental effect on the management of the public lands of the United States, including the national forests and BLM lands. That's a subject that your committee is much more competent in than the Committee on Governmental Affairs, and I would just hope that you won't let a piece of legislation of that importance get by without demanding its re-referral to your committee so you can hold hearings on it.

SENATOR McCLURE: I think you can be assured that we are not about to let Senator Roth and Senator Percy take that away from us completely.

MR. CALLISON: That's good news. Thank you, sir.

MR. TIM LILLIBOW (Oregon Wilderness Coalition): I am wondering specifically about wilderness designations that would deal with anadromous fish habitat.

We have a few areas here in Oregon, and I'm sure there are others in the United States, where development activities are, in my estimation anyway, threatening the anadromous fish runs. I am wondering if you would make a few comments on the potential to go ahead and designate as wilderness those areas that are in dire need and that are having problems, where we're losing the fish runs.

SENATOR McCLURE: Surely. First of all, I don't think wilderness is the only way, and certainly not the only appropriate way, to deal with the question of the protection of fisheries.

The land managers have the expertise to manage non-wilderness lands in a way that does not adversely affect anadromous fisheries. We have been fighting that battle for many years on the Salmon River drainage in Idaho, and there is a great controversy right now over the South Fork of the Salmon management plan.

I will be very candid with you. I support the Forest Service plan with respect to the South Fork because the best professional fish, wildlife and land managers have drawn up a plan that they believe is sufficient to protect the fisheries in that area. And they also are pledged, as I am and others are, that at the first sign that the plan is not working well, we will stop and take another look.

And that, I think, is what we ought to be doing in many of these areas. Wilderness is an appropriate method of protecting resources—and we will take a careful look at it—but it is not the only way to protect resource values.

MR. DOUG PIFER (National Rifle Association of America, Washington, D.C.): I am sure that the people here are also interested in any comments by your committee or on any legislation that might happen this year that might restrict hunting activity in wilderness areas.

SENATOR McCLURE: I don't believe that there is any likelihood that we will see any further efforts in the lower 48 states to use land management and prescriptive land management directives to limit hunting and fishing opportunities. There was some of that apparently in the Alaska lands bill, where attempts were made to restrict hunting possibilities managed by the State of Alaska to accomplish the aims of some other people who wish to have a different kind of wildlife management on some of those areas.

But, outside the Alaska lands issue, I don't believe we are going to see any attempt by prescriptive direction of the Congress to interfere with fish and wildlife management by the states. That is a matter I have been adamant on for a good many years, and I am happy to say this Administration supports it wholly. The last Administration did not obstruct our efforts to make certain that that was written in whatever statute was necessary at the time. So I think we will continue that.

The states have responsibility for management of fish and wildlife; the federal government has responsibility for the management of the habitat, except in those instances where there is a specific reason to legislate otherwise.

MR. C. R. GUTERMUTH (Wildfowl Foundation, Arlington, Virginia): I'm extremely interested in the future of the cooperative fisheries and wildlife research program. The House appropriation, as I understand it, is allowing $4.4 million for it, but it's my understanding that in the Senate bill there's only $3 million. This isn't sufficient to maintain that program. I'm wondering what chance there is of getting the House appropriation matched.

SENATOR McCLURE: I don't know that it is possible to answer that question yet. I will give you a categorical answer, as I am not only the Chairman of the Energy and Natural Resources Committee, I also am the Chairman of the Interior Subcommittee of the Appropriations Committee, and that item comes through my subcommittee.

We are going to do the best we can in very tight budget circumstances this year, but I don't believe it is possible for us to look at any set of figures today and indicate which one is the right one and which one is the wrong one, because something is going to give in this budget fight.

Right now, the pressure of the growth of social welfare income maintenance programs is driving the spending away from almost every other area of federal endeavor. That is the unfinished part of what we must do to get the economy straightened around again. But until we do that, every other area of the budget is pinched very, very hard. We are going to do the best we can, but it is a tough year.

MS. PAULINE PLAZA (National Audubon Society, Boulder, Colorado): We've had a lot of debate in Colorado about mineral development in wilderness study areas, particularly BLM wilderness study areas, and I wonder what your feelings and the feelings of your committee are on that topic.

SENATOR McCLURE: The wilderness study areas we are going to have to take on a state-by-state basis, where those states have already passed an Omnibus Wilderness Act. I am not prepared to answer that with respect to Colorado. We have not had a chance to look at that closely enough, nor to get the input of various groups.

We will make no decision on that until we have had that opportunity. But in those states where an Omnibus bill has already passed, as in the case of Colorado, we will have to look at the study areas with a different view than we do in general across the United States.

Outlook for Fish and Wildlife in the 97th Congress

Honorable John B. Breaux
United States Representative, Louisiana

I am very pleased to be able to be here today to share some remarks with all of the professionals and their associates gathered here. I have attended this meeting before and have always been very impressed with the quality of the people who are in attendance and also with the content of the work that they do.

I have looked over some of the recommendations that members of this group have made to me in the past year, and so far during this year. For instance, I have looked at the recommendations for an additional 3-percent tax on all the boats in my congressional district, an additional 11-percent tax for all of the hand-loaded ammunition in my area, and an increase in the duck stamp fee for all of the hunters in my congressional district. I wonder whether those making these recommendations are friends. I'm the one who's got to go back and try and sell these recommendations to my constituents in southwest Louisiana. But these are suggestions that we're going to take very seriously, and in a few seconds I'll discuss them in more detail.

It is a tough year, and it's going to be a tough time for those of us who are interested in wildlife and wildlife conservation and environmental programs. It's like that throughout the Federal budget. If you consider the areas that we in the Congress are having to look at with regard to spending levels and spending programs, you'll find that there are very few areas in the 1982 budget that are not going to be facing some rather significant curtailments and cutbacks.

Look at the area that you are particularly interested in. Despite the fact that the fish and wildlife budget is sustaining some rather severe and restricted recommendations, everything is relative to a certain extent. In comparison to some of the other programs that are under the jurisdiction of the committee that I happen to be Chairman of, I suggest that the cuts recommended for the Fish and Wildlife Service were actually very moderate in comparison with cuts in other areas.

For instance, one of the agencies that my committee has jurisdiction over is the National Marine Fisheries Service. That Service recommends and develops programs for commercial fisheries in the United States and throughout the world where we have programs. Their budget is facing a 38-percent recommended cut in spending authority compared with last year. In contrast, the Fish and Wildlife Service is looking at some cuts that range in the neighborhood of three or four percent. In fact, there are some recommended increases in the fish and wildlife budget that I think are appropriate and in keeping with what we are trying to recommend in the Congress. There are some cuts that I think are significant.

One area which I have some severe problems with is the funding that has been proposed for refuge acquisition. Others among you should also have cause to be concerned. The Administration's proposal for refuge acquisition under the Land and Water Conservation Fund recommended that the National Park Service receive approximately $60 million for new park acquisition out of the Land and Water Conservation Fund, while the Fish and Wildlife Service would receive $1 million for the acquisition of new refuge lands. I believe the Office of Management and

Budget, a group which doesn't understand these areas, had much input into this recommendation.

I thought that this year was unusual, and that someone had made a mistake by making this type of an imbalanced recommendation. Therefore my staff and I checked not only this Administration, but previous ones. It's not a Republican problem or a Democrat problem; I think it's a combined problem. The statistics that were reported back to me give an indication of what I perceive to be a very serious problem. In checking back over the past five years, I found that the Fish and Wildlife Service has always been on the short end of the funding stick, so to speak, usually receiving only about 10-percent of the amount received by the Park Service out of the Land and Water Conservation Fund.

Now, I'm all for parks, and I don't want anyone saying that, "Well, Congressman Breaux is up here saying we should abolish parks and we shouldn't fund acquisition for new parkland." No one has yet been able to convince me that a split of a limited amount of money that has $60 million of it going to the acquisition of parklands and less than $1 million going to the acquisition of wildlife refuge land is a fair split. I don't buy it, I don't think it's fair, and I think we need to do something about it.

I think one of the things that has caused problems in this area is the fact that we have a user fee, basically in the form of the duck stamp program, whereby people who enjoy the sport of hunting—and some who do not hunt, but who do in fact buy duck stamps anyway—are willing to put up dollars and have actually provided millions of dollars to be used for the acquisition of wildlife refuge lands and wetlands for migratory waterfowl. Last year, duck stamps raised about $16 million. Hunters are willing to buy stamps. Hunters, however, are not going to be willing to continue to put up their own money if, in fact, they are in effect penalizing themselves in doing so. I frankly think that some legal eager beaver in OMB has sat down and said, "Well, you know, the parks need new land but these fellows who enjoy hunting are going out and buying duck stamps and they're raising $16 million, so, heck, let's let them pay for any wildlife acquisition, and we're just going to subtract that amount and give them that much less out of the Land and Water Conservation Fund." I think that's unfair. And I think that it's something that should be corrected, and I am going to look with very, very critical eyes at any proposal that says, "Well, we need to increase the duck stamp a lot more because we need money for the Fund."

I submit that if we had a fair division between parks and wildlife refuges of the money coming out of the Land and Water Conservation Fund, we should not have a need for an increase in the duck stamp at this time. I don't think people who contribute through a user fee mind paying if they think they're getting a fair shake. But I think that they are not getting a fair shake. The money is for the Land and Water Conservation Fund, which is a user tax in itself. It's derived from a tax on motorboat fuel and the sale of excess government property and also from the revenues from offshore oil and gas leasing. So you can see from where that money is derived: the sportsman, through the motorboat fuel tax, is contributing to the Land and Water Conservation Fund.

I'm not saying that people who enjoy parks are not contributing because, in fact, they are. But if you add the contributions sportsmen make through duck stamps, plus what they're contributing to the motorboat fuel tax, you find that we have a pot that has about $900 million in it, and it's being used $60 million for parks and less than $1 million for acquisition of wildlife areas. I think that's something that needs to be discussed and looked at with a very critical eye. And I, for one, am going to make sure that we look very closely at how any increase in duck stamp revenues is going to be allocated.

I think that it's very important also to understand that acquisition of wildlife habitat in wetland areas under that program is as important, not only from a sport hunting standpoint, but from an environmental and ecological standpoint, as the acquisition of parklands. Our subcommittee in the House had a hearing in November on the loss of wetland habitat in the Mississippi Flyway. The results are absolutely astounding. In my own State, Louisiana, which has a large number of wetlands—25 percent, they tell me, of all of the wetlands in all of North America—we are losing 40 square miles of coastal marsh per year. Forty square miles because of erosion and because of canals and dredging projects, et cetera. Many of these projects are necessary, so we have to do everything we can to try and offset them by preserving and protecting the areas that are still unaffected. We're losing about 200,000 acres of bottomland hardwoods to agricultural conversion just in that flyway area; 40,000 acres or so of potholes in the upper Midwest are being drained each year. In addition, not only is it necessary from a wildlife standpoint, it's very important to preserve and protect these lands to insure the preservation of endangered species that the government is spending millions of dollars trying to protect. So the acquisition of these type of lands, I would say, is critically important and deserves a better and a fairer share from the people over in OMB than I think is represented by the budget that the Department of Interior was forced to swallow.

We have wildlife refuges that are congressionally authorized out of our committee and signed into law that are just sitting there waiting for money to be appropriated so the mandate of Congress can be carried out. And it's not as if the money is not there. It's not as if we're raiding the general treasury in order to say, "We need to buy more wildlife refuges." The money is there in a fund that is being derived from the fuel tax and the OCVS revenues. The problem that I have is that it's not being divided up appropriately. I think that all of you who are concerned about that can make a very eloquent, very clear, and very strong case for the fact that we deserve better than a 60-to-1 division of some very precious funds.

I don't think an acquisition moratorium makes any sense for parks. Certainly, I'm not advocating that. But it certainly doesn't make any sense to institute a moratorium on wildlife habitat acquisition when we can show that such habitat is disappearing at an alarming rate.

The general message is this: I'm not pleased with the recommendation of the budget people as it concerns wildlife habitat acquisition. I think that you should let your representatives and senators from your home States know that what we're trying to do is to correct that imbalance. Our committee is recommending an additional $15 million out of that fund for refuge acquisition. We could use your help and your professional input into seeing that the appropriate appropriations committees in the Congress follow what we're doing.

In addition, the budget contains some rather alarming recommendations for another section that you and I are concerned about, such as the fish and wildlife research cooperative units. Cooperative units have played valuable roles in producing wildlife managers and professionals and in coming up with research, suggestions, and recommendations that eventually have become the law of the land. It is a program that I think has brought back to us an ample return for the dollars that have been spent. The recommendation in the budget this year is for zero funding of the program, meaning that it would be eliminated. Last year we ended up with about $4.4 million, which is really not a significant amount of money for a national program. We are recommending in our committee an authorization of the same level as last year, at least $4.4 million. That certainly does not allow any expansion, but it at the same time does not bring about the death knell for a program that I think needs to be continued. I can say that we probably have gotten more mail on this particular issue than on any other subject so far this year. It shows that professionals out there have an interest in this, and it's more than just a passing interest. You have tried to express to our committee, and I know to the Senate also, that it is a program that is certainly worth keeping and that you can show some very tangible results it has produced.

But let's not kid ourselves. It's not going to be easy. We are going to try and balance the budget. We shouldn't balance it on the back of any particular constituent or interest group. It should be across-the-board (and we could talk about that, but we're limited in this case to our fish and wildlife areas). I think we have a recognition of the fact that this is a viable program. It's turning out good professionals who will, in the future, make the difference. Our committee is trying to recommend level funding, also recognizing that we're going to have to make some consolidations. There are going to have to be some changes. We are going to have to be more regional in an approach.

If the Federal Government is going to be involved, the Federal Government has an obligation not to be localized. It can't be one State, one State, one State. There is a State need, but the States are going to have to dig into their pockets to pay for some of those particular needs. This program is going to have to concentrate more on regional and national concerns if it's going to continue to be funded by our national government. The Units do perform a valuable service, and we are going to follow through with our recommendations.

Our committee is also recommending some increases in other areas. For example, we're recommending increases in the endangered species grants to the states and endangered species law enforcement. We're also recommending increases in funding for the Wildlife Disease Laboratory in Madison, Wisconsin, which OMB has recommended eliminating, as well as for aquaculture and nongame species, which we consider to be very important.

But at the same time we're trying to be responsible, and when our committee received the budget message, we said, "All right. We respect your authority to submit a budget that comes up with a particular final total." What we're going to try to do is say, "We might agree with the total, but we want to change the priorities," because we are an authorizing committee in the Congress that hopefully understands the programs better than someone in OMB.

So while we are recommending increases in some areas, we are at the same time recognizing that there are some areas where we can decrease funding. And it's not because the program is not a good program; but the question that we have to ask in 1982 is not only whether it's a good program, but whether it's a program that, on a national level, we can afford to continue to fund with a limited amount of revenues. Keeping that premise in mind, we are recommending decreases as far as the federal involvement is concerned in the animal damage control program, Fish and Wildlife Service administration, and some hatchery construction programs, which we find are to some extent duplicative. We are fighting this budget and hopefully we will have something that we can all stand behind and support while we move forward to completion during the month of May.

With regard to legislation we are considering, there are a number of critical subjects that our committee has already addressed this year. We have made some substantive changes, at least as far as recommending them to the full Congress. And we have some other things that are on our schedule to be addressed in the weeks and months to come.

The endangered species program is, of course, a pressing issue. We have had hearings on the Endangered Species Act and have had testimony from representatives of your organizations, from the States and from the various interest groups that are concerned about the Endangered Species Act. We are presently drafting a package of amendments. There will be amendments to the Endangered Species Act. We are certainly going to correct, if I have anything to say about it, a Court of Appeals decision in the bobcat case. I think that it's absolutely critical that that be done. The Court has made some mistakes in interpreting what the intent of the Congress is. They always tell us what we intended when we wrote the legislation. Those who wrote it can say, "I never meant that," and the Court can say, "Oh, yes, you did. We know what you really meant." Despite our acts to the contrary, they continue to tell us that we meant something that we know we didn't mean.

The approach that we're going to take on the bobcat decision is to state very clearly to the Secretary that, in making a no-detriment finding for handling of a species, we make those findings on the basis of the best available biological information derived from modern wildlife management techniques. Estimates of population size, which have gotten us into problem areas, will be specifically mentioned as not being required. If they don't get that message, we'll rewrite it again. But it will be pretty clear that we're saying that, in determining whether the taking of a species is or is not to the detriment of that particular species, reliable population estimates are not necessary.

Those of you who are professionals in this field have come before our committee time after time and said that in some cases—and the bobcat is an example—a reliable population estimate, a number of a particular species that might exist, is impossible to obtain. And, in fact, other methods of biological assessment are better at determining the health and the condition of a species. So, heaven help us, why not use that other method? Despite the fact that the courts think we should not be allowed to do that, we will, in fact, legislatively make it very clear that this is an acceptable practice. The result would be a victory for professional wildlife managers such as yourselves and the people that you represent.

We are also going to abolish the International Convention Advisory Commission as part of endangered species authorization. It's something that has been zero-funded in the past. I don't think that will make a substantial difference, it's just recognizing what has happened.

We are going to try and address the experimental population issue by allowing States and organizations to try and introduce experimental populations of a species that may be threatened or endangered without having to go through the problems of obtaining permits and designating critical habitat that the Endangered Species

Act requires. Such requirements make it more difficult for State agencies to rebuild a population. Some of you have come before our committee and made this recommendation, and I think it's a healthy recommendation and one that we will incorporate in our legislation.

At the same time, we are going to try to unclog the listing process for endangered species, which seems to have come to a slow-down or, some would say, a complete halt, and to streamline the Section 7 exemption process of the Endangered Species Act.

I think that if we get the amendments that we are proposing passed, the result will be a more balanced and more workable Act. There are interest groups on both sides of every issue in endangered species. It's very emotional, but our job, and one that I think everyone would support, is to try and make the Act workable. It doesn't do us any good if we create legislation that merely guarantees immediate access to the courts on every issue that ever comes up with regard to the enforcement and workability of the Act. The amendments we are going to suggest, and hopefully get adopted, will make the Act more workable and, at the same time, result in a stronger and better Act of which we can all be proud.

We still have before our committee a proposal to expand the existing Dingell-Johnson legislation. It's something that is controversial, particularly in a time of a slow-down in the economy. I honestly don't know if there is ever a good time for Congress to move on increasing taxes. Most of us who are in this business are fearful of raising taxes and we can probably always say, "Well, this is not the appropriate time and this is not the appropriate place." Maybe there's never an appropriate time to try and get a tax increase.

I would only say to all of you that this proposal has a great deal of support from the Reagan Administration. Secretary Arnett, in fact, himself has testified to that effect and strongly put the strength of the Administration behind the expansion of the Dingell-Johnson tax that imposes a three-percent tax on fishing boats, motors, and boating trailers and adds a number of different fishing items and equipment to the existing ten-percent tax.

The outlook at this time is questionable. We are presently polling our committee members to see how they would vote on this particular legislation and the reports that are coming back to me in our House committee say that's almost evenly divided. People who have been involved in the issue have sided and come down almost eight-to-eight in our subcommittee on the Democratic side, and the Republican side is almost the same, with a little bit more support there for an increase in this fee. All of the states have come in and said, "We support the increase. We need the money."

One of the concerns that I have involves the whole concept of the user fee. I am a strong supporter of user fees. I think that people who enjoy a particular activity are willing and able in most cases to put up financial support for the programs that they enjoy and benefit from. I also will caution you that, as a member of Congress for ten years, I have seen program after program that have had user fees involved in them not use the fees for the purpose for which the program was created. I've seen user fees in fishery programs, I've seen user fees in wildlife programs, I've seen user fees in a whole slew of other areas that have found their way, not into the program which they were intended to cover, but into the general treasury to finance highways and construction and everything else.

We can ensure, I think, that the user fee be used for the purpose for which it was intended, but we always have a problem with the appropriating committees. When they see this whole new bundle of money, they think of about a hundred different other priorities that they would rather spend it on. We have to be very careful in adopting an increase in user fees because we want to make darned sure that it goes where it was intended to go. So we have tried to put together a blue ribbon committee that will try and assure that if, in fact, we are able to get this Dingell-Johnson expansion program adopted this year, we will be able to use the money for the purpose for which it was intended.

Don't give up hope on the Dingell-Johnson expansion. Continue your active interest and support for it.

This summer, in another area, we plan to take up wetlands legislation, including the Wetlands Loan Act and legislation to use the tax code to try and encourage the sale of wetlands to State or Federal Government and also to conservation organizations. I support the extension of the Wetlands Loan Fund, but, as I indicated earlier, at this time I certainly am not willing to stand up and support an increase in the price of the duck stamp. I do think that an extension of the Wetlands Loan Act is needed and certainly will continue to support that.

All in all, if you look back on the Congress that we are presently in, the 97th Congress, I think it's been a good Congress for the issues that you are particularly concerned about. We passed the Lacey Act last year. I think we made some substantial improvements that were based on recommendations from professional wildlife managers such as yourselves. The Lacey Act, while good in intent, was not strong enough to act as a deterrent to those who commit crimes against wildlife and sell illegally-taken animals. What we did—and this was controversial because there were some groups who opposed it—was to dramatically beef up the penalties in the Lacey Act so that state wildlife agencies can still get enforcement support from the Federal Government.

In addition, we became involved with the reauthorization of the Marine Mammal Protection Act and, I think, again made some substantive changes that recognized the realities of life. We did that by turning over the management of marine mammals to the State, if the State has an acceptable program. And we found, particularly in the State of Alaska, that the Federal Government can't do it all. It doesn't have the resources and it doesn't have the people-power to police and enforce every single act in every single corner of the United States. So what we did was make some corrections there that I think are definitely in the resource's interest.

I will close with these few comments. I have, as I indicated, been in this business for approximately ten years as a member of Congress and before that on a staff looking at wildlife issues. Over that period we've gone through some peaks and valleys. We have gone through a period of time where development interests were at the apex of their operations and moving very strongly, and wildlife issues and wildlife protection suffered.

We then moved into a period where Congress became very involved, along with the States, in passing wildlife protection statutes, environmental laws, such as the National Environmental Policy Act, the Clean Water Act, the Clean Air Act, the Ocean Dumping Act, and we could go on and on. This was a period of aggressive action on the part of our government in protecting wildlife.

I think that the decade of the '80s will be a decade of trying to balance those various competing interests, development interests on one hand, protection interests on the other hand, and trying to make it all work. I would only salute those of you who are in this on a professional basis, who have to make those balancing acts work. They're not easy. I'm not telling you anything that you do not know.

But, hopefully, with the cooperative spirit that I've seen generated here and the spirit that I have seen generated in the Congress, the '80s will become the era of balancing the competing interests, which ultimately will lead to the best interests of everyone involved.

Thank you very much for asking me to speak to all of you. I appreciate the invitation.

Resource Management Thrusts and Opportunities: Fish and Wildlife—A Fuller Dimension to Improved Resource Management

John B. Crowell, Jr.
Assistant Secretary for Natural Resources and Environment
U.S. Department of Agriculture
Washington, D.C.

It's nice to be back in Portland and to speak again in my own neck of the woods. It's a special pleasure to come back here for this important conference and to participate in this opening session. I welcome this opportunity to discuss our efforts to improve resource management on the national forests and how our major thrusts will affect the fish and wildlife resource in particular.

It has been a little more than a year since President Reagan was inaugurated, and a little less time than that since I was confirmed and sworn in as assistant secretary of agriculture. We have moved to establish and implement some changed emphases in our resource management programs. So, by now there should be little mistake about our intent to improve natural resource management on the national forests. We intend to increase the productivity of these resources without corresponding increases in federal appropriations. We intend to generate increased receipts to the U.S. Treasury by emphasizing revenue-producing activities such as timber management and oil, gas, and minerals development outside of wilderness areas. We intend that the users pay more of the cost of services that traditionally have been subsidized or provided free of charge. We intend to foster compatibility among resource uses by avoiding land management practices that promote single uses to the detriment of other multiple uses. Those are our major thrusts for improving the way national forest resources are managed.

Many of our initiatives in these areas are well known. Some have created controversy, and critics have greeted a few with a high level of rhetoric that has left the public with little understanding of the true dimensions of our programs for the national forests. I hope this panel, and this conference, can provide some understanding of where we truly stand with our management objectives for the national forests.

Our priorities are quite clear—more fully to use the timber resources of the national forests for this generation, to manage the timber so that future generations can enjoy even greater bounty, and to encourage development of the timber, oil, gas, and mineral resources that are so plentiful on the public lands. Those priorities are precisely where they must be, given the overwhelming need to reduce the federal budget, to get America's economy once again on-track, and to get Americans back to work.

Additionally, our initiatives in resource management are directed at the broad array of resources on the national forests—not timber, minerals, oil, and gas alone. We are working to improve integrated management of all the forest's resources—fish and wildlife, rangelands, recreation, and wilderness together. Our fish and wildlife programs are a very important part of that effort. Consistent with this, our 1983 fish and wildlife budget proposal for the Forest Service reflects a million-dollar increase above the 1981 appropriation—making it the only major federal fish and wildlife program to remain relatively unscathed in budget reductions. I have also established a fish and wildlife committee—made up of some of the top fish and wildlife experts in the U.S. Department of Agriculture—to advise me and to help me ensure a wise fish and wildlife policy integrated with the multiple use requirements of the national forests. The fish and wildlife resource is a major consideration.

Old-Growth

One of my major initiatives has been to speed up harvest of the slow-growing or decadent, overmature timber stands in the Pacific Northwest—the old-growth. Simply put, this old-growth offers the greatest immediate potential for increasing timber harvest from the national forests and for meeting the nation's wood needs in the short-term—over the next 20 to 40 years. This can be done at reasonable cost—so that returns to the treasury are likely to be high—while meeting multiple use needs and increasing the productivity of the national forests as well.

That said, let me make three points about this initiative:

First, we recognize that these older timber stands provide optimum or preferred habitat for several wildlife species—as well as aesthetic values—and that we therefore need to retain an old-growth component for multiple use purposes.

Second, we aren't going to be "liquidating" the national forests through this effort, as some are charging—we don't plan to come even close to cutting all of the old-growth stands in the Pacific Northwest.

And third, we intend to manage old-growth components on the national forests in areas large enough and well-enough distributed to sustain viable populations of species that need old-growth habitat.

We Will Consider Fish and Wildlife Habitat Needs

We intend to recognize fish and wildlife habitat requirements in developing forest management prescriptions for the old-growth. For example, we are identifying and managing habitat to meet the recovery objectives of the bald eagle—habitat which includes an old-growth component. Having started here in the Pacific Northwest, and now nationwide, we are identifying the relationships between wildlife habitat and other forest values, to better predict the consequences of management alternatives on fish and wildlife. That will equip forest managers for making better-informed and balanced resource management decisions and for avoiding or mitigating the negative consequences for wildlife and fish.

One of the problems we face in doing this for many wildlife species is that we don't know enough about the habitat role of old-growth stands, or whether younger stands can help fulfill this role. We are trying to address this problem with a 5-year research program for managing old-growth with wildlife habitats. This program will involve forests west of the Cascades, from Canada to northern California. It will identify plants and animals which depend on old growth, or find their optimum habitat there, and try to determine their biological requirements. It will describe, inventory, and classify old-growth ecosystems and will evaluate different ways of managing old-growth stands.

This is an effort that involves the Forest Service and other federal agencies; the forestry and fish and game agencies of Oregon, Washington and California; several universities; the forest industry; and several interested wildlife groups. We hope that this program will shortly provide the knowledge we need for informed, responsible management of the old-growth stands—management which can help us maintain viable populations of wildlife species, while integrating their additional habitat needs with sound silvicultural practices.

We Aren't Running Out of Old-Growth

Let's turn to my second point—that we aren't going to liquidate all the old-growth forests. There are 4.5 million acres of commercial forest land on the west-side national forests of Oregon and Washington that have timber stands over rotation age. These acres make up nearly two-thirds of the commercial forest land on those west-side forests, and their timber is a valuable resource with great potential for the regional and national economy. Of those 4.5 million acres, 2.4 million acres are in stands over 250 years old, and from which less than 10 percent of the timber has been removed. That is about a quarter of the area of those national forests. On top of that, there's some old-growth on private lands and on lands administered by the Bureau of Land Management. In spite of the clear need to accelerate harvest rates of the stands now over rotation age, it will take decades to work through this old-growth—and we plan to always retain an old-growth component.

In addition to the commercial old-growth already described, there's still a great deal more that's protected in research areas, in designated wilderness areas, and in national parks and similar forested areas that have been legislatively withdrawn from timber harvest. Olympic, Mount Rainier, North Cascades, Crater Lake and Redwood national parks all have large expanses of old-growth. In the national parks and national forests of the Pacific Northwest, there are about 2.7 million acres of Douglas-fir forest cover in existing or proposed wilderness alone—and most of this is old-growth. All of this old growth on non-commercial lands will also help meet the habitat needs of wildlife species preferring late-successional forest cover. Altogether, we are in no danger of running out of old-growth, and never will be.

We Will Manage Old-Growth to Maintain Viable Wildlife Populations

My third point on the old-growth is that we will manage the wildlife as one of many important resources in these stands. The Forest Service is well along with forest planning under the requirements of the National Forest Management Act of 1976. As the Forest Service plans the management of each national forest, it will plan to retain and manage an old-growth component that—at a minimum—will be adequate to ensure viable populations of the species which need old-growth. The planning process will also test alternatives that retain amounts of old-growth above that minimum. It will identify these alternative levels, not only for wildlife habitat, but for all the various values these stands provide—including timber. And it will evaluate the financial tradeoffs for each alternative. In that way, we can determine the best long-term approach for managing the old-growth.

We have recently proposed some changes in the regulations that govern this planning process on each of the national forests. Though most of our revisions have been editorial—reducing complexity, jargon, and redundancy—we have also used our experience with the process to make some substantive improvements. However, there has been some concern that our proposed changes will lead to forest plans that are designed to increase timber management at the expense of population viability for several wildlife or fish species.

This is not the case. What we are trying to do is to increase the land manager's flexibility in meeting fish and wildlife management objectives on the ground, and thereby do a better job of resource management. For example, the National Forest Management Act requires that the forest planning regulations "provide for diversity of plant and animal communities based on suitability and capability of the specific land area in order to meet overall multiple use objectives." In enacting this language, Congress intended that the habitat objectives would be established in the planning process and then followed on the ground by land managers. However, the foggy wording of the existing planning regulations implies that forest managers cannot alter the habitat of existing species, and that the existing habitat is to be maintained regardless of the cost and of the benefits foregone. We have tried to clarify this to conform with the law and in order to ensure the land manager's flexibility to manage the land area for all resource values.

Had we not done this, it could become quite difficult to do anything on the national forests without appearing to violate the regulations in some form. Even to do nothing could appear to violate these regulations if it would result in successional changes in the plant community that are detrimental to any management indicator species.

For example, consider a management indicator species that requires early succession, such as the Roosevelt elk. Given the principles of natural succession—that young growth matures and eventually becomes old growth—our failure periodically to interrupt the results of this plant succession, as nature commonly does by fire, would adversely affect elk populations.

Yet, managing for the elk could diminish habitat for the spotted owl—another management indicator species. Either way would appear to violate the existing planning regulations.

That illustrates why these particular changes to the regulations were necessary. The revised regulations will still require that all planning alternatives, as a minimum, provide for retention and management of habitat sufficient to maintain viable populations of the wildlife. This constitutes direction that's still more explicit than the statute itself, and which is more specific in the protections afforded fish and wildlife.

Since we published these revised regulations for public comment, we have received some constructive suggestions on how they can be further improved, and we expect to receive more before the public comment period closes on April 23, 1982. Through the revised regulations, in whatever form they take, wildlife and fish considerations will remain an essential part of forest planning. The 1983 proposed budget for wildlife and fish confirms that.

Let's look at how this forest planning system might work with the northern spotted owl, which is representative of the many wildlife species that find optimum habitat in the old-growth. Current information tentatively indicate that owl pairs may need as much as 300 acres of old-growth around the nest, and perhaps another 700 acres of old-growth within one and one-half miles. This information also suggests that nesting sites should be less than 12 miles apart to ensure adequate distribution of adult birds.

Right now, on the National Forests of Oregon and Washington, we have enough old-growth to provide habitat for 1,365 pairs of owls on a nesting interval of 2 miles. In its draft regional plan, the Forest Service is proposing a goal to retain an old-growth component sufficient to support at least 375 pairs of owls. And, through the planning process on each forest, it will evaluate alternatives which would retain and manage enough old-growth to sustain population levels well above that minimum. One part of this evaluation is an analysis of the financial tradeoffs in retaining this old-growth habitat.

Planners on the Siskiyou National Forest, for example, are testing alternatives which provide old-growth habitat sufficient to support owl populations ranging from a minimum of 31 pairs, up to 50 pairs. For each alternative, they have determined the average annual cost—in terms of the timber values foregone—when old-growth habitat is set aside.

For example, preliminary data indicates the Siskiyou can retain enough old-growth for 31 pairs of owls at a fairly reasonable opportunity cost, primarily because the forest can sustain 23 owl-pairs in designated wilderness—where the calculations assume no timber values. Supporting a higher population level of 40 pairs of owls, however, would increase this opportunity cost substantially. On one of the forests east of the Cascades, the planners have tentatively estimated that the average timber opportunity cost of providing habitat sufficient to support a maximum 12 pairs of owls is more than $100,000 per pair, annually.

Whatever population level is ultimately sustained, the habitat will be distributed throughout the existing range of the species, so that the owls can interact with others. Forest plans, once implemented, will be monitored to ensure that they are achieving the anticipated results, and to make whatever adjustments might be needed.

In practice, some of the planning alternatives considered by the national forest planning teams may call for more habitat for some selected species than exists now. For example, one forest plan alternative must address the long-term goals established through RPA—which, for fish and wildlife, call for significant increases in elk, anadromous fish and many other species. Correspondingly, some alternatives may provide less habitat than now exists. These alternatives will be evaluated according to many different criteria, including their social and financial impacts, the goods and services they produce, and their overall protection and enhancement of the environment. As for how the fisheries and wildlife resource will fare in that sort of analysis, let me suggest that manipulating tree cover is usually too expensive to justify for wildlife purposes alone. We can do direct habitat improvement work, but biologists will buy more mileage for many wildlife species when the habitat management efforts for those species can be integrated with other resource programs.

For example, consider a management area on the Winema National Forest, near Klamath Falls, Oregon. Last year, this area contained 16 bald eagle nests—seven of them active. There are also at least two pairs of spotted owls, some wetlands, habitat for several other wildlife species and significant timber values within the management area. It used to be that, for bald eagle nests, the silviculturists would draw a 300-acre circle around the nest, and stay out of it. But biologists know more about the eagle's habitat requirements now; they know the specific old-growth characteristics the eagles prefer.

So, the biologists and silviculturists on the Winema have devised a combination of silvicultural methods to sustain or increase the number of eagles on the area, maintain the habitat for spotted owls and other wildlife, protect the aesthetics and ensure perpetual yields of timber, too.

Though it's not accurate to say that "good timber management is always good wildlife management," let's admit that neither is it all negative. Whether timber management is good or bad for wildlife and fish depends a lot on how well the biologists and silviculturists can work together. Twenty years ago Robert H. Giles told this conference that "the time has come to face up to the fact that the harvest of wood, a forester's function, has greater influence on wildlife than any active technique available to the wildlifer. In one sale a forester can influence more cover over a longer time than a wildlife manager can create in a decade. The wildlifer, realizing the potentials of the wood harvest, must not only increase the effectiveness of his present practices, but must provide guidance for foresters so their efforts will not so strongly negate his efforts and can be made to complement them."

As I close, let me say that you can help—and we want your help—in our efforts to improve management on the national forests. Our priorities are clear, but our initiatives are directed at the broad array of resources on these forests. We are working to improve the integrated management of those resources together. Your help with the fish and wildlife resources can lend a fuller dimension to our efforts.

Resource Management Thrusts and Opportunities: National Parks and Wildlife Refuges

G. Ray Arnett
Assistant Secretary of Fish and Wildlife and Parks
U.S. Department of the Interior
Washington, D.C.

It's always a pleasure to participate in the North American. And it's especially good to be here this year to share with you some of the more important accomplishments made this year on behalf of our national parks, wildlife refuges and wildlife conservation programs.

It has been an interesting year indeed since the last North American. A year ago at the Conference held in Washington, D.C., Interior Secretary Jim Watt outlined some of the Administration's goals and some of his personal goals in resource management, and the role resources could play in economic recovery and energy independence for the U.S. His message was clear and precise. There would be orderly, phased development. There would be resource use as well as resource protection. And development wouldn't be at the unnecessary expense of natural resources.

Well, it's been an interesting year. Somehow, it got to be very convenient for some folks to misconstrue what the Secretary had said. Some of those folks just seemed determined to make James Watt a household name—and they succeeded. And those same folks succeeded, too, in increasing the membership roles of a few of the environmental groups. But I don't think they succeeded very well in listening to and understanding what the Secretary said a year ago. . . . So, as succinctly and plainly as possible, I will spell out again that the goals of this Administration weren't designed to create the perfect agenda for environmentalism, nor for development interests for that matter. The goals weren't pipe-dream perfection stuff for anybody . . . but common sense management, balanced economic growth geared to benefit the entire country . . . through orderly phased development and resource use based on wise, scientific wildlife, fishery and resources management. And I'm happy to say we've stuck to that original goal—no matter how others have tried to bungle it or misinterpret it—and I'm delighted to report we've made some pretty important achievements in the last year.

Now, remember back about a year or so ago, how some would have you believe that our goals were to develop hit lists on the national wildlife refuges . . . to sell off and drill for oil in national parks . . . and to draw a bead, figuratively if not literally, on endangered species. Well, in all three instances just the opposite took place, as we intended: we increased the size of the National Wildlife Refuge System (adding some critically important bottomland hardwood habitats too). We initiated stronger and more effective policies to address the real-world policies of maintenance and human safety in our national parks by adding $191 million to the park budget. And we nearly doubled the number of recovery plans for endangered species over 1980. These are just a few of our accomplishments—I'll mention more in a little while.

The point to be made for now is that . . . the Jeremiahs may have had their fun predicting gloom and doom . . . and the Chicken Littles have had their hour running around bumping into everything and shouting about all manner of woes . . . but the fact remains, there are conservation programs underway now that are as sound as—or more sound than—any that have gone before. There is continuity to our conservation efforts; there has been perseverance to get the job done under tight fiscal circumstances; and there have been many outstanding achievements made for American resources and the American people by the professionals in the National Park Service and Fish and Wildlife Service.

This has been a year of changes, to be sure. This is what Ronald Reagan promised the American people during the campaign. Many of the changes were brought about directly because of budget cuts. Some other changes were less fiscal than philosophical . . . For example, the need to be good neighbors, to work more closely with the States . . . the need to be more cooperative, not just with *some* conservation groups (as it had been in the past) but with all the public, including developers. These objectives made sense a year ago and they make sense today. Our original agenda remains unchanged.

One of our special objectives is better, more believable, more solid information on our resources, our parks, wildlife and wildlands. We don't need pious guestimates; we don't need glittering ecological generalizations. There was entirely too much of that in the past and a lot of erroneous conclusions and questionable resource decisions were the result. The public has enjoyed about as much of that as it can stand! Instead, we need believable data interpretation; we need complete information. We need data on wildlife and resources, on our parks and refuges; and we want it comprehensive, accurate and up-to-date. We can ill afford to editorialize on wildlife populations if all we have are questionable shreds of data. Sooner or later, it's a bluff that will be called—and then, truly, resources will be imperiled.

Obviously, good information doesn't come cheap. It costs money and these are pretty tight times for the natural resource community. But you can get the most for your dollar by planning to spend it wisely and keeping tabs on the progress of your projects.

The National Park Service has taken some encouraging steps toward improving its baseline information. Surprisingly, few parks have ever had an adequate inventory of their resources. Few have had adequate information to implement enlightened management strategies. Knowledge of the identity and location of park resources is essential to sound park management. Hence, high priority will be given to conducting field studies of all types of resources—the physical, biological, archeological and historical.

This system will take time to implement. It'll cost money, too. But it will be worth it. It will be an investment in good management—a system that addresses the reality of the park resources and a system that can quickly and efficiently convey this information to managers. And in reference to the National Parks, I'm sure you all remember when Secretary Watt declared those famous words: "We'll fix the plumbing." Well, indeed we will. Now, park maintenance is not a glamorous topic in the conservation community. In fact, you'll find a few Park Service employees in the regional and Washington offices whose eyes begin to glaze over at the mere mention of the topic. But . . . with park superintendents, with park staff, and with park visitors, it's a most welcomed goal. They know and have known the maintenance problems that plague many of the parks' facilities. It's far from being a frivolous matter. Human health and safety are at issue . . . as well as basic enjoyment of our parks, for the majority of our citizens who want to use them. Everyone knows that some wilderness areas are wonderful and inspirational—for those who enjoy them—but, wilderness isn't for everyone. In fact, it's used by very few—mostly the young and hardy who have the necessary time to acquire a wilderness experience.

Most people, however, are limited. They want a good, safe, accessible park. They want facilities they can use; facilities that work; drinking water that's safe; a place to rest, to change the baby's diaper . . . These are just a few of the reasons why we doubled our requested funding over what the previous Administration wanted to start correcting these problems. And the Congress is supporting this initiative—as we seek one billion dollars over the next five years to restore and improve the National Parks.

In line with this, we instituted a near moratorium on park land fee acquisition. I know that some of you and a few groups would and do argue that, in the face of increasing inflation and human populations, we must set aside as much park land as possible right now, today, in order to meet future demand. I understand what they're trying to get at in their argument; but, I don't think it's likely, realistic or all that desirable to make a direct linkage between population growth and Federal acquisition of park lands. The real pressures exerted by the current human population—and the increasing human use of the parks each year—suggest strongly that we better take care first and foremost of those parks we have . . . before their values are hopelessly compromised and their resources irretrievably lost and "loved to death." That's why the immediate issue . . . practical day-in and day-out care and maintenance of our National Parks . . . must not be slighted. Let's show the parks and the people who use them some basic, genuine respect: let's fix up the parks; let's encourage folks to use them; let's keep the parks properly maintained in a systematic, conscientious ongoing way . . . so there won't have to be a repeat of this kind of situation we're faced with now to try to correct so many years of neglect and underfunding.

I'm sure that many of you are aware of some of the more publicized changes this past year within the Fish and Wildlife Service. While the overall thrust of these reported changes may have emphasized budget cuts, there was an overriding managerial goal as well—to manage better, to get back to the essentials and stress the core missions of the Service. One of the more visible changes was the closure of Area Offices. By September 30, they will be closed. Some of the Area Offices' staff will be reassigned to the Regional Offices, but many will be placed where they are needed most—at the project level, at the field level, closer to the resource. The closure of Area Offices was not, I should emphasize, strictly a budget move. It was not intended as a fiscal response. It was motivated by the recognition that the Service needed to streamline its chain of command. It needed to improve the link between field stations and regional offices. Now, this is not to say the Area Office concept has not performed some valuable jobs for the Service and provided some valuable assistance to the States. But in the wider perspective—taking in not only the current budget pictures, but also management and resource needs—the time was right for a change.

I realize the closure of Area Offices may strike some as something of a contradiction to the Department's overall "good neighbor" policy and to our repeated goal of working more closely with the States. . . . I'll grant that an Area Office was usually closer, geographically, to individual State wildlife agencies. But, day in and day out, States found that they still had to conduct much, if not most, of their dealings with regional offices . . . though it sometimes took several phone calls between States, Area and Regional offices to sort that out . . . So, with the shift back to regional operations, the Service will be making concerted efforts to maintain continuing and even better communications with each State within that region. Close cooperation in something as important as wildlife resource protection and management cannot be left to chance. The Service will have to initiate continuous, productive outreach to State sportsmen groups, wildlife agencies, and political leaders to learn what they're doing, what's going on, to find out what the States see as important. The Fish and Wildlife Service can't afford to conduct its planning or activities in a vacuum. The Service needs State input, State advice to achieve a balanced view on which to base its plans and commit its fiscal and manpower resources.

The "good neighbor" policy you heard about is offered to the States, to be sure. It is also for the benefit of the resource and the general public. In the case of refuges, it means taking a good hard look at the issue of access. And asking some direct questions to see if there aren't ways to manage and protect wildlife *and* to accommodate legitimate and valid human uses that won't compromise or interfere with the resource. We have made decisions on the Pea Island and Chincoteague National Wildlife Refuges, for example, that illustrate well our commitment to safeguard resources and recognize the reality of public needs. We also want to increase the recreational potential, within reason and within limits, on national wildlife refuges. As many of you are aware, the recently completed 1980 National Hunting and Fishery Survey indicates that once again, Americans are not only interested in the outdoors, they're actively pursuing outdoor recreation. Carefully managed and with conscientiously applied programs, the refuges can afford excellent recreational opportunities for millions of Americans.

One of our most important resource management goals in the 1980s will be to help those millions of Americans who treasure wildlife . . . to help them to better understand wildlife . . . to learn about the habitat that wildlife require . . . about wildlife management, how it works, why it works, and why we need more, rather than less, good sound scientific wildlife management in the years and decades ahead.

It may be all well and good for some people to entertain fantasies about peaceable kingdoms where wild creatures are ever in harmony and balance, and where the lamb and the lion will lie together. Well, there may be a garden of Eden that exists on this planet, but I'm not sure. However, our collective experiences, our observations and our records tell us that without wildlife conservation, without the benefit of wildlife management, many species of wildlife would be gone today. Wildlife management has been a success. Sound scientific management can continue to bring solid results; it's no time to back away from it now. As mentioned earlier, in the Park Service and in the Fish and Wildlife Service, there is an increased emphasis on basic information, reliable information . . . and practical, realistic solutions. Wildlife management is a day-to-day pursuit. It's work that requires diligence and a sense of commitment. There are no technological substitutes for a good, practical wildlife biologist or a good, common-sense wildlife manager.

Our resource budgets may remain tight for some time yet. Our resource decisions in the future may be more challenging than at any time in the past. The need to develop and better utilize our natural resources is real; it won't go away. The need for resource managers and for the public alike is to realize that there can be protection along with development; there can be wise use. There can be common sense, and there can be cooperation. And I pledge you my best efforts to help bring about a balance that will get America moving again without sacrificing our environment or wildlife resources.

Resource Management Thrusts and Opportunities: BLM-Administered Public Lands

D. Dean Bibles
Assistant Director
U.S. Bureau of Land Management
Washington, D.C.

Director Burford regrets that he could not be with you today. Congressional hearings have a high priority in our scheduling, so he's up on the Hill. Bob did want me to tell you about some of the actions we are taking relative to resource management on the public lands we administer, and how these actions influence wildlife and other renewable resources.

It is no surprise to most of us that the 80s are bringing some dramatic departures from past resource management practices, plus significant changes in emphasis.

Many of us learned early in our education or careers that the definition for conservation boiled down to wise use of natural resources. In fact, environment was then only a textbook word meaning the surroundings of a living organism. Unfortunately, there now seems to be a tendency to lump people who are interested in natural resources into one of four broad categories: either you're a *developer,* a *conservationist,* an *environmentalist,* or a *protectionist.*

Such generalities are naive and dangerous. But if such a narrow viewpoint was used to label BLM's natural resource philosophy, I would hope that the conservationist approach would be the choice.

However, we seldom deal in the luxury of simplistic generalities. There are lands under BLM jurisdiction where resource development should have more emphasis. These are lands that can help reduce America's dependence on foreign sources for oil and gas and strategic minerals. There are also areas where a protectionist philosophy should prevail.

But, for most of the lands we administer, aggressive management will be used to provide expanded resource use rather than favoring a more passive role of resource protection. In all we do, we hope to establish and maintain *balance.*

The "sagebrush rebellion" has helped us recognize that changes must and should be made in the management of public land and related resources. We are rapidly decentralizing our organizational structure from the top to the ground. Headquarters and state office personnel allocations are being substantially reduced to shift our capabilities to the District and Resource Area offices. This will increase our sensitivity to local needs and favor on-the-ground solutions to resource conflicts and problems.

And, in an effort to be more responsive to local needs, we are streamlining our procedures—inventory, data systems, planning, rights-of-way processing, State land selections, withdrawal review, and energy and mineral leasing. Without question, our top priority is fostering the production of energy and strategic minerals. This means improved access and simplified procedures to expedite exploration and development.

This does not mean that the Administration lacks concern for renewable resources. This concern, however, will be in the context of major national priorities such as national defense, energy self-sufficiency, and restoring a viable economy. The key role of the public lands will be to contribute to domestic production of food and fiber; energy minerals; and to facilitate discoveries of non-energy minerals that are critical to our national well-being. Other uses, such as recreation and wildlife, will be woven into our plans for mineral development and rangeland management.

I see two major components in the current shift of management to the local scene and the corresponding decrease in Federal involvement. Reductions in Federal funding to try and reduce the heavy budget deficit are bound to continue over the short run. It is unrealistic to expect that any significant Federal funding will accompany the shift of responsibilities to the local land manager.

Second, a philosophy is emerging that those who benefit from public lands and resources should pay for those benefits.

In relating these factors to the Bureau's wildlife program, we look for an enlarged role by the State wildlife agencies. Under expanded State participation, you will see decreased Federal spending on habitat management overhead. This is happening now.

I can see the questions already forming—are we abdicating our statutory responsibilities to protect the fish and wildlife resources of the public lands? Definitely not! Our responsibilities for managing public land wildlife habitats, as spelled out in such legislation as the Sikes Act, the Public Rangelands Improvement Act, the Endangered Species Act, and the Federal Land Policy and Management Act, are fairly specific.

The potential impacts of other land-use activities will determine our priorities for wildlife over the short run. Where changes in wildlife habitat seem likely, our efforts will maintain the quality of such habitats or develop alternative habitat areas for those priority species involved.

We are improving our resource management planning by making the process more issue oriented—focusing toward locations where major land use actions are occurring and where wildlife or other resource needs, values, and conflicts are apparent.

As a major component of our wildlife inventories, we will continue to consult with the States for wildlife population data, and to cooperate in actual work leading to credible wildlife components of all Resource Management Plans.

The Resource Management Plan remains the basic vehicle for resolving wildlife conflicts with other public land uses, and for establishing wildlife objectives and priorities. Our wildlifers will provide technical representation for these plans, and strongly advocate wildlife needs and values in specific planning efforts. Other wildlife interests will also have opportunities for involvement in developing these plans.

Once a Resource Management Plan is approved and any subsequent resource development begins, increasing emphasis will be placed on monitoring to ensure that wildlife objectives are being met, and that wildlife stipulations and any mitigating measures are being followed in an effective manner. Through such monitoring, we will measure the effects of our management and make changes where needed.

We will also be working to enhance the habitat for priority species of wildlife through Habitat Management Plans, and through incorporating wildlife objectives in other activities such as livestock grazing, timber, mining, and rights-of-way. Priority in this case means those species having high economic, recreational, social, aesthetic, or scientific values. These activity plans are developed and implemented under the authority of the Sikes Act in close cooperation with the States.

Several new policies affecting public land resources are now in the evolutionary stage. One of these is a new wildlife policy. Early drafts of this policy have been reviewed by the various States, conservation organizations, and user interests. Although basically a compilation of existing policies into one cohesive document, the Administration is carefully reviewing it, and when completed, it will represent the Administration's policies, philosophies and priorities regarding our wildlife habitat work. We expect this policy document to be approved shortly.

As most of you know, public lands administered by the Bureau of Land Management were not covered by the Wilderness Act of 1964. The Federal Land Policy and Management Act of 1976 changed this and we are taking a close look at about 24 million acres designated as Wilderness Study Areas. The Bureau recently issued its wilderness management policy, and some features of it affect the wildlife resource and our Federal-State responsibilities. A few of these are appropriate to discuss; however, the policies relate only to Congressionally-designated wilderness units:

- Wilderness management plans will specify wildlife habitat conditions to be maintained. Development of these plans will involve State wildlife people.
- Manipulation of vegetation to benefit wildlife may be approved by BLM State Directors.
- Habitat changes through chemical or mechanical means may be approved by State Directors when necessary to correct conditions caused by humans.
- Wildfire or prescribed burning may be authorized.
- Temporary facilities for trapping or transplanting of wildlife may be authorized.
- Under certain conditions, the Bureau may authorize permanent wildlife facilities such as watering places, enclosures, or stream improvements.

We are maintaining a strong commitment to protect threatened or endangered species and fully intend to use our various authorities to manage aggressively on behalf of such species.

In September 1981, Interior Solicitor Coldiron issued an opinion rescinding prior opinions that established those Federal appropriative water rights referred to as "non-reserved." The Solicitor concluded that the Federal government must acquire water as would any other private claimant within the various States.

A new Public Lands Water Rights Policy for livestock watering was subsequently issued by BLM in December 1981. Although this policy may have some spin-off effects on wildlife, it does not relate to water developed solely for wildlife purposes, nor does it affect Federal reserved water rights. We are analyzing the potential impacts of this policy on wildlife, fisheries, and recreation where State water laws fail to recognize these as beneficial uses of water.

A final policy on livestock grazing on the public lands was announced two weeks ago. Highlights of this policy include making grazing management more efficient and cost effective under the existing resource management planning system and classifying grazing allotments into one of three categories based on similar characteristics, management needs, and potential for improvement for both livestock and wildlife. Improving the efficiency and cost effectiveness of the grazing program within the planning system will allow us to use "selective management" in assigning management priorities among allotments within a planning area.

In carrying this philosophy even farther, grazing allotments would be categorized into those where we would manage to maintain a current satisfactory condition, manage to improve a current unsatisfactory condition, or manage at a custodial level while continuing to protect existing resource values. Funding will be mainly directed at those areas where a currently unsatisfactory condition can be improved significantly with a limited investment. The Bureau has also produced a Rangeland Improvement Policy that should become final any day now. It basically covers construction, funding, and maintenance of rangeland improvements. There would be more restrictive use of range betterment funds: Funds would be earmarked for on-the-ground work. We expect to avoid overhead and administrative cost charges to this fund. This Rangeland Improvement Policy would not affect wildlife project funds, the ways in which rangeland improvements can benefit wildlife, or our overall wildlife program operations.

A policy on the *maintenance* of rangeland improvements is not final, but the trend is to have range users carry part or all of the costs. There are also opportunities for wildlife and other conservation groups to became involved through construction of watering places and other habitat improvements.

The Bureau's resource management planning system is being reviewed to determine the need for amendments to the planning regulations. The basic thrust is to streamline the planning process so that decisions will not be delayed.

Proposed amendments were published last November and we are now developing final regulations based in part on the many well-developed comments that were received. The final rules will reflect consideration of the public comments and our objectives of shorter plan preparation time, lower planning costs, increased field manager authority, and simplified regulations that are easier to understand.

We are committed to assuring full public participation opportunities for wildlife and other interests as called for by the Federal Land Policy and Management Act.

Although increased local operational authority at our District and Area Office levels, and some relaxation of Bureauwide standards, might be seen as having potential for inconsistencies in the planning process, we are confident that close monitoring of significant resource actions will see that wildlife receives full consideration. The Bureau continues to emphasize wildlife programs and cooperation with State agencies under the Sikes Act. New policy initiatives call for increased cooperation and coordination with the Forest Service and their Sikes Act programs, including development of more statewide plans and long-range goals.

At the end of Fiscal Year 1981, BLM had prepared 194 Sikes Act Habitat Management Plans (HMPs) in 12 western States. These HMPs address on-the-ground habitat improvement, maintenance, and protection actions for more than 1600 miles of stream and almost 33 million acres of public land. Expenditures to date for Sikes Act Habitat Management Plans now totals nearly $12 million. State agencies are working partners in these habitat plans, contributing manpower and money to the projects.

In summation, major changes are occurring that will affect the wildlife resources of the public lands. And with fewer Federal dollars or personnel, and emphasis on decentralization, the States face a bigger role concerning public land wildlife resources. It is also unlikely that Federal funds will be provided in support of this additional responsibility.

In June 1981, the Wildlife Management Institute completed an evaluation for the Bureau's wildlife and fisheries program. BLM contracted with the Institute for this study. The report contained 36 recommendations for improving wildlife habitat management on the public lands. The main thrust of this evaluation's findings dealt with improving our coordination with State wildlife agencies, the Forest Service, other Federal agencies, and user interests. Other findings outlined constructive suggestions for improvements in the planning-NEPA processes, wildlife personnel training, personnel and organizational function, and stronger coordination between BLM's wildlife program and each of our other resource programs. Within constraints of funding and personnel ceilings, we are moving out with a plan to implement the Institute's recommendations. We have a limited number of copies of this report and, while they last, you can get one from the Bureau's Wildlife Division in Washington.

Management of public land wildlife resources is facing its greatest challenge. It will be a monumental task to provide for wildlife's needs and maintain a viable species diversity and abundance in view of the many conflicts and strong competition from other uses. I believe it can be done, but only through an appropriate emphasis on well-planned priorities, management innovations, and an even higher level of cooperation between the federal land managers, the State wildlife agencies, and the concerned private organizations and individuals.

Habitat Classification—Assessments For Wildlife and Fish

Chairman:
HAL SALWASSER
National Wildlife Ecologist
USDA Forest Service
Washington, D.C.
Cochairman:
WILLIAM B. KROHN
Project Leader, Habitat Classification and Evaluation
Office of Biological Services
U.S. Fish and Wildlife Service
Washington, D.C.

Opening Remarks

William B. Krohn and Hal Salwasser

Comprehensive planning and management of natural resources require the assessment of existing and future conditions of fish and wildlife. Fish and wildlife, hereafter referred to as wildlife resources, can be inventoried and assessed either in terms of animals or habitats. Both approaches are useful given certain management objectives. For example, population inventories in concert with other data, are often used to assess the impacts of hunting. In contrast, habitat inventories are used to evaluate the impacts of grazing, or other land and water uses, on wildlife resources. Our objective is not to compare or contrast the two approaches, but to focus on habitat assessments and the growing need for wildlife resource managers to more effectively influence the planning and management of land and water (i.e., habitats).

There is increasing recognition in the wildlife resource profession of the need to more fully understand and quantify the relationships between species and their habitats. For example, a review of wildlife research needs by Sanderson et al. (1979:167) stated that "The basic goal in wildlife research is an information base on animals and their habitats that will allow prediction of the effects of changes in animal-habitat relationships." Concurrent with this basic goal is the recognition that ". . . knowledge on relationships among habitat, wildlife abundance and land use is poorly developed . . ." (New England Research Inc. 1980:65) and that ". . . Research is needed to provide data for verifying functional curves and correlating biotic and abiotic variables to habitat quality" (U.S. Army Corps of Engineers 1980:81).

There is a growing consensus that classification, as such, is only a part of habitat assessment. There is also a growing recognition that user needs, when translated into specific analyses, should drive habitat evaluation systems.[1] Thus, this session emphasizes habitat assessment over habitat classification and is designed to address four questions: (1) What must a habitat evaluation accomplish? (2) What methods are being developed and used? (3) How are the methods related? and (4) What is needed to improve the art and science of habitat assessment?

To address these four questions, the session has been organized into an introduction, three panels, and closing remarks. After these introductory remarks, the first paper will discuss the needs for and approaches to habitat assessment. Next, the three panels will cover the following topics: (1) species-habitat modeling, (2) model application and testing, and (3) habitat evaluation programs. A discussion period will follow each panel. Finally, the closing remarks will summarize the session.

We are pleased that you are here today to help us take a look at specific habitat assessment methods, to evaluate how far we have come towards a common assessment approach, and to help us chart a course for future improvements.

Literature Cited

New England Research, Inc. 1980. Investigation of the relationship between land use and wildlife abundance. Vol. I: literature survey. Contract rep. 80–C2. U.S. Army Corps of Engineers, Fort Belvoir, Va. 146 pp.

Sanderson, G. C., E. D. Ables, R. D. Sparrowe, J. R. Grieb, L. D. Harris, and A. N. Moen. 1979. Research needs in wildlife. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 166–175.

U.S. Army Corps of Engineers. 1980. A habitat evaluation system for water resources planning. U.S. Army Corps of Engineers, Vicksburg, Ms. 89 pp.

[1]For a supporting rationale, see: Coulombe, H. N., J. D. Buffington, and W. B. Krohn. 1982 (In press). Relationships between classification, mapping, inventory, analysis, and information systems. Proceedings of In-Place Resource Inventories: Principles and Practices. University of Maine, Orono.

Needs For and Approaches To Wildlife Habitat Assessment[1]

Jack Ward Thomas

U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, La Grande, Oregon

The 1970s—A Time of Revolution

The period, 1969–1980, brought a dramatic change in how Americans view wildlife and its management. The change, a revolution in perception, was simply the recognition that *all* wildlife are important in and of themselves and as part of a larger functioning whole—an ecosystem. This perceptual revolution in concept is now fixed firmly in law, but its impacts are only gradually working their way into full-scale application by governmental agencies at both state and federal levels.

For many years prior to 1969, wildlife was essentially defined, in the practice of governmental bodies, as those species hunted for sport, trapped for furs, controlled to accomplish human objectives, or of particular aesthetic value. Governmental management of these species was based on funding obtained from or supported largely by clearly identified constituencies.

Universities evolved specialized programs in wildlife biology and management to produce the knowledge and trained professionals to meet these needs. Many such programs were oriented to training in zoology which emphasized the animal and populations while paying less attention to habitat.

As a result, most wildlife research was focused on a few species, and was directed to their taxonomy, population level and dynamics, life history, behavior, distribution, and food habits. Comparatively little effort was spent on defining habitat requirements of even these select species. And, little attention was given to the study, welfare, and management of other species.

For many decades preceding the revolution, scientists expanded the science of ecology. They taught principles of ecological management to generations of wildlife managers and researchers. Those students went to work in mission-oriented organizations that served well-defined constituencies such as graziers, hunters and fishermen, and the wood-products industry. Simultaneously, these ideas about a holistic management philosophy were reaching thousands of other people. New interest groups formed around wildlife for reasons other than or in addition to sport hunting, trapping, nuisance wildlife control, etc.

Suddenly, as if a dam had broken, there was a flood of state and federal legislation that mandated these revolutionary perceptions into actions that instructed those who serve in government agencies on how wildlife would be considered and managed. To many practicing wildlife professionals this has caused wrenching adjustments to new realities.

The seminal piece of legislation that stirred this revolution in concept was the

[1]This paper, in a very similar format, was first prepared (Thomas 1982) for inclusion in a book prepared by the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency. William T. Mason, Jr., Editor, has given permission for the use of that material.

National Environment Policy Act of 1969 or NEPA (U.S. Laws, Statutes, etc., Public Law 91-190). NEPA required that the environmental consequences, including impacts on wildlife, of any activity involving federal funds be described prior to action on the project. This made it necessary for wildlife to be much more broadly defined but also *understood and described in relationship to alterations in habitat*. Other pieces of legislation emerged in 1969 and the 1970s that also mandated better and broader consideration of wildlife. These included the National Forest Management Act of 1976 (U.S. Laws, Statutes, etc., Public Law 94-588), the Endangered Species Conservation Act of 1969 (U.S. Laws, Statutes, etc., Public Law 91-135), the Endangered Species Act of 1973 (U.S. Laws, Statutes, etc., Public Law 93-205), and the Forest and Rangeland Renewable Resources Planning Act of 1974 (U.S. Laws, Statutes, etc., Public Law 93-378). Still, the National Environmental Policy Act of 1969 set the stage in terms of what had to be described and considered in order to be responsive to the new legislative mandates.

That revolutionary concept, now embodied in law and associated regulations and tested in the courts, makes it essential that biologists be able to relate all species to habitat conditions and be able to predict species response to habitat alterations. The task is enormous and perhaps one of the most challenging ever to face professionals in wildlife biology and other areas of applied ecology.

Management Needs and the Data Base

Sufficient data to accomplish this task are available for relatively few of the vertebrate species in the United States. Research data on the relationships of species to habitat continues to emerge, mostly in bits and pieces, and seemingly at an increasing rate. But it will be many decades, if ever, before a data base totally derived from well-designed site-specific research is available in a form that is readily adaptable to planning. This is further aggravated by the fact that existing information on species/habitat relationships is scattered throughout the literature and is not consistent in terms of research approach, analysis, or reporting. Existing and emerging research data on species/habitat relationships can be generally categorized as fragments of information of varying quality from many locations that contribute, like pieces of a jig-saw puzzle, to some useful understanding of species/habitat relationships.

In short, it has become increasingly obvious that biologists should try to put existing knowledge and theory into a framework that can be utilized in land-use planning and in helping meet legal mandates. That process requires innovative use of basic ecological principles in formulating systems for analyzing and interpreting existing data. When statistically sound results from replicated scientific studies are not available, the opinions of "qualified experts" will have to serve until the gaps in scientific knowledge, identified through planning and evaluation process, are filled. Efforts to develop procedures to investigate the relationship between land-use and wildlife abundance have been thoroughly reviewed elsewhere (New England Research, Inc. 1980).

Wildlife Management Strategies

The scientifically based art of wildlife population and habitat management is usually considered in one of three ways: (1) featured species management (Holbrook 1974), (2) species richness management (Siderits and Radtke 1977), or (3) some combination of the two (Figure 1). In featured species management, the objective is production of selected species in desired numbers in specified places. With species richness management, the aim is to insure that a broad spectrum of species is maintained within a geographic area of concern (Figure 2).

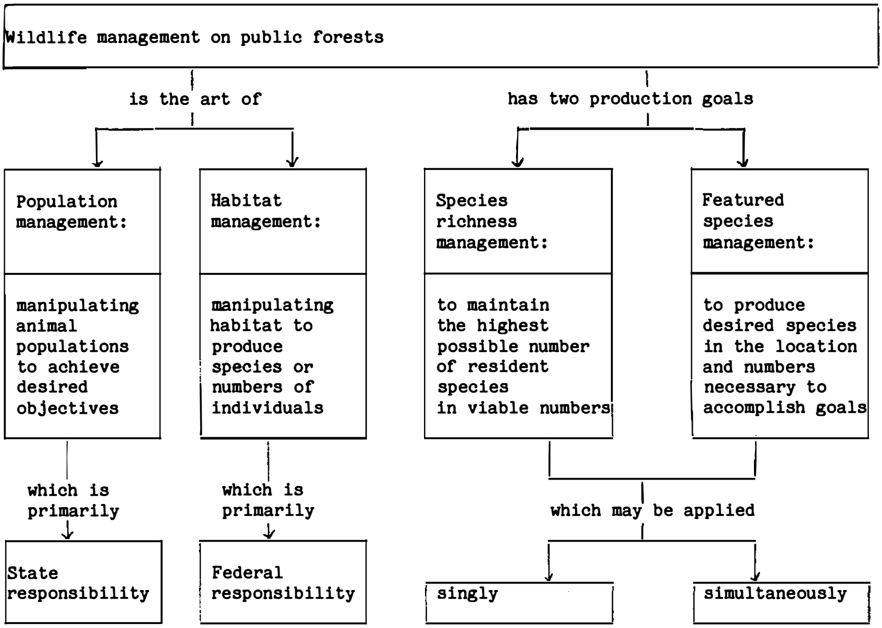


Figure 1. The arts and goals of wildlife management on public lands (after Thomas 1979a).

Production goal	Management for species richness	Featured species management
Objective	Insure that all resident species exist in viable numbers. All species are important.	Produce selected species in desired numbers in designated locations. Production of selected species is of prime importance.
Process	Manipulate vegetation so that characteristic stages of each plant community are represented in the vegetative mosaic.	Manipulate vegetation so that limiting factors are made less limiting.

Figure 2. Production goals, objectives, and processes for wildlife habitat management on public lands (after Thomas 1979a).

Featured species management has been the most common type of management pursued by state and federal agencies. The information needed to carry out the habitat manipulation aspects was accomplished by determining the habitat requirements of the featured species. As a result, much of the research on species/habitat relationships has been focused on comparatively few species. This information was usually gathered by studying how a species was related to its habitat in a particular place.

Species richness management came more into vogue with both state and federal land management agencies with the advent of increasing environmental awareness and the resultant federal legislation. The vast number of wildlife species present, or potentially present, in any area makes it impractical to study, individually, the relationship of each species to its habitat. There are probable advantages, in terms of costs and time, to be gained by describing habitats by categories such as plant communities and successional stages or structural conditions and, then, by relating the species present to those habitats (Thomas 1979b).

Habitat Analysis—Habitat Evaluation Procedures (HEP)

Two predominant approaches evolved to answer the demands of the law and challenges of the "environmental 70s" for information on species/habitat relationships. The U.S. Fish and Wildlife Service sponsored the development of a process or technique to evaluate habitat suitability for individual species called Habitat Evaluation Procedure (HEP) (Flood et al. 1977, U.S. Fish and Wildlife Service 1980). The procedure is particularly well-adapted to evaluating habitat suitability or judging habitat manipulation responses for individual (featured) species. This and similar procedures (McCuen and Whitaker 1975, Willis 1975, Whitaker and McCuen 1976, Whitaker et al. 1976, Nichols et al. 1977, Williams et al. 1978, Russell et al. 1980) are numerical rating schemes in which key habitat factors are described and rated, the scores weighted appropriately, and a final value calculated. The overall suitability of the habitat is estimated. Habitat deficiencies or limiting factors that can be altered to benefit the species in question can be identified.

A somewhat similar system was developed by USDA Forest Service research scientists in modeling impacts of management alternatives to achieve multiple-use forest management in the eastern United States (Boyce 1977). In this approach, the consequences of manipulating key habitat characters, such as the proportion of the area in identifiable structural states, frequency of openings or the basal area of trees, were evaluated for selected wildlife species and other multiple-use products.

Such systems have the advantage of being largely objective and usable by different observers. The question, of course, is how well the developers of the particular species rating system or species/habitat model identify the truly significant habitat variables to be evaluated and how appropriately they are valued or weighted in the mathematical rating scheme. Ideally, each HEP for each species in each ecologically distinct area would be tested repeatedly and "fine-tuned" accordingly. In practice this has seldom been the case because of the large research investment required.

HEP can be adapted to guide efforts in species richness evaluation and management, preparation of environmental impact statements, and generalized wildlife habitat evaluation. This is done by preparing a HEP for a species that serves as an indicator of certain habitat conditions or, conversely, stands as a surrogate for a group of species that requires the same or very similar habitats. This is, for example, in keeping with the regulations issued pursuant to the National Forest Management Act of 1976 (U.S. Laws, Statutes, etc., Public Law 94-588) that requires the inventory of "indicator species" as a means of determining if wildlife planning objectives are being met.

Habitat Analysis—Wildlife and Fish Habitat Relationships (WFHR)

A quite different approach was independently developed by David R. Patton of the USDA Forest Service (Patton 1978) in the southwestern United States and by a team of 16 contributors from the USDA Forest Service, the Bureau of Land Management, and the Oregon Department of Fish and Wildlife for the Blue Mountains of Oregon and Washington (Thomas et al. 1976, Thomas 1979b). These systems use habitat as the key to analysis. Habitats are classified or categorized and the wildlife associated with these conditions identified. The earlier work of Reynolds and Johnson (1964), though confined to one small study area, was much the same in approach.

These efforts (Patton 1978, Thomas 1979b), though regional in scope, presented principles, concepts, and techniques that were found to be adaptable to other areas. These efforts provided the seminal direction and framework for the development of species/habitat information systems and models that are underway or planned for most of the USDA Forest Service's nine regions (Nelson and Salwasser 1982). This approach to systematic consideration of species/habitat information has become known in the USDA Forest Service as the Wildlife and Fish Habitat Relationships (WFHR) system, although considerations of fish life are just now being developed.

Salwasser et al. (1980) said that:

> Wildlife and Fish Habitat Relationships is a relatively new term—it is not a new philosophy or approach to resource management. It is simply the comprehensive organization of the vast array of existing information in a format that is useful in managing animals through managing their corresponding habitats. The philosophical basis of WFHR dates back to Joseph Grinnel and Aldo Leopold. Intertwined is the current state-of-the-art of ecosystem approaches to natural resource management; in this case, an attempt to view wildlife habitat from the animal community as well as the single species perspective. The philosophy has been incorporated in the . . . [environmental legislation of the 1970s that was mentioned earlier].

The WFHR system has already been adapted for use in other areas of the west (Wischnofske 1977, Verner and Boss 1980, Capp et al. n.d., and others). The system, originally applied to forest lands, is being adapted for rangelands of the Great Basin in southeastern Oregon in order to demonstrate applicability to rangeland conditions. Six of 14 planned "chapters" of this effort have been printed (Bowers et al. 1979, Maser et al. 1979a, Maser et al. 1979b, Thomas et al. 1979a, Thomas et al. 1979b, Dealy et al. 1981).

The WFHR system divides habitat considerations for terrestrial wildlife into three general parts: (1) the habitat (described by plant community and structural condition) association of each species for feeding, reproduction, and resting; (2) the value of special habitat elements (such as snags, edges, dead and down woody material, riparian zones, cliffs, caves, and talus) to associated species; and (3) development of more elaborate habitat capability models for selected or featured species (Patton 1978, Thomas 1979b, Verner and Boss 1980). The information on species relationships to habitat is readily put into a form suitable for computer manipulation for use in long-range planning or in analyzing impacts, across the species spectrum, of management alternatives that involve manipulation of vegetation. There have been several successful computer programs developed to handle various kinds and varieties of WFHR data bases. Successful computer application has included both mini-computers and standard computers. By far the best known of these systems for storage and recall of data has been Patton's (1978) RUN WILD system and modifications thereof such as the "Procedure" for Pennsylvania (Thomas 1982). Other systems of analysis, similar in terms of predicting generalized wildlife responses to alterations in habitat have been developed for such purposes as evaluating impacts of water development (Daniel and Lamaire 1974, Golet 1976, Larson 1976), transportation systems (Smith 1974, Herin 1977), forest management (Buckner and Perkins 1974), or the general evaluation of wildlife habitat (Graber and Graber 1976, Brabander and Barclay 1977).

Habitat Management and Indicator Species

Thomas et al. (1979c) grouped species into "life forms" that showed affinity to similar habitat. This concept was expanded from that proposed by Haapanen (1966) for birds in the Finnish forest. Previous systematic groupings of species have been largely morphological in nature. Such "life form" groupings are flexible. Analysis can create as many as make biological sense in terms of habitat use in a localized area. Some workers (Hal Salwasser, USDA Forest Service, pers. comm.) believe that ecological guilds (Severinghaus 1981) may have more flexibility than life forms for the purposes described above. The important thing is that it probably will be necessary to group species in some manner that accounts for reaction to habitat.

These groupings were developed in anticipation of the regulations issued pursuant to the National Forest Management Act of 1976 that specified monitoring "indicator species" in National Forest System management. Indicator species, theoretically, represent or reflect the welfare of a larger group of species. The regulations call for a description of just what changes in the status of the chosen indicator species do indeed indicate. Once appropriate life forms are created for local situations, the welfare of the species that occur within that life form within a plant community and successional stage can, again theoretically, be represented by the status of an indicator species chosen from within that group. Some have tried to expand the use of the life form concept beyond the specific area for which the information was developed; it works poorly in such cases.

The appropriateness of using indicator species to reflect changes in habitat suitability or condition is a subject of debate. Sampling of indicator species (of which there may be several) over vast areas of National Forests will be costly in time and money. Sampling must be intense enough to discern statistical differences in populations between areas within sampling periods and between sampling periods within areas. Then the population or occurrence changes must be carefully interpreted to assure that they reflect changes in habitat conditions rather than normal perturbations in population levels. The description of just what an indicator species indicates must be described as accepted for the short term and somehow tested over the long term. Some fear that such an approach will be very, perhaps prohibitively so, expensive to carry out. And, there is concern that such activities will divert scarce professional wildlife personnel and funds from more important duties.

Monitoring Habitat Conditions

It seems much easier to inventory habitats, as categorized by plant communities and successional stage or other acceptable descriptors, and relate these inventories to species. Such information might be obtained by relatively minor changes in the routine information collected in standard forest survey efforts. These approaches are already being tested by USDA Forest Service forest inventory personnel in the Pacific Northwest and in the South (McClure et al. 1979). This approach has the advantage of being capable of "piggy backing" onto existing comparatively well-financed and well-established efforts for many forest and rangeland areas already being regularly and systematically collected by the Bureau of Land Management and the USDA Forest Service.

The data so collected can be manipulated in or used in conjunction with existing linear programming models for considering alternatives for manipulation or allocation of timber and range resources. The USDA Forest Service's Timber RAM (resource allocation model) is an example of such a linear programming model (Navon 1971).

Monitoring of Indicator Species

The regulations issued pursuant to the National Forest Management Act of 1976 clearly require use of the indicator species approach in monitoring wildlife activities for National Forests. It is likely, though, that habitat inventory and analysis based on species/habitat relationships will be an additional means through which the welfare of the entire spectrum of vertebrate wildlife species is considered in Forest Service planning. Indicator species will probably be chosen primarily, as directed by the National Forest Management Act of 1976 regulations, from those species that are taken for food, sport, or hides and those that are threatened or endangered. The status of such species will probably indicate little beyond their own numbers. So, when such species are chosen as indicators, they are likely to be the same as the "featured" (Thomas 1979a) or "selected" (Salwasser et al. 1980, Verner and Boss 1980) species already provided for in the WFHR process.

Land-Use Planning

Land-use plans and environmental impact statements prepared using the WFHR approach have been evaluated by some experienced reviewers as more comprehensive, better formulated, and more responsive to intent of the law than those prepared before this planning tool became available (William Morse, Wildlife Management Institute, pers. comm.). The system has weaknesses, however. The information in the data base ranges from the thorough, sound, well-documented, and site-specific to speculations of knowledgeable biologists. To many, if not most, managers who deal continually with decision making under conditions of uncertainty this seems quite acceptable. Some scientists, on the other hand, are appalled.

Land-use planning is presently based on interpretation and extrapolation of existing theory and data. Such an approach, obviously, has an inherent danger of human error. The entire WFHR system has been called "a working hypothesis" (Thomas 1979c). Research is already underway to test critical hypotheses and to improve the data base by providing additional or site specific data or both.

Most importantly, a system or framework for analysis exists that is acceptable to most of the concerned publics and state and federal agencies. Any such system must meet that bio-political test of acceptability if it is to be used successfully in land-use planning and preparation of environmental impact statements. This does not imply that arguments about resource allocations or management prescriptions are resolved by the existence of an acceptable system for data organization and analysis.

The development of a generally acceptable system, however, has provided a gaming board on which defined pieces may be manipulated in a game of problem resolutions involving economics, politics, law, ecology, aesthetics, and philosophy. Until the advent of such procedures as HEP and WFHR in the 1970s, those interested in wildlife seemingly could not participate as effectively as other interest groups in the land-use planning process. With the development of such procedures, it has been easier for land-use planners to consider wildlife values.

HEP or WFHR Approaches—Which Is Best?

Which of these two general approaches to species/habitat relationships analysis is best depends on the type of analysis required and the objectives of management. Close examination of the two approaches shows that they are not radically different in concept or development. They are really two ways to achieve the same goal—improved ability to predict wildlife response to potential alterations in habitat.

The HEP type approaches begin with the analysis of habitat for a single species. These species may be the featured or indicator species described earlier. Species can be selected, however, that might serve in land-use planning or the analysis of alternative management actions as the indicator of the welfare of other species.

The WFHR system starts with a data base that describes the general habitat requirements of all resident species; then, in one case (Thomas et al. 1979c), combines those into groups based on similar habitat responses. This makes it possible to more rationally select an indicator species for the group. Once an indicator species is selected it is necessary to develop a special and much more detailed write-up of how the habitat of this species can be measured in land-use planning and subsequent management.

Existing examples of this type of treatment for a featured or selected species include Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) and Rocky Mountain elk (*Cervus elaphus nelsoni*) in the Blue Mountains of Oregon and Washington (Thomas et al. 1979d) and native trout (*Salmo* sp.) in the Great Basin of southeastern Oregon (Bowers et al. 1979). If the status of the featured species is an "indicator" of management success, it is then necessary to adequately census the species on a periodic basis.

HEP could be used to provide the habitat analysis mechanism when it is deemed necessary to fully describe habitat relationships for a featured species. In fact, species featured under a WFHR system must have a special document prepared describing habitat requirements for the species and a process for their evaluation by procedures that have been very similar, conceptually if not yet procedurally, to the habitat suitability indices produced by the HEP procedure.

WFHR and HEP were originally developed to serve different needs. Experience has shown that managers and analysts end up needing and using both systems. So, WFHR and HEP, used in conjunction, play different but synergistic roles.

Both approaches (HEP and WFHR) to meeting the demands for wildlife considerations in planning and action mandated by the environmental laws of the 1970s have been praised by some managers and practitioners. Others, primarily researchers, have criticized the "stretching" of available knowledge and ecological theory required to produce such operational systems. Those concerns are certainly valid. However, agencies are making and will continue strong attempts to meet requirements of the law. Moreover, HEP and WFHR programs have directed the attention of the wildlife research community to some of the major problems that must be resolved. Likewise, information required to improve the data base and the theoretical foundation of these presently operational systems has been identified.

Management Decisions Made Under Uncertainty

The dilemma has been described this way:

> The knowledge necessary to make a perfect analysis of the impacts of potential courses of . . . management action on wildlife habitat does not exist. It probably never will. But more knowledge is available than has yet been brought to bear on the subject. To be useful, that knowledge must be organized so it makes sense. . . .
>
> Perhaps the greatest challenge that faces professionals engaged in . . . research and management is the organization of knowledge and insights into forms that can be readily applied. To say we don't know enough is to take refuge behind a half-truth and ignore the fact that decisions will be made regardless of the amount of information available . . . it is far better to examine available knowledge, combine it with expert opinion on how the system operates, and make predictions about the consequences of alternative management actions [Thomas 1979c].

The 1970s—Just the Beginning

It seems likely that these two basic approaches, HEP and WFHR, will continue parallel evolution. Eventually, they may be melded into a single system. Indeed, Nelson and Salwasser (1982) show that the Forest Service's WFHR program now incorporates habitat suitability index type models to meet special analysis needs. They almost certainly will become more quantitative and more reliable as better data become available (Salwasser et al. 1980). There have also been efforts, in many ways parallel, to develop a national data base and a national application of species/habitat relationships data (Schweitzer and Cushwa 1978, Schweitzer et al. 1978).

Each successful effort should produce a better, more reliable and sophisticated product. The initial efforts should be quickly outdated and outmoded. The important thing is that the first steps on a long journey have been taken. There is, in my opinion, no turning back.

There *was* a revolution in the 1970s in the way we view and consider wildlife in planning and management. The National Environmental Policy Act of 1969 was the beginning. *Planning, execution,* and *accountability* will be bywords for those concerned with land-use planning and wildlife management in the 1980s. And, today's wildlife biologists are much better able to participate effectively in land-use planning than they were in 1970. *Planning, execution,* and *accountability* will become bywords for those concerned with land-use planning and wildlife management in the future. Improvements in those abilities will continue and accelerate in the 1980s.

References Cited

Bowers, W., B. Hosford, A. Oakley, and C. Bond. 1979. Native trout. *In* J. W. Thomas and C. Maser, eds. Wildlife habitats in managed rangelands—the Great Basin of Southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-84. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 16 pp.

Boyce, S. G. 1977. Management of eastern hardwood forests for multiple benefits (DYNAST-MB). USDA For. Serv. Res. Pap. SE-168. Asheville, N.C. 116 pp.

Brabander, J. J., and J. S. Barclay. 1977. A practical application of satellite imagery to wildlife habitat evaluation. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 31: 300–306.

Buckner, J. L., and C. J. Perkins. 1974. A plan of forest wildlife habitat evaluation and its use by International Paper Company. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 28: 675–682.

Capp, J., B. Carter, J. Deibert, J. Inman, and E. Styskel. n.d. Wildlife habitat relationships of South Central Oregon. USDA For. Serv., Portland, Oreg. 230 pp.

Daniel, C., and R. Lamaire. 1974. Evaluating effects of water resource developments on wildlife habitat. Wildl. Soc. Bull. 2(3): 114–118.

Dealy, J. E., D. A. Leckenby, and D. Concannon. 1981. Plant communities in managed rangelands and their importance to wildlife. *In* J. W. Thomas and C. Maser, eds. Wildlife habitats in managed rangelands—the Great Basin of Southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-120. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 66 pp.

Flood, B. S., M. E. Sangster, R. D. Sparrowe, and T. S. Baskett. 1977. A handbook for habitat evaluation procedures. Resour. Publ. 132. U.S. Dep. Inter., Fish and Wildl. Serv., Washington, D.C. 77 pp.

Golet, F. C. 1976. Wildlife wetland evaluation model. *In* Larson, J. S., ed. Models for assessment of freshwater wetlands. Water Resour. Res. Center Publ. No. 32. Univ. Massachusetts, Amherst.

Graber, J. W., and R. R. Graber. 1976. Environmental evaluation using birds and their habitats. Ill. Nat. Hist. Surv. Biol. Notes No. 97., Dep. Registration and Education, Urbana.

Haapanen, A. 1966. Bird fauna of the Finnish forest in relation to forest succession. II. Ann. Zool. Fenn. 3(3): 176–200.

Herin, K. C. 1977. Wildlife assessment project No. 36-22-RF-092-5 (11) Doniphan County. Environmental Support Section, Engineering Ser. Dep., Kansas DOT, Topeka.

Holbrook, H. L. 1974. A system for wildlife habitat management on southern National Forests. Wildl. Soc. Bull. 6(3): 119–123.

Larson, J. S., ed. 1976. Models for assessment of freshwater wetlands. Water Resour. Res. Center Publ. No. 32. Univ. Massachusetts, Amherst.

Maser, C., J. M. Geist, D. M. Concannon, R. Anderson, and B. Lovell. 1979a. Geomorphic and edaphic habitats. *In* J. W. Thomas and C. Maser, eds. Wildlife habitats in managed rangelands—the Great Basin of Southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-99. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 84 pp.

Maser, C., J. W. Thomas, I. D. Luman, and R. Anderson. 1979b. Manmade habitats. *In* J. W. Thomas and C. Maser, eds., Wildlife habitats in managed rangelands—the Great

Basin of Southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-86. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 39 pp.

McClure, J. P., N. D. Cost, and H. A. Knight. 1979. Multiresource inventories—a new concept for forest survey. USDA For. Serv. Res. Pap. SE-191, Southeast. For. Exp. Stn., Asheville, N.C.

McCuen, R. H., and G. A. Whitaker. 1975. A computerized methodology for estimating the impact of water resource projects on the terrestrial ecosystem. Proc. Annu. Conf. Southeast. Assoc. Fish and Game Comm. 29: 354–364.

Navon, D. I. 1971. Timber RAM users' manual. Part 1: smokey forest case study. USDA For. Serv., Pac. Northwest For. and Range Exp. Stn., Berkeley, Calif. 36 pp.

Nelson, R. N., and H. Salwasser. 1982. The Forest Service wildlife and fish habitat relationships program. Trans. N. Amer. Wildl. and Nat. Resour. Conf. 47: 174–183.

New England Research, Inc. 1980. Investigation of the relationship between land use and wildlife abundance: Volume 1, Literature survey. Contract Report 80-C2. U.S. Army Engineers Institute for Water Resources, Fort Belvoir, Va. 146 pp.

Nichols, B. E., J. L. Sandt, and G. A. Whitaker. 1977. Delmarva's wildlife work group's procedure for habitat analysis. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 31: 8–17.

Patton, D. R. 1978. Run wild: a storage and retrieval system for wildlife habitat information. USDA For. Serv. Gen. Tech. Rep. RM-51. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 8 pp.

Reynolds, H. G., and R. R. Johnson. 1964. Habitat relations of vertebrates of the Sierra Ancha Experimental Forest. USDA For. Serv. Res. Pap. RM-4. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 16 pp.

Russell, K. R., G. L. Williams, B. A. Hughes, and D. S. Walsworth. 1980. WILDMIS—A wildlife mitigation and management planning system—demonstrated on oil shale development. Colo. Coop. Unit, Colo. State Univ., Fort Collins, Colo.

Salwasser, H., H. Black, Jr., and T. Hanley. 1980. The Forest Service fish and wildlife habitat relationships system. USDA For. Serv., Pac. Southwest Reg., San Francisco, Calif. Typescript. 23 pp.

Schweitzer, D. L., and C. T. Cushwa. 1978. A national assessment of wildlife and fish. Wildl. Soc. Bull. 6(3): 149–152.

Schweitzer, D. L., C. T. Cushwa, and T. W. Hoekstra. 1978. The 1979 national assessment of wildlife and fish: a progress report. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 266–273.

Severinghaus, W. D. 1981. Guild theory development as a mechanism for assessing environmental impact. Environ. Manage. 5(3): 187–190.

Siderits, K., and R. E. Radke. 1977. Enhancing forest wildlife habitat through diversity. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 42: 425–434.

Smith, W. L. 1974. Quantifying impact of transportation systems. J. Urban Planning and Dev. Div. March 1974: 79–91.

Thomas, J. W. 1979a. Introduction. Pages 10–21 *in* J. W. Thomas, ed. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. Agric. Handb. No. 553. U.S. Gov. Print. Off., Washington, D.C. 512 pp.

Thomas, J. W., Tech. ed. 1979b. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. Agric. Handb. No. 553. U.S. Gov. Print. Off., Washington, D.C. 512 pp.

Thomas, J. W. 1979c. Preface. Pages IV–V *in* J. W. Thomas, ed. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. Agric. Handb. No. 553. U.S. Gov. Print. Off., Washington, D.C. 512 pp.

Thomas, J. W., C. Maser, and J. Rodiek. 1979a. Riparian zones. *In* J. W. Thomas and C. Maser, eds. Wildlife habitats in managed rangelands—the Great Basin of Southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-80. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 18 pp.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979b. Edges. *In* J. W. Thomas and C. Maser, eds. Wildlife habitats in managed rangelands—the Great Basin of Southeastern Oregon. USDA For. Serv. Gen. Tech. Rep. PNW-85. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 17 pp.

Thomas, J. W., R. J. Miller, H. Black, J. E. Rodiek, and C. Maser. 1976. Guidelines for maintaining and enhancing wildlife habitat in the Blue Mountains of Oregon and Washington. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 41: 452–476.

Thomas, J. W., R. J. Miller, C. Maser, R. G. Anderson, and B. E. Carter. 1979c. Plant communities and successional stages. Pages 22–39 *in* J. W. Thomas, ed. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. Agric. Handb. No. 553. U.S. Gov. Print. Off., Washington, D.C. 512 pp.

Thomas, J. W., H. Black, Jr., R. J. Scherzinger, and R. J. Pedersen. 1979d. Deer and elk. Pages 104–127 *in* J. W. Thomas, ed. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. U.S. Dep. Agric. Agric. Handb. No. 553. U.S. Gov. Print. Off., Washington, D.C. 512 pp.

Thomas, J. W. 1982. Species/habitat relationships—a key to considering wildlife in planning and land management decisions. *In* W. T. Mason, Jr., ed. The effects of environmental impacts on fish and wildlife habitats—research progress of the past decade. U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency, Washington, D.C. In press.

U.S. Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP). Division of Ecological Services, U.S. Fish and Wildlife Service, Department of the Interior, Washington, D.C.

U.S. Laws, Statutes, etc. Public Law 91–135. [H.R. 11363], December 5, 1969. Endangered Species Conservation Act of 1969. *In its* United States statutes at large. 1969. Vol. 83, p. 275. Washington, D.C., U.S. Gov. Print. Off., 1970. [16 U.S.C. sec. 668 (1970).]

U.S. Laws, Statutes, etc. Public Law 91–190. [S. 1075], Jan. 1, 1970. National Environmental Policy Act of 1969. An act to establish a national policy for the environment, to provide for the establishment of a Council on Environmental Quality, and for other purposes. *In its* United States statutes at large. 1969. Vol. 83, p. 852–856. U.S. Gov. Print. Off., Washington, D.C. 1970. [42 U.S.C. sec. 4321, et seq. (1970).]

U.S. Laws, Statutes, etc. Public Law 93–205. [S. 1983], December 28, 1973. Endangered Species Act of 1973. *In its* United States statutes at large. 1973. Vol. 87, p. 884. [16 U.S.C. sec. 668 (1976).]

U.S. Laws, Statutes, etc. Public Law 93–378. [S. 2296], Aug. 17, 1974. Forest and Rangeland Renewable Resources Planning Act of 1974. An act to provide for the Forest Service, Department of Agriculture, to protect, develop, and enhance the productivity and other values of certain of the Nation's lands and resources, and for other purposes. *In its* United States statutes at large. 1974. Vol. 88, Part 1, p. 476–480. U.S. Gov. Print. Off., Washington, D.C. 1976. [16 U.S.C. sec. 1601 (1976).]

U.S. Laws, Statutes, etc. Public Law 94–588. [S. 3091], Oct. 22, 1976. National Forest Management Act of 1976. *In* United States code congressional and administrative news. 94th Congr. 2nd Sess., 1976. Vol. 2, p. 2949–2963. West Publ. Co., St. Paul, Minn. [1976.] [16 U.S.C. sec. 1600 (1976).]

Verner, J., and A. S. Boss, Tech. coord. 1980. California wildlife and their habitats: western Sierra Nevada. USDA For. Serv. Gen. Tech. Rep. PSW-37. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif. 439 pp.

Whitaker, G. A., and R. H. McCuen. 1976. A proposed methodology for assessing the quality of wildlife habitat. Ecol. Modelling 2: 251–272.

Whitaker, G. A., E. R. Roach, R. H. McCuen. 1976. Inventorying habitats and rating their value for wildlife species. Presented at 30th Annu. Conf. Southeast. Assoc. Game and Fish Comm. Multilith. 18 pp.

Williams, G. L., K. R. Russell, and W. K. Seitz. 1978. Pattern recognition as a tool in the ecological analysis of habitat. Colo. Coop. Unit, Colo. State Univ., Fort Collins, Colo.

Willis, R. 1975. A technique for estimating potential wildlife populations through habitat evaluations. Pittman-Robertson Game Manage. Tech. Ser. No. 23. Kentucky Dep. Fish and Wildl. Resour., Frankfort. 12 pp. Multilith.

Wischnofske, M. 1977. Wildlife habitat relationships of eastern Washington. USDA For. Serv., Wenatchee National Forest, Wenatchee, Wash. 193 pp.

Habitat Models for Land-Use Planning: Assumptions and Strategies for Development

Adrian H. Farmer, Michael J. Armbruster, James W. Terrell, and Richard L. Schroeder

Habitat Evaluation Procedures Group, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colorado

Introduction

Wildlife managers have long recognized that management goals must be constrained by the availability and suitability of habitat. This recognition, combined with ever increasing land development pressures, has resulted in environmental legislation emphasizing systematic approaches to collection and analysis of habitat information. Wildlife planners have responded with a variety of approaches to the development of models that quantify habitat requirements.

The use of habitat models in wildlife management is certainly not a new concept. Early models attempted to relate habitat quality and quantity as defined by various life requisites (Trippensee 1948). Conceptually, these early approaches are identical to many contemporary efforts directed at modeling habitat.

This paper has two objectives related to contemporary habitat modeling approaches. The first objective is to characterize the assumptions and limitations inherent to operational habitat models. Various approaches to habitat modeling, some of which will be discussed at this conference, are described in their own terminology—which tends to obscure the fact that they have common ideals and are subject to the same sets of limitations.

The second objective of this paper is to describe a strategy for development of habitat models consistent with these potential limitations. There seems to be two divergent perspectives on operational habitat models. The first is an ideal perspective, which views operational habitat models with skepticism because the current state of habitat knowledge is limited. The second is a pragmatic perspective, which recognizes that available habitat information, no matter how incomplete, can be used to improve the credibility of a land-use decision. The strategy outlined in this paper is directed toward the latter perspective but may help to bridge the gap between the pragmatic and ideal.

The Habitat Approach to Land-Use Planning

Habitat has many definitions (Coulombe 1977) but has been defined theoretically as the location that supports a wildlife population including space, food, cover, and other animals (Giles 1978) and often is characterized by vegetation, landform, and hydrology (Odum 1971). Variations in food, cover, and physical features of habitat often are paralleled by observed differences in animal abundance. As a possible explanation for these variations, the concept of habitat preferences has been devised (Ricklefs 1973). The supporting logic for this concept is that populations display genetically determined preferences for habitats that favor their survival and reproduction. Wildlife managers attempt to decipher the causal relationships associated with habitat preference and then use this knowledge for land use planning.

Application of habitat concepts to land-use planning requires systematic methods of relating habitat conditions to potential population abundance, i.e., a habitat model. A model is a representation of a system or phenomenon and contains information in a predetermined form intended to be interpreted in accordance with predetermined rules (Thesen 1974). In order to accomplish its objectives, a model must be structured in a form that allows the user to interpret its output. The output of a habitat model must, therefore, at least have implicit units of measure that address characteristics of both the wildlife population and its habitat, i.e., "a land parameter measured in animal units" (Giles 1978:194). The concept of carrying capacity is often used in this context.

Carrying capacity as used in the field of population ecology is the density of organisms at which the net reproductive rate equals unity (Pianka 1974). In this context, carrying capacity is dynamically defined as an equilibrium between population birth and death rates which are regulated by the interaction of habitat variables and the population itself (Figure 1).

The habitat approach to land-use planning is focused at assessing potential wildlife population limits. A distinctive aspect of the habitat approach is that the wildlife manager can perform the analyses without case-by-case measurement of the wildlife population. However, carrying capacity, as defined previously, may be unmanageable because of extensive data requirements and the unknowns concerning specific relationships. But since it is a broad concept and accounts for all environmental factors that limit wildlife populations, we can use it as a standard

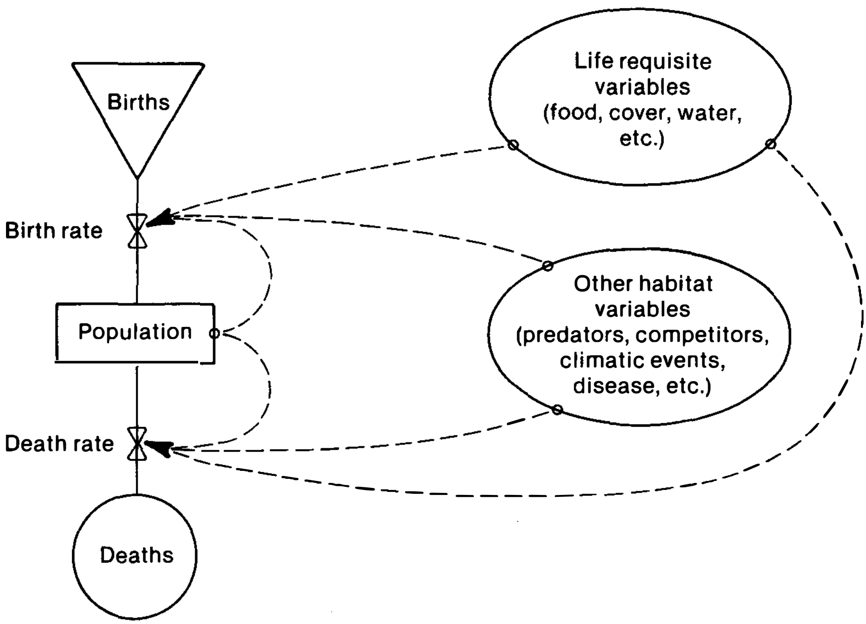


Figure 1. Diagrammatic view of carrying capacity, defined as existing populations, which is determined by birth and death rates.

against which operational definitions of habitat and associated carrying capacity estimates are based.

Assumptions and Limitations of Operational Habitat Models

Operational habitat models include only a subset of the variables required by theoretical definitions of habitat. Habitat models are frequently constructed around easily measured physical and floristic variables thought to represent food, cover, and reproductive needs of a wildlife population. Operational habitat models may exclude some types of habitat information (e.g., other species populations) that may have a more subtle and, in some cases, perhaps a more influential effect on population limits.

The model builder and model user must constantly be aware of the void between theoretical and operational definitions of habitat. The unreliability of operational habitat models in accurately depicting population limits may arise from a combination of situations involving the kinds of habitat information excluded from the model. For purposes of discussion, habitat models can be characterized by breadth and depth of detail. Model breadth is proportional to the number of habitat components (e.g., seasonal habitat, food, cover, other animals) addressed. Model depth is proportional to the number and kinds of variables chosen to describe each habitat component. Habitat models almost always emphasize either depth or breadth, rather than both simultaneously. A habitat model with depth but little breadth of detail, for example, might include many variables related to food energetics (i.e., a food carrying capacity model), including those that define the allocation of food resources to food competitors. If sufficient data were available, the model might be expected to produce reasonable estimates of observed populations under conditions when food resources impose limits on the population. Of course, the potential limitation of this model is that the population may be limited by habitat variables other than those directly related to food, and the model excludes information of concern to the wildlife manager.

More commonly, operational habitat models consider a relatively large breadth of habitat components such as food, cover, and reproductive requirements, with each component being assessed with little detail. Thermal cover, for example, may be measured by vegetation structure only. However, the significance of various conditions of vegetation structure for determining the suitability of thermal cover may be dependent on other environmental variables that contribute to determination of energy budgets and thus population growth rates (Kendeigh et al. 1977).

The potential limitation of models with little depth is that numerous weakly supported assumptions are required in the model, and it may be difficult for the model user to define conditions under which the model is likely to succeed or fail in providing accurate estimates of population limits.

The problems of restricted model breadth or depth are amplified when existing information is used to construct a model. Wildlife populations are subject to limits imposed by the total environment, yet the entire spectrum of variables composing the total environment is never described. In addition, individual studies are often site-specific and unrelated, making generalizations concerning habitat model relationships difficult. Synthesizing available data into model relationships involves considerable judgment and often requires subjective decisions. As the number of assumptions that must be made in this data synthesis increases, the probability that a habitat model will be unreliable in accurately depicting population limits also increases.

These considerations provide the basis for several conclusions concerning operational habitat models:

1. A habitat model must have sufficient breadth to encompass components that are instrumental in determining population limits.
2. It is not reasonable to expect a given habitat model to be a universally reliable indicator of population limits because key habitat components may vary between areas of model application.
3. A habitat model with restricted depth may be insensitive to subtle environmental changes and may predict only relative changes in population limits with perhaps a high degree of reliability in predicting the direction of change (+ or −), but a lower degree of reliability in predicting the magnitude of change.
4. A habitat model should be structured for a particular application to enhance its credibility with respect to the above points.
5. Numerous assumptions will be made during model construction, particularly if no new habitat information is collected specifically for the modeling effort.
6. The model assumptions must be clearly stated in order to evaluate the model's credibility in contributing to a land-use decision.

These considerations are integral to the following strategy for model construction.

Strategy for Development of Habitat Models

Land use impacts on wildlife are a function of the habitat variables affected by the particular land use and the degree to which these variables are significant determinants of wildlife population limits. A habitat model developed for land-use planning should define the habitat variables that are likely to be limiting for the population at the model application site and synthesize measures of the variables into a description of habitat that is useful for decision making. The model building strategy outlined below works within these guidelines. This strategy is a synopsis of one described by the U.S. Fish and Wildlife Service (1981) and is based on strategies developed for approaches to ecosystem modeling (Hall and Day 1977, Holling 1978, Innis 1979). The model building strategy is comprised of three basic phases: (1) setting objectives; (2) formulating model relationships; and (3) evaluating model performance.

Model Objectives

Setting clear objectives helps to insure that model construction occurs within well-defined limits and terminates at a pre-selected level of detail appropriate for the problem to be solved. Model objectives generally include statements concerning the kinds of information required to solve a land use problem, but also must take into account limitations of money, time, and data availability. Habitat model objectives discussed herein include: (1) defining an acceptance level for model output; (2) defining the breadth of habitat to be modeled; and (3) defining the geographical area to which the model is applicable.

Defining an acceptance level for model outputs. The ideal habitat model from a technical perspective will produce very precise and accurate estimates of population limits in terms of individuals per unit area. However, an acceptance level for model outputs should be defined because obtaining the ideal may not be technically feasible for reasons discussed earlier or may not be necessary for a land use application. The acceptance level will vary depending on the reliability required in a particular land use study. The acceptance level defines an operational end point of model development; i.e., when the model is suitable for actual use. Clearly stated acceptance levels are a necessary prerequisite for later stages of model development (i.e., model evaluation) and include statements about required precision and accuracy.

Model output precision may be set at two possible levels: (1) unitless outputs in verbal (e.g., rating of poor, good, excellent) or index form; and (2) outputs in measurable units (e.g., individuals per unit area). Many land use studies require model outputs only in the verbal or index form because the needs of these studies can be met by merely ranking alternatives. The advantage of producing only unitless ratings is that precise and accurate data are not required and the number of model assumptions can be kept to a minimum. However, the assumptions that are made must be clearly stated.

Models that must provide outputs in measurable units require accurate and precise empirical information. The data requirements often cannot be met with available information and therefore additional assumptions are required to construct the model. Construction of a model with measurable output units may therefore require additional efforts in testing and reformulating assumptions.

Given an output precision level, a habitat model should meet a prescribed level of accuracy in mimicking reality. There are several possible standards against which a model's reality can be judged. The most defensible test may be a comparison against observed population limits. Although desirable in the long term, it may not be necessary or possible within cost constraints to conduct these tests for many land use studies. Other acceptable standards may be review of the model predictions by study team members or species authorities. If the model predictions reflect the reviewers concept of reality, the model is accepted.

Model breadth. The number of habitat components included in a model should not be overly constrained for reasons discussed earlier. However, setting limits on the habitat components to be included in the model puts bounds on the amount of habitat information required and may reduce the data gathering effort. In constraining model breadth, the model builder must make assumptions about which habitat components are likely to be affected by the land use to the extent that wildlife population limits will be altered. Possible bounds on model breadth include perceived critical seasonal or life stage (e.g., juveniles) habitats.

Geographic area of model applicability. Defining the geographic area of model applicability also will limit the information required to build a model. For a particular land use study, the geographic limits must include the area affected by the land use change. However, if one desires to apply a habitat model to multiple studies, it may be cost effective to build a more general model. This would be modified to accommodate geographic variation in habitat use and land use impacts for individual applications.

Model Relationships

After model objectives have been set, the model builder develops hypotheses about the habitat that will be modeled. These hypotheses involve identification of habitat variables and development of assumptions about the functional relationships of habitat variables into a model consistent with the objectives set for the model.

Developing model hypotheses can be simplified by dividing the habitat into components. These components can include seasonal habitats, specific habitats for species life stages (e.g., juveniles, adults), or life requisites (e.g., food, cover). This subdivision may continue through several levels where components are divided into subcomponents to the point that a clear hypothesis can be stated for the lowest level subcomponents, i.e., each subcomponent can be functionally related to one or more measurable habitat variables.

Interspersion of habitat components may be an important model consideration. Many species utilize habitat mosaics, and individual habitat needs may be associated with specific types of vegetation or landform. Therefore, a habitat model may need to include characteristics of more than one vegetation type and incorporate hypotheses about their spatial configuration. To develop the spatial hypotheses efficiently, habitat components may be linked to vegetation type sections of a model (Figure 2). This model structure introduces a set of spatial variables describing the interspersion of habitat components using vegetation types only as abstract measurement units.

A model based on habitat components explicitly describes hypothesized causal relationships between habitat variables and carrying capacity. Basing the model on a component structure allows the wildlife manager to exercise professional

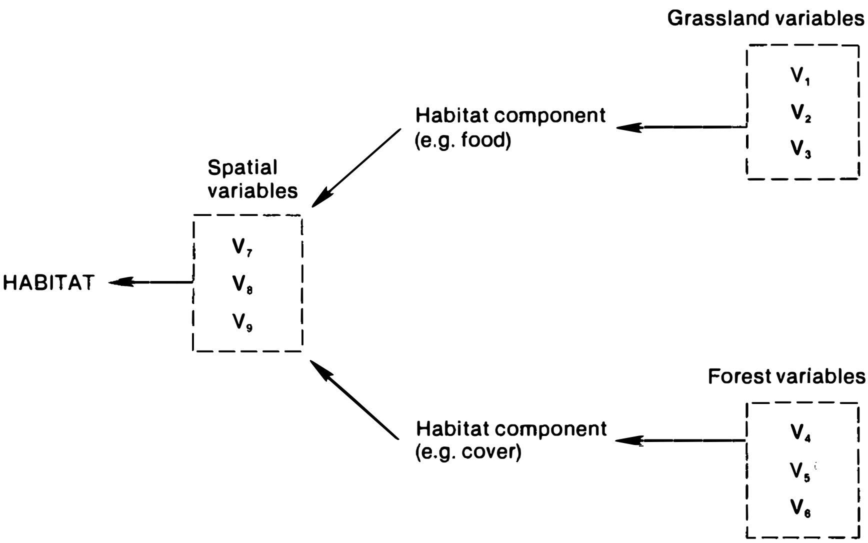


Figure 2. Graphic habitat model, structured around cover type and spatial variables.

opinion in interpretation of model results. The model structure provides a template against which potentially significant habitat variables (not included in the model) can be assessed as possible causes of unreliable model results. Finally, a component structure permits model improvement because individual assumptions can be isolated and tested and functional relationships reformulated as needed.

Unfortunately, there are no guidelines available to help determine a priori which functional relationships are most appropriate for a particular habitat model. However, we believe that clearly stating functional relationships is an extremely important requirement in model building. The use of verbal statements to explain functional relationships may be sufficient in some cases. However, even seemingly simple habitat relationships often are difficult to define clearly in words, particularly when the relationships are nonlinear or when there are interactions between two or more variables.

Mathematics is useful as ". . . a precise and subtle language designed to express certain kinds of ideas more briefly, more accurately, and more usefully than ordinary language" (Halmos 1968:386). We recognize that wildlife managers may resist the use of mathematics, at least partly because expressed hypotheses about habitat relationships may be proven incorrect. However, a major value of clearly stated functional relationships is that the process of proving them wrong increases understanding. Mathematical language improves the credibility of habitat models by making the repeated formulation, testing, and reformulation of hypotheses more rigorous.

Model Evaluation

Model evaluation is identical to hypothesis testing (Holling 1978). In modeling terms, this means understanding the model's behavior to the point that one may anticipate when the model is most likely to be unreliable. Models, as simplifications of real systems, contain less information than the systems they represent and will therefore always be unreliable to some degree. The degree of unreliability will vary with the situation; therefore, the evaluation process should be directed at understanding model behavior throughout the anticipated range of application. Evaluation should be an integral part of *model building,* not an a posteriori endeavor. Model evaluation can be described in two phases: (1) verification, which is directed toward evaluating how well the model matches the model builder's perceptions; and (2) validation, which is directed toward determining how well the model builder's perceptions match reality.

Verification. "To verify" means to determine or prove the truth of something. During this stage of evaluation, we are concerned with whether or not the habitat model and its components behave as the model builder intended and if this behavior conforms to currently accepted biological theory and operational feasibility.

One way to verify habitat models is through the use of sample data sets. Data sets used in the verification exercise should originate from existing habitats used by the species of interest. The sample data are assigned to model variables, and the resulting model behavior compared to the hypothesized response. This exercise can be used to identify logic flaws in the modeler's perceptions as reflected in model design (Halfon 1979).

Verification can be expanded into what is often referred to as a sensitivity analysis where the emphasis is on identification of those variables, or functional relationships, that most critically affect model output. This is usually accomplished by manipulating input values of a selected variable(s) over a wide range of possibilities, while maintaining other variables constant. This identifies variables to which the model is very sensitive and alerts the model builder to variables that will require a precise field measurement.

The final stage of model verification should include a field application to make sure that model variables can be satisfactorily measured. The most critical variables in terms of model behavior are measured with the appropriate techniques to determine if the required accuracy level can be obtained under field conditions. The field sites used should contain enough variety so that all of the measurement techniques required for model variables can be applied and evaluated. As a result of these field exercises, the model builder can develop a list of variables and measurement techniques that are theoretically and operationally acceptable.

Validation. Validation is an attempt to determine the degree of agreement between model behavior (i.e., its output) and the real situation it was designed to mimic. "To validate" may be a misleading phrase; we tend to agree with Holling (1978) and others, that, like hypothesis testing, the actual process involves efforts directed more at invalidation, or understanding a model's degree of unreliability.

Validation efforts usually involve evaluation of the model's outputs against some standard of comparison. The standard should be a data set that was not included or consulted during model development. Identification of a standard is not an easy task. A seemingly obvious choice, both from a theoretical and operational standpoint, would be densities of populations using the habitats of interest. This inclination is reflected in recent studies: ". . . the system whose habitat ratings consistently correspond more closely to relative abundance values would be the most accurate" (Whelan et al. 1979:400), and "The real test . . . is whether the scores reflect animal abundance or wildlife usage of the habitat" (Baskett et al. 1980:146). However, there are several factors that should be considered when attempting to validate a habitat model with animal abundance data.

Attempts to validate a model heavily laden with assumptions (i.e., untested hypotheses) will have a high likelihood of ending in failure and/or frustration. This is because no insight is gained about the conditions under which the individual assumptions are likely to be invalid, thereby resulting in unrealistic model behavior. The best recourse is to design a set of validation efforts directed toward individual model assumptions before attempting to evaluate behavior of the entire model.

The ultimate objective of the validation process is a comparison of overall model behavior to observed animal abundance. However, the goal of validation *is not* to determine if a model can explain variations in any animal abundance data set. Most models can be adjusted to fit a given data set, but the adjusted model may not be reliable when exposed to new conditions such as a major land use change (Holling 1978). Therefore the validation process should be conducted on sites that emulate actual land-use changes similar, if not identical, to those of interest. This can be accomplished by comparing estimates of animal abundance on altered sites against those of unaltered sites. Such comparisons should give some indication as to the reliability of model projections under conditions of actual use. If projections do not correspond well with observed conditions, then model hypotheses can be reformulated based on the information gained.

The population abundance data set also must meet other criteria. The data must represent a long enough time span such that there is some confidence in the data as a measure of population limits. Moreover, the abundance data need be no more rigorous than the acceptance level set for model outputs (i.e., precision and accuracy as defined by model objectives). For models with unitless outputs, highly precise and accurate population density data are not required. Other types of abundance data, such as frequency of use (the proportion of years a habitat is occupied) and similar indices of habitat occupancy, may be adequate standards against which to judge model behavior.

In situations where validation is not or cannot be currently attempted, the overall model performance will remain unknown in terms of both acceptance and ideal goals. However, if the model meets a lower acceptance level that permits use, then a long-term monitoring plan can be initiated to facilitate the validation process. Attaining the goal of more precisely defining the causal relationships that influence animal abundance requires a long-term commitment of time and resources. Monitoring of land-use changes over an extended period to determine how well the habitat model predicts changes in population limits should be accompanied by an effort to reformulate cause and effect relationships in the model. Such monitoring efforts are not commonly included in the land-use planning process.

Finally, validation should not be used to reject one particular model because it fails to meet a pre-set acceptance level. Validation efforts should be used to select the "best" of two or more models for a particular application. When carried to completion, validation involves rejection and reformulation of alternative hypotheses with the ultimate selection of the most practical model for a land use application.

Discussion

This paper has emphasized the limitations of habitat models for land use planning. This emphasis was intentional because we believe that habitat models are often used for purposes other than those intended. When they fail to perform at ideal levels, they are often considered unreliable and useless, and therefore discarded. This situation occurs most frequently when habitat models that are based on simple variable sets and numerous assumptions are employed as predictors of actual animal abundance without first adequately testing the assumptions. Animal densities at any one time are the expression of previous environmental influences regulating birth rates, death rates, or both. Unless habitat models include all variables which causally explain such influences, precise correspondence between output and observed populations should not be expected for most species.

Current attempts to operationally define habitat with models are often viewed with skepticism: "Even to attempt to standardize something so complex as an evaluation of natural populations will strike many biologists as ludicrous" (Graber and Graber 1976:2). Such feelings are understandable; science deals in facts, and facts require time to acquire. However, wildlife scientists must be cognizant of the wildlife manager's need to be able to deal in values. "To say we don't know enough is to take refuge behind a half-truth and ignore the fact the decisions will be made regardless of the amount of information available . . . it is far better to examine available knowledge, combine it with expert opinion on how the system operates, and makes predictions about the consequences of alternative management actions" (Thomas 1979:preface).

Habitat models that do not precisely mimic animal abundance are not without value for land-use planning. They provide a format for the systematic use of habitat requirement information in making value judgements about the effects of different management options. The operational acceptance of the model will be dependent on the user's decisions about whether or not the model is useful in facilitating land use decisions. We can attain this level of acceptance through improved communications between model builders and users, directed at realistic operational objectives.

References Cited

Baskett, T. S., D. A. Darrow, D. L. Hallett, M. J. Armbruster, J. A. Ellis, B. F. Sparrowe, and P. A. Korte. 1980. A handbook for terrestrial habitat evaluation in Central Missouri. Resour. Publ. 133. U.S. Fish and Wildl. Serv., Washington, D.C. 155 pp.

Coulombe, H. N. 1977. Summary remarks. Pages 593–602 *in* A. Marmelstein, general chairman. Classification, inventory, and analysis of fish and wildlife habitat: the proceedings of a National symposium. FWS/OBS-78/76. U.S. Fish and Wildl. Serv. Washington, D.C. 604 pp.

Giles, R. H. Jr. 1978. Wildlife management. W. H. Freeman and Co. San Francisco, Ca. 416 pp.

Graber, J. W., and R. R. Graber, 1976. Environmental evaluations using birds and their habitats. Illinois Natural History Survey, Biol. Notes No. 97, Urbana, Il.

Halfon, E. 1979. Computer-based development of large-scale ecological models: problems and prospects. Pages 197–209 *in* G. S. Innis and R. V. O'Neill, eds. Systems analysis of ecosystems. International Co-operative Publishing House, Fairland, Md. 402 pp.

Hall, C. A. S., and J. W. Day, Jr. 1977. Ecosystem modeling in theory and practice. John Wiley and Sons, New York. 684 pp.

Halmos, P. R. 1968. Mathematics as a creative art. Scientist 56(4):375–389.

Holling, C. S., ed. 1978. Adaptive environmental assessment and management. John Wiley and Sons, New York. 377 pp.

Innis, G. 1979. A spiral approach to ecosystem simulation. I. Pages 210–386 *in* G. S. Innis and R. V. O'Neill, eds. Systems analysis of ecosystems. International Co-operative Publishing House, Fairland, Md. 402 pp.

Kendeigh, S. C., V. R. Dol'nick, and V. M. Gavrilov. 1977. Avian energetics. Pages 127–204 *in* J. Pinowski and S. C. Kendeigh, eds. Granivorous birds in ecosystems. IBP Prog. 12, Cambridge Univ. Press, Cambridge, England. 431 pp.

Odum, E. P. 1971. Fundamentals of ecology, W. B. Saunders Company, Philadelphia, Pa. 547 pp.

Pianka, E. R. 1974. Evolutionary ecology. Harper and Row Publishers, New York. 356 pp.

Ricklefs, R. E. 1973. Ecology. Chiron Press. Newton, Mass. 861 pp.

Thesen, A. 1974. Some notes on systems models and modelling. Int. J. Systems Sci. 5(2):145–152.

Thomas, J. W., tech. ed 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA For. Serv. Agric. Handb. 553. U.S. Dep. of Agric. Washington, D.C. 512 pp.

Trippensee, R. E. 1948. Wildlife management: upland game and general principles. Vol 1. McGraw-Hill Book Company, New York. 479 pp.

U.S. Fish and Wildlife Service. 1981. Standard for the development of habitat suitability index models. FWS/DES-ESM 103. U.S. Dep. Inter. Washington, D.C. Unpaged.

Whelan, J. B., A. R. Tipton, J. F. Williamson, P. R. Johansen, J. P. McClure, and N. D. Cost. 1979. A comparison of three systems for evaluating forest wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44:392–403.

Development and Use of a Habitat Gradient Model to Evaluate Wildlife Habitat

Henry L. Short
Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colorado

Introduction

Ecologists and wildlife managers are increasingly confronted with the problems of predicting the value of surface cover as wildlife habitat and developing management alternatives to offset wildlife values lost because of land-use change. These problems have become urgent and more acute because of increased demand for products from the land and diminished fiscal and manpower resources for obtaining meaningful environmental information for the decision maker. This paper describes a relatively rapid, simple, and quantitative process for evaluating the quality of an area as wildlife habitat.

An assumption basic to this process is that a potential natural vegetation type (PNVT) (Küchler 1964) can serve as a bound for developing a habitat gradient model. The vegetative community could achieve a common structure throughout the PNVT, given sufficient time and satisfactory growing conditions. Presumably the wildlife community could also attain a common structure if the structure of the vegetative community became similar throughout the PNVT. This would occur because of a similar distribution of food sources, breeding substrates, cover conditions, and other habitat characteristics throughout the PNVT. Even though the structure of the vegetative community and the dependent wildlife community may never achieve this potential, the potential can be used as a baseline value for comparative purposes. The current vegetation types within a PNVT are the result of a variety of edaphic, traumatic, and man-induced factors. These current vegetation types vary in life stage and structure as well as in rates of energy fixation, energy flow, nutrient cycling, and other basic ecological criteria. These differences among current vegetation types result in a variety of available habitat conditions for wildlife and account for the fact that wildlife communities vary in structure between vegetative cover types within a PNVT.

Short and Burnham (1982) have developed a process for correlating wildlife species with the structure of vegetative communities. This process is dependent on the ways in which wildlife species use different layers of vegetation. The number of layers of vegetation (vegetative strata) present in a vegetative community has been shown to be significantly related to the number of species of breeding birds that will be present (Balda 1975). This positive relationship between numbers of species and complexity of vegetative structure has been observed for birds in a variety of North American habitats; e.g, in herbaceous, cedar field, and oak forest communities in New Jersey (Kricher 1973); in nine seral stages in the Georgia Piedmont (Johnston and Odum 1956); and in bare ground, shrub, and bottomland forest habitats on strip mined lands in Illinois (Karr 1968).

The total density of cover and the distribution of total cover between strata also contribute to the variation in structure between vegetative communities. Density of cover is measured as the total amount of cover or the sum of the vertical projections of the canopy cover of each vegetative strata to the ground surface. Density of cover can exceed 100 percent if more than one stratum is present. The equitability of the distribution of vegetative cover between strata is determined by the foliar height diversity (FHD) measure of MacArthur and MacArthur (1961). The FHD measure has its highest value when cover is equally distributed between strata. Numerous studies have shown significant positive correlations between the FHD measure and the number of wildlife species present.

Wildlife species occupy specific niches within the structure of a vegetative community. The niche has been abstractly described as a response surface developed around a variety of resource gradients (Whittaker 1977). Variations between habitats in the presence and abundance of wildlife species can be related to the values of the different resource gradients within a vegetative community that are important to each species. Theoretically, it should be possible to develop a habitat gradient for a PNVT that would demonstrate the dependency of wildlife species on the values of the resource gradients that are present in the different vegetative communities. The presence and abundance of each wildlife species can be represented by a bell-shaped distribution curve somewhere along the habitat gradient (Levenson and Stearns 1980). The position of this curve corresponds to the acceptable values of the various resource gradients that are important to the species. When bell-shaped distribution curves are plotted for the total wildlife community, they should form a wildlife species gradient along the habitat gradient (Levenson and Stearns 1980).

The first objective of this paper is to demonstrate that a habitat gradient for a PNVT can be developed from information on the number of vegetative strata present, the total density of vegetative cover, and the distribution of vegetative cover between strata. This information, needed to position habitats along the habitat gradient, can be obtained by ground surveys or by estimating the structure of vegetative cover from carefully interpreted aerial photographs. The second objective of this paper is to demonstrate that the structure of vegetative communities, as indicated by their positions along the habitat gradient, is predictive of the number of wildlife species that can occur in these areas. Finally, the paper will discuss how the position a vegetative community occupies along a habitat gradient can be expected to vary following land use or management changes and how to predict the resulting impact on the wildlife community from the new position the habitat occupies along the gradient.

Methods

Guild Blocks

The relationship between wildlife species and vegetative strata can be expressed in terms of guild blocks (Short and Burnham 1982). Guild blocks are derived from two resource gradients that are universally important to terrestrial wildlife species. These gradients are: (1) physical positions within the structure of a vegetative community where food sources occur; and (2) physical positions within the structure of a vegetative community where breeding substrates occur.

Guild blocks for a vegetative community can be defined by constructing a matrix where the y-axis represents loci where food sources occur and the x-axis represents loci where breeding occurs. The x-axis also contains a position for species that feed in the area but breed elsewhere. The number of available guild blocks will vary for different vegetative communities depending on the number of vegetative strata that are present. An upland grass community, for example, is described by a 3x3 matrix, with nine guild blocks available as wildlife habitat (Figure 1). These guild blocks describe, in a general manner, the ways in which wildlife can use the grassland community. For example, the guild block in the center of the matrix represents the habitat use pattern for those wildlife species that breed and feed on the ground surface. The matrix guild blocks are closely related to the general concept of life forms described by Thomas (1979).

A shrub steppe habitat includes an additional vegetative stratum, resulting in a 4x4 matrix that describes 16 ways in which wildlife can use this habitat. Habitats dominated by small trees, such as pinyons and junipers, are represented by a 5x5 matrix with 25 guild blocks. These small trees are classified as part of the shrub stratum based on their height. In terms of wildlife use, however, they are structurally intermediate between shrubs and large trees because they have a tree bole large enough to be used as a breeding or feeding substrate, or both, by excavators or cavity users.

Pole-sized trees in forest lands may be 10 to 20 m (33 ft. to 66 ft.) tall and still not have a tree bole of sufficient diameter to be used by wildlife as a breeding or feeding substrate. These habitats are also described by a 5x5 matrix because of the presence of a tree canopy. Habitats that contain mature trees with a bole large enough to be useful to wildlife are represented by a 6x6 matrix that contains 36 guild blocks (Figure 2).

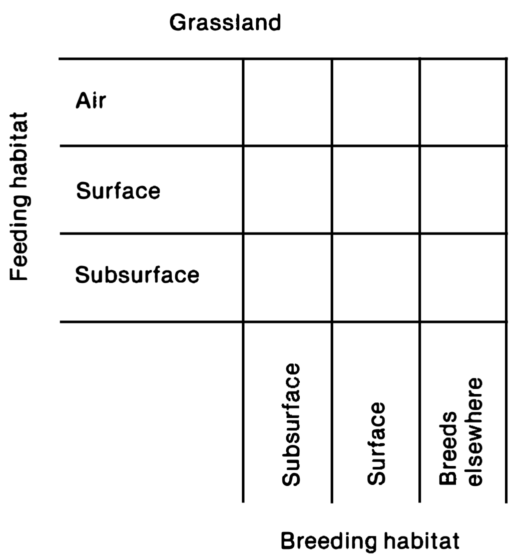


Figure 1. Nine guild blocks exist in upland grassland habitats. The guild blocks indicate the ways in which wildlife species can use grassland habitat.

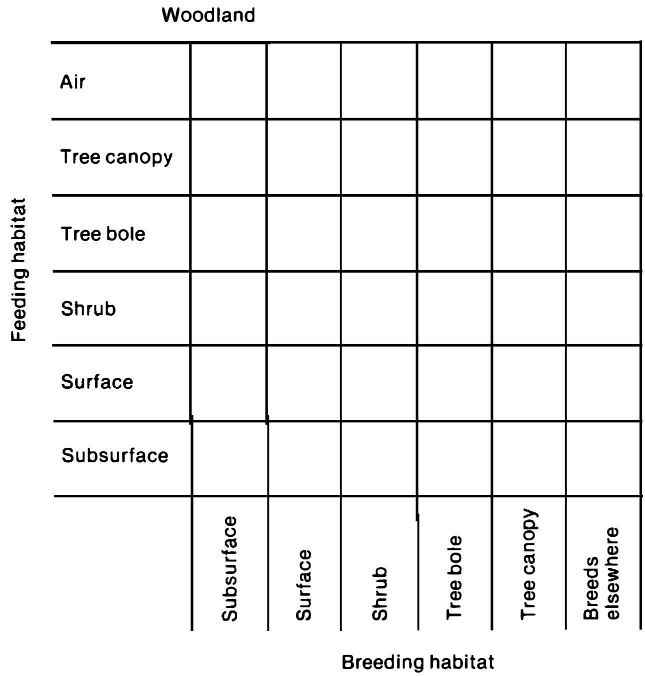


Figure 2. Thirty-six guild blocks exist in mature upland forest habitats. The guild blocks indicate the ways in which wildlife species can use forest habitat.

The guild block concept relates the occurrence of groups of wildlife species to major structural features of the vegetative community. The use of guild blocks does not permit a detailed description of the niche requirements of a particular species because all of the potentially important resource gradients are not included.

Structure of Vegetative Communities

The total percentage of cover and the equitability of cover between vegetative strata were determined for 10 vegetative communities on the U.S. Bureau of Land Management (BLM) Hualapai-Aquarius Planning Unit. This planning unit contains several different cover types within the Upper and Lower Sonoran Desert of westcentral Arizona (Table 1).

Vegetative structure was determined using the line transect toe point method from transects near the areas where faunal surveys occurred. Toe points were recorded about every four paces until at least 50 toe point hits on vegetation in a study site were tallied. The plant part or substrate encountered at each sample toe point was identified and recorded, as were plant hits in five ascending vertical strata. Plant hits were clumped into three strata: (1) a surface vegetation class ($\leq$ 0.6 m [2 ft.] tall); (2) a shrub midstory class ($>$ 0.6 m but $<$ 5 m [$>$ 2 ft. $<$ 16.4 ft.]); and (3) a tree canopy class ($\geq$ 5 m [16.4 ft] tall). These strata adequately

Table 1. Data from Arizona habitats used to develop the habitat gradient model.

	No. of guild blocks	Percentage of distribution by canopy class[a] <0.5	0.5–5m	>5m	Strata cover equitability[b]	Percentage of cover	Log (cover × equitability)	Habitat gradient value-guild blocks × log (cover × equitability)	No. herp. sp.[c]	No. bird sp.[d]	No. mammal sp.[e]	Total no. terrestrial sp.
Cottonwood-willow riparian	36	23.1	42.3	34.6	1.069	64.4	1.84	66.2	18	65	6	89
Pinyon-juniper	25	33.2	56.1	10.7	0.929	54.6	1.71	42.6	17	27	9	53
Closed chaparral	16	36.4	63.6		0.656	96.6	1.80	28.8	22	19	6	47
Open chaparral	16	61.0	39.0		0.669	51.9	1.54	24.6	11	22	5	38
Desert grassland	9	71.2	28.8		0.600	43.7	1.41	12.8	8	13	6	27
Joshua tree	16	63.1	35.1	1.8	0.730	42.6	1.49	23.9	12	20	8	40
Creosote bush	16	62.6	37.4		0.661	28.1	1.27	20.3	13	17	7	37
Saguaro-palo verde	25	54.5	45.5		0.689	40.2	1.44	36.1	23	33	6	62
Mesquite bosque	25	14.1	63.9	22.0	0.895	60.0	1.73	43.2	15	49	5	69
Juniper-mixed shrub	25	51.0	49.0		0.693	34.8	1.38	34.6	19	26	10	55

[a]From original data collected by Robert S. Hall and K. B. Jones.
[b]Uses Shannon formula (Shannon and Weaver 1963).
[c]Jones 1980.
[d]Hall 1980.
[e]Peck 1979.

partition the flora of the Sonoran desert. A ground surface stratum that extends to 0.6 m (2 ft.) above the surface approximates that used by MacArthur and MacArthur (1961). These authors also determined that a tree canopy stratum beginning at about 5 m (16.4 ft.) above the surface was useful for measuring foliar height diversity. The percentage of the sample points that encountered vegetation on the ground surface, in the shrub stratum, and in the tree canopy stratum were used to produce estimates of plant cover in each stratum. The total cover was determined by summing the percentage of cover recorded for each vegetative stratum present. Both percentage of total cover and the percentage of distribution of total cover between vegetative strata are recorded in Table 1.

The species of amphibians, reptiles, birds, and mammals present on each study site were determined with techniques described by Peck (1979), Hall (1980), and Jones (1980).

Results

The 10 Arizona study sites evaluated in this paper included a desert grassland community (nine guild blocks), four shrub dominated communities (16 guild blocks each); a riparian-mesquite bosque, a saguaro-palo verde community, and two communities with dwarf trees (25 guild blocks each); and a cottonwood-willow riparian treeland (36 guild blocks each). The saguaro, in the saguaro-palo verde habitat, was considered a tree without a canopy on the basis of its height and the use of its bole by wildlife.

The number of wildlife species that used the 10 habitat types throughout the year had a highly significant ($r = 0.98$) positive correlation with the number of guild blocks present (Figure 3). The variability in the number of species using habitats with equal numbers of guild blocks is largely accounted for when measures of total cover and equitability of cover between strata are considered in the model.

The variability in species richness between the 10 study sites was not significantly ($r = 0.28$) related to the relative amounts of cover. This occurs because two sites can have identical amounts of total cover with the cover restricted to only one stratum on one site and divided among several strata on the other site.

Species richness on the 10 study sites was correlated with the equitability measure ($r = 0.83$), because of the relationship between high equitability values and multiple strata, and with the product of total cover × equitability ($r = 0.64$). In both cases, however, the structural variables accounted for less than 70 percent of the variability in the prediction of the number of species that occurred on the study sites.

The product of number of guild blocks × percentage of cover × equitability of cover between strata produced a continuum or gradient of habitat conditions that illustrates the increase in species richness that occurs as habitats become more complex. The correlation coefficient between species richness and guild blocks × cover × equitability is $r = 0.89$.

A sigmoid species richness curve should exist for each group of habitats (9, 16, 25, or 36 guild blocks). The sigmoid curve for habitat types with little cover or low equitability of cover should indicate the presence of only a few species. The number of species represented by the sigmoid curve should increase as percentage of cover or equitability of cover increases. There is some maximum number of species that

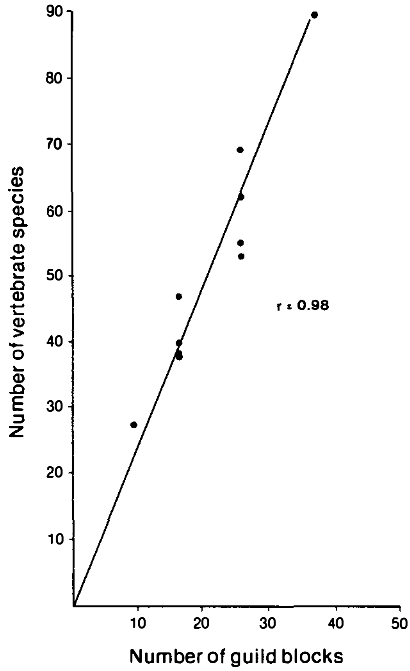


Figure 3. The number of guild blocks in 10 habitat types in westcentral Arizona is highly correlated ($r = 0.98$) with the number of wildlife species occurring in those habitats.

can exist in a particular habitat type. This maximum species richness or species packing should occur as the product of total cover and equitability of cover approaches the maximum for that habitat type.

The log transformation of the product of cover × equitability for the Arizona data was used to convert individual sigmoid curves for each habitat type into a single species richness gradient that corresponded to the habitat gradient, demonstrating the positive relationship between species richness and vegetative structure. The product of guild blocks and log (cover × equitability) accounted for about 93 percent of the variability ($r = 0.97$) in predicting the numbers of wildlife species present on the 10 study sites (Figure 4).

Discussion

Interpreting the Habitat Gradient

The habitat gradient potentially varies from simple ecosystems with little vegetation or structural diversity at one end to complex ecosystems with extensive vegetation and structural diversity at the other end. The extremes of the corresponding species richness gradient are few or no wildlife species where amount and diversity of vegetation is very low and a maximum number of species where

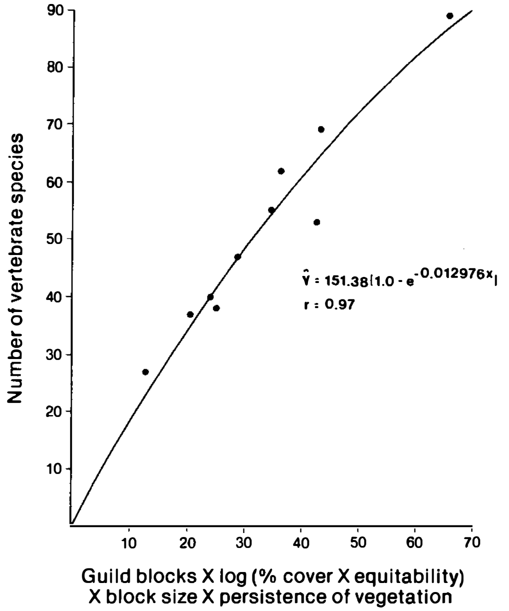


Figure 4. The relationship predicting species richness from the product of guild blocks × log (cover × equitability) × block size × persistence of vegetation for 10 habitat types in west-central Arizona ($r = 0.97$).

the structural diversity and complexity of vegetation is greatest. Because the habitat gradient has a defined end point, which represents optimal habitat conditions, intermediate habitats along the gradient can be compared with the optimal conditions to provide an index of relative habitat quality.

A change in the vegetative structure of a habitat results in a change in the position of the habitat along the gradient and causes the habitat to become suitable for a different group of wildlife species. A different series of species-habitat distribution curves are encountered that result in a different species richness value for the habitat. The objective of modeling habitat requirements for a species is to describe that species' bell-shaped distribution curve along the habitat gradient. Concepts in the species richness model are therefore just as applicable to studies of featured species as to studies of wildlife communities.

Additional Variables in the Habitat Gradient Model

Samson (1980) determined, on the basis of a literature review, that the size of islands of habitat can be used to predict the number of birds present in several temperate habitats. Species that are sensitive to habitat size tend to disappear as habitat becomes fragmented. Unfortunately, land use change often results in a reduction in habitat block size. Few studies have described the minimum block size necessary to provide suitable habitat for particular wildlife species. The block size multiplier must remain undefined until better predictors of the relationship between habitat area and species richness are developed. This multiplier, however, is important in determining the value of land as wildlife habitat.

Persistence of surface vegetation is a multiplier which weights the effects of agriculture, other intensive management of surface vegetation, or natural ephemeral vegetation on the quality of wildlife habitat. Persistence considers the length of time the vegetation is present and the extent of cover. For example, the persistence multiplier for an agricultural cropland is:

6 months fallow because of autumn plowing 6 × 0 percent ground cover	= 0
1 month early growth × 5 percent ground coverage	= 5
1 month mid-growth × 25 percent ground coverage	= 25
1 month mid-growth × 50 percent ground coverage	= 50
1 month near mature growth × 80 percent ground coverage	= 80
2 months mature growth × 100 percent ground coverage	= 200
Average persistence	= 360 ÷ 12
	= 30%

Block size and persistence of surface vegetation are included in the wildlife habitate gradient model (Figure 4). Both multipliers in this example are 1.

The predictive relationship in Figure 4 indicates that those habitats along a habitat gradient for a PNVT that contain the most guild blocks will support the most wildlife species. If two habitats along a gradient have the same number of guild blocks available for wildlife use, the habitat with the greatest total cover and equitability of cover between strata, largest block size, and most persistent cover will support the most wildlife species and guilds.

The Habitat Gradient Model as an Index

Four different PNVT (Küchler 1964) are represented in the habitat gradient model described in Figure 4: (1) juniper-pinyon woodland; (2) grama-tobosa shrub-steppe; (3) creosote bush-bur sage; (4) and the palo verde-cactus shrub type. The variables included in the habitat gradient model were sufficiently critical to wildlife that a regional habitat gradient could be developed to represent the diverse vegetative structures encountered.

The habitat gradient model can be used to develop a habitat gradient within any single PNVT. There will always be an upper limit to the vegetative diversity that can be represented along any habitat gradient. This upper limit can be used as the denominator in proportions used to estimate habitat quality for any other point along the habitat gradient for the same PNVT (Figure 5). This denominator is calculated as: number of guild blocks for the climax vegetation in the PNVT × log (maximum cover that has been observed to be distributed equally between strata × maximum equitability value for the strata present in the climax vegetation) × large block size × maximum persistency of vegetative cover. The actual wildlife value for any current habitat within the PNVT can be used as the numerator in the proportion in order to develop an index. The proportion, expressed as a

$$\text{Wildlife habitat quality coefficient} = \frac{\text{Actual values}}{\text{Potential values}}$$

$$= \frac{\left[\begin{array}{c}\text{Number guild}\\ \text{blocks present}\end{array}\right]\left[\log\left(\begin{array}{c}\text{Density of}\\ \text{total cover}\end{array} \times \begin{array}{c}\text{Equitability of}\\ \text{cover between}\\ \text{strata}\end{array}\right)\right]\left[\begin{array}{c}\text{Habitat}\\ \text{block}\\ \text{size}\end{array}\right]\left[\begin{array}{c}\text{Persistence}\\ \text{of cover}\end{array}\right]}{\left[\begin{array}{c}\text{Number guild}\\ \text{blocks in}\\ \text{potential}\\ \text{vegetation}\\ \text{type}\\ \\ 9 = \text{grassland}\\ 16 = \text{shrubland}\\ 25 = \text{small trees}\\ 36 = \text{treeland}\end{array}\right]\left[\log\left(\begin{array}{c}\text{Maximum}\\ \text{density of}\\ \text{vegetation in}\\ \text{potential}\\ \text{vegetation}\\ \text{type}\\ 100\% \text{ if one}\\ \text{stratum}\\ 150\% \text{ if two}\\ \text{or three}\\ \text{strata}\end{array} \times \begin{array}{c}\text{Maximum}\\ \text{equitability}\\ \text{coefficient}\\ \\ 0.1 \text{ if one}\\ \text{stratum}\\ 0.69 \text{ if two}\\ \text{strata}\\ 1.10 \text{ if three}\\ \text{strata}\end{array}\right)\right]\left[\begin{array}{c}\text{Habitat}\\ \text{block}\\ \text{size} = 1\end{array}\right]\left[\begin{array}{c}\text{Persistence}\\ = 1 \text{ if surface}\\ \text{vegetation}\\ \text{remains in place}\\ \text{throughout year.}\\ \text{Calculate value}\\ \text{if potential}\\ \text{surface vegetation}\\ \text{is deciduous or}\\ \text{ephemeral.}\end{array}\right]}$$

Figure 5. Form of the habitat gradient model when used as an index of wildlife habitat quality. The numerator represents measured values in a current vegetation type, and the denominator represents optimal values that are measurable in a potential natural vegetation type.

percentage, can be used to compare quality between different habitats within the PNVT.

Use of the Habitat Gradient Model in Land Use Planning

The five variables (guild blocks, percentage of total cover, equitability of cover, block size, and persistence of cover) in the habitat gradient model represent vegetative characteristics that are affected by land use changes. Values for these variables can be manipulated to reflect anticipated habitat changes, and the habitat gradient model used to predict the impact of the potential change on habitat quality.

Impacts of proposed management alternatives on a wildlife community or a particular wildlife species can be predicted with the habitat gradient model. Predicting impacts for a single species requires the development of the bell-shaped distribution curve that describes favorable habitat conditions for that species. If the position of the vegetative community on the habitat gradient, following management, represents the habitat structure required by the species, then the species would not be expected to be adversely affected by the habitat channge. If, however, the predicted new position of the vegetative community on the habitat gradient does not describe the habitat requirements of the species, the species will probably be adversely affected by the proposed change in habitat conditions.

When the model is used to predict the impacts of management on the total wildlife community, wildlife species are assigned a relative value. In the following example, all species have been assigned the same value and the conversion of native grassland to grazing or intensive agriculture are the land use changes that are considered. Management objectives for this example are to: (1) retain some native habitat and fauna; and (2) provide a more complex vegetative structure on the remaining area so that the remaining area × wildlife species richness value equals the former total habitat area × wildlife species richness value.

The maximum wildlife habitat value for 100 units of grassland with abundant cover is calculated according to the formula in Figure 5:

Original wildlife habitat value = 100 units area × 9 guild blocks × log (100 percent cover × 0.1 equitability) × 1 habitat block size × 1 persistence
= 900

The wildlife habitat value would be about 30 percent less if the cover value of the grassland was reduced 50 percent by some new land use, such as grazing.

New wildlife habitat value = 100 × 9 × log (50 × 0.1) × 1 × 1
= 629

Proportion of original wildlife habitat value = 629/900
= 70%

The position of the 100-unit area of grassland on the habitat gradient for the PNVT would shift to the left, and fewer wildlife species would be expected to occur. Species whose distribution curves indicate a perference for 50 percent grassland cover should respond favorably to the change in habitat conditions, while species that require more than 50 percent cover probably would be adversely affected.

Habitat quality value for the grassland would also change if the entire area was converted to cropland. Subsurface and surface strata would be unsuitable as breeding habitat for wildlife if agricultural operations included spring discing, summer cultivation, autumn plowing, and fallow field conditions during winter. The number of guild blocks available as habitat would be reduced to three. The only wildlife that would remain are those species that bred elsewhere and fed in the subsurface (rarely), on the surface, or in the air. Crop cover at maturity might be as high as 100 percent but cover persistence might be, for example, only 33 percent.

The wildlife habitat value of the cropland would be only about 11 percent of the value of the original grassland.

Cropland wildlife habitat value = 100 × 3 × log (100 × 0.1) × 1 × 0.33
= 100

Proportion of original wildlife habitat value = 100/900
= 11%

The vegetative structure on the remaining grassland could be modified to help compensate for wildlife habitat loss if only part of the area is converted to cropland. For example, the development of shrub dominated fence rows or shelterbelts could increase the value of wildlife habitat because these areas contain 16 guild blocks. Converting 27 percent of the grassland to a shelterbelt of multiflora rose would retain the original area × wildlife habitat value of the total grassland (900), provided the shrub midstory and the underlying native grassland surface cover each provided 60 percent cover.

Shelterbelt habitat cover	$= 27 \times 16 \times \log(120 \times 0.68) \times 1 \times 1$
	$= 826$
Cropland wildlife habitat value	$= 73 \times 3 \times \log(100 \times 0.1) \times 1 \times 0.33$
	$= 73$
Total wildlife habitat value	$= 899$

It must be emphasized that this example is more an exercise in arithmetic than biology because each species has been considered of equal value in the analysis. The example is justified, however, because it illustrates that land use change in native grassland need not result in the complete destruction of native prairie as wildlife habitat.

Converting 27 percent of the grassland to a shrub-dominated grassland association (shelterbelt), scattered throughout the 100 unit area, would result in both agricultural and wildlife benefits. Shelterbelts help reduce loss of cropland to wind and water erosion and provide protection from adverse climatic conditions for homes and livestock. Wildlife benefits because the loss of habitat carrying capacity over much of the area is compensated for by the development of more complex habitat over the remaining area, even though different wildlife species may be favored. Martin (1980) recommended that shelterbelts be as close together as feasible and as large as possible, because larger shelterbelts are used by more species.

Use of Data from Aerial Photographs in the Habitat Gradient Model

Data from aerial photographs can be used to locate a vegetative community on a habitat gradient, although some initial ground truthing is needed. Ground truthing is done in the major current vegetation types in order to develop a predictive relationship between percentage of cover in the highest stratum and percentage of cover in the lower strata.

The relationship between overstory crown cover and shrub cover has been described for mixed coniferous forests in Oregon by Young et al. (1967). Percentage of crown cover has been correlated with forage production, which is a function of surface cover, in ponderosa pine habitats in the Black Hills (Pase 1958), pine-hardwood forests in Texas (Halls and Schuster 1965), and ponderosa pine and pinyon-juniper habitats in northern Arizona (Jameson 1967). Predictive relationships, like those in Figure 6, can be developed for percentage of overstory cover and percentage of cover in the understory and midstory. Estimates of percentage of crown closure can be determined from aerial photographs. The estimates are occular and are usually done with printed density scales or with comparative stereograms (Avery 1978).

Tree crown diameter, which can be determined from 1:20,000 aerial photographs

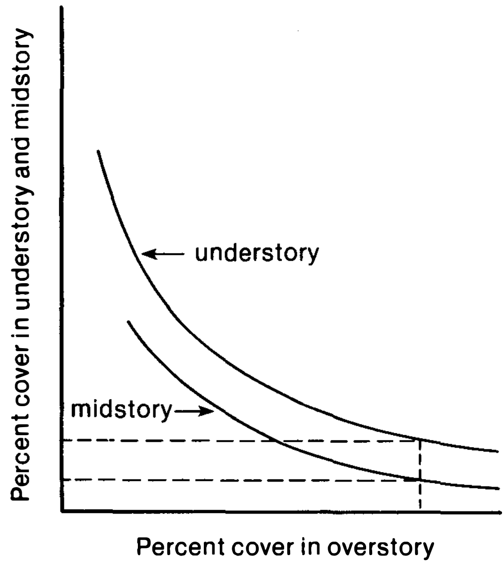
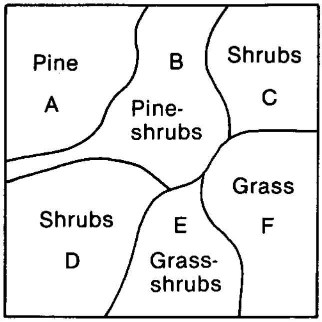


Figure 6. Form of prediction curves to estimate midstory and understory cover from values of cover measured in the overstory.

(Avery 1978), is related to trunk diameter for most conifers and many hardwoods. Individual crown diameters are most accurately measured in open growth stands, although average diameters of dominant trees in dense stands can be determined. The relationship between crown diameter and trunk diameter can be used to determine whether or not a tree bole is large enough to be used by wildlife. This distinction determines if the tree stand provides 25 or 36 guild blocks.

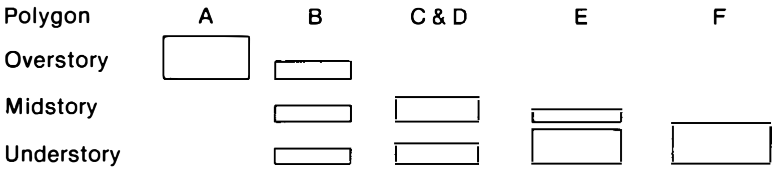
Current vegetative types that can be identified on an aerial photograph are separated into polygons on the basis of the number of strata and guild blocks present. The area of each polygon and the percentage of canopy cover in the highest stratum of each polygon are determined. The prediction equations developed to relate percentage of canopy cover in the highest stratum with percentage of canopy cover in the lower strata are used to estimate cover values for the lower strata that are present. Percentage of canopy cover values for all of the strata are assumed to provide a measure of percentage of total cover. The percentage of the total cover that is present in each stratum is used to calculate the equitability of cover using the Shannon formula (Shannon and Weaver 1963). The block size multiplier is applied when information is available on how fragmentation of habitat affects species use. The vegetation persistence multiplier is applied for agricultural areas.

Figure 7 illustrates how the wildlife habitat value is determined from aerial photographs for a hypothetical 100-unit area of mixed cover types. The polygons of different vegetation cover types (A–F) are demarcated and the area and cover profile of each polygon determined. Polygon A, a pine woodland, has a dense tree canopy and an average tree canopy size that indicates the presence of suitable



Photointerpretation of land area 100 units in size

Apparent vertical profile of polygons as determined from the canopy form observed from aerial photos and from ground truthing data.



Calculation of wildlife habitat value for 100 unit area

Polygon	Area	No. guild blocks	Density of canopy in highest stratum	Estimated midstory if treeland polygon (Fig. 6)	Estimated understory if treeland polygon (Fig. 6)	Estimated understory if shrubland polygon	Total estimated percent cover	Estimated equitability of cover	Block size multiplier	Cover persistence value	Area x guild block x log (cover x equitability) x block size x persistence	
A	15	36	100	0	0		100	0.1	1	1	540	
B	30	36	40	40	40		120	1.1	1	1	2290	
C	10	16	60			60	120	0.65	1	1	303	4052
D	15	16	60			60	120	0.65	1	1	454	
E	10	16	30			90	120	0.5	1	1	285	
F	20	9	100				100	0.1	1	1	180	
Ideal	100	36	50	50	50		150	1.1	1	1	7983	

$$\frac{\text{Wildlife value x Area}}{\text{Ideal wildlife value x Area}} = \frac{4052}{7983} = 51\%$$

Figure 7. Procedure for characterizing the wildlife habitat value of lands from interpreted aerial photographs. The process involves predicting the structure of a vegetative community from the aerial photographs and suitable prediction equations, calculating wildlife habitat values for the land area, and comparing these values to the wildlife habitat values potentially obtainable on that land unit.

boles for wildlife use. Polygon B, a pine-shrub association, contains several strata and is essentially a large unit of "edge" between polygons of treeland habitat and areas with only midstory or understory strata. Polygons C, D, and E are shrub and shrub-grass habitats, while polygon F is a grassland. The vegetative structural conditions that would be optimal for this PNVT, represented by the upper limit of the habitat diversity gradient, are also listed in Figure 7.

The wildlife habitat value of each polygon is determined and the values summed for the entire area being evaluated (Figure 7). The wildlife habitat value for optimal conditions is also determined for the total area. Ideal habitat would consist of large blocks of habitat, at least several square miles in area, with cover conditions similar to those in polygon B. The index obtained by comparing the current wildlife habitat value with the optimal habitat value is 51, about two-thirds of the way along the habitat gradient in Figure 4.

Habitat quality values, estimated from aerial photographs, can be directly compared between areas of the same size within a PNVT. In addition, estimates of the number of expected wildlife species, extrapolated from the habitat gradient, can be compared between areas within the PNVT if the species richness curve for that PNVT has been determined.

Optimal habitat for this example is the most heterogeneous habitat possible in this PNVT. Specifically, it is that habitat where all forest strata exist and where both the greatest possible total cover and the most equitable distribution of cover among strata occur, i.e., where an edge situation occurs around each tree in the overstory. This optimal habitat, represented by the denominator of the wildlife habitat value equation in Figure 7, is essentially a 100-unit block of edge.

Conclusions

The variety of habitats that exist within a PNVT can be described in terms of a habitat gradient. The variation in the vegetative structure of these habitats, will be accompanied by a corresponding variation in the structure of the wildlife communities that are present.

Comparing the structure of the vegetation on individual habitat sites with the maximum vegetative diversity that can occur in a PNVT provides a measure of habitat quality. Data about the structure of vegetative communmities, needed to estimate habitat quality, can be determined from field inventory data or from interpreted aerial photography, supplemented with ground truth information.

Regional or national assessments of habitat quality for wildlife can be accomplished by measuring the structural diversity of habitats within a PNVT and summing these measurements across all PNV types. Assessments done at two or more different times would describe changes that have occurred in habitat quantity and quality.

The vegetative variables that describe habitat diversity are measureable. They can be simulated in planning efforts in order to predict the effect of land use change on wildlife habitat and manipulated in actual wildlife management procedures in order to alter the habitat quality of land units.

Acknowledgments

I am indebted to the interest and careful field and laboratory work of T. Cordery, L. Kepner, W. Kepner, B. Millsap, D. Schaeffer, and J. Zook, of the Phoenix District Office, U.S. Bureau of Land Management (BLM). The development of the wildlife habitat gradient model resulted from a cooperative agreement between the U.S. Fish and Wildlife Service and the BLM, and was stimulated by ancillary efforts resulting from a cooperative agreement between the FWS and the U.S. Soil Conservation Service. I acknowledge and appreciate the support and interest expressed by R. G. Streeter and C. I. Short throughout the course of this study.

Literature Cited

Avery, T. E. 1978. Forester's guide to aerial photo interpretation. Agric. Hndbk. 308. USDA For. Serv., Washington, D.C. 41 pp.

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59–90 *in* Proceeding of the Symposium on management of forest and range habitats for nongame birds. Gen. Tech. Rep. 1. USDA For. Serv., Washington, D.C.

Hall, R. S. 1980. Avifauna of the Haulapai and Aquarius planning units, Mohave and Yavapai counties, Arizona. USDI Bur. Land Manage., Phoenix District Office, Phoenix, Az. 161 pp. Unpubl.

Halls, L. K., and J. L. Schuster. 1965. Tree-herbage relations in pine-hardwood forests of Texas. J. For. 63: 282–283.

Jameson, D. A. 1967. The relationship of tree overstory and herbaceous understory vegetation. J. Range Manage. 20: 247–249.

Johnston, D. W., and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology 37(1): 50–62.

Jones, K. B. 1980. Distribution, ecology, and habitat management of the reptiles and amphibians of the Hualapai-Aquarius planning area, Mohave and Yavapai countries, Arizona: An inventory and analysis by standard habitat site. USDI Bur. Land Manage., Phoenix District Office, Phoenix, Az. 216 pp. Unpubl.

Karr, J. R. 1968. Habitat and avian diversity on strip-mined lands in east-central Illinois. Condor 70: 348–357.

Kricher, J. C. 1973. Summer bird species diversity in relation to secondary succession on the New Jersey piedmont. Amer. Midl. Natur. 89(1): 121–137.

Küchler, A. W. 1964. The potential natural vegetation of the conterminous United States. American Geographical Society, Special Research Publication 36. 155 pp.

Levenson, J. B., and F. W. Stearns. 1980. Application of diversity to regional ecological assessment: A review with recommendations. Argonne National Laboratory AA-21. 34 pp.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42(3): 594–598.

Martin, T. E. 1980. Diversity and abundance of spring migratory birds using habitat islands on the great plains. Condor 82: 430–439.

Pase, C. P. 1958. Herbage production and composition under immature ponderosa pine stands in the Black Hills. J. Range Manage. 11: 238–243.

Peck, R. L. 1979. Small mammal inventory of the Aquarius and Hualapai planning units, Mohave and Yavapai counties, Arizona. USDI Bur. of Land Manage., Phoenix District Office, Phoenix, Az. 105 pp. Unpubl.

Samson, F. B. 1980. Use of montane meadows by birds. Pages 113–129 *in* R. M. DeGraff and N. G. Tilgham, compilers. Workshop Proceedings, Management of western forests and grasslands for nongame birds. Gen. Tech. Report. INT-86 USDA For. Serv., Ogden, Ut.

Shannon, C. E., and W. Weaver. 1963. The mathematical theory of communications. Univ. Illinois Press, Urbana. 117 pp.

Short, H. L., and K. P. Burnham. 1982. Technique for structuring wildlife guilds to evaluate impacts on wildlife communities. Special Scientific Report Wildl. 244. USDI Fish and Wildl. Serv., Fort Collins, Colo.

Thomas, J. W., ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handbk. 533. USDA For. Serv., Washington, D.C. 512 pp.

Young, J. A., D. W. Hedrick, and R. F. Keniston. 1967. Forest cover and logging. J. For. 65(11): 807–813.

Whittaker, R. H. 1977. Evolution of species diversity in land communities. Evol. Biol. 10: 1–67.

Wildlife Communities and Land Classification Systems

Douglas B. Inkley and Stanley H. Anderson
Wyoming Cooperative Fishery and Wildlife Research Unit Laramie, Wyoming

Introduction

Land classification systems (LCSs) are systematic methods of dividing land into distinct units based upon characteristics such as climate, crop production, vegetative type, or population density. LCSs can provide the structural framework for natural resource data bases that facilitate efficient inventory, research, and management of these natural resources.

Several LCSs are presently being used to classify habitats occupied by wildlife. Forest Service species-habitat relationships systems (Patton 1978, Thomas 1979, Verner and Boss 1980) use potential natural vegetation types (Küchler 1964) and other vegetation classifications to indicate wildlife habitat preferences. The dependence of wildlife upon habitat suggests that wildlife communities should be distributed in patterns similar to that of vegetation types. However, the degree of correlation between the LCSs presently in use and wildlife communities has not been determined. Our objective was to develop an objective procedure for determining the degree to which LCSs represent wildlife communities. Effective wildlife management based on habitat relationships models requires that the wildlife resources be distributed in a manner similar to the LCS used.

Land Classification Systems

The development of LCSs depends upon their intended use. LCSs are generally designed to represent changes in characteristics of one or several parameters. A rainfall map, a classification of land based upon annual average precipitation, represents a one-parameter LCS. One-parameter LCSs help us conceptualize changing patterns of that single parameter. An LCS simultaneously representing changing patterns of two or more parameters is an integrated LCS. Integrated LCSs are useful for understanding and interpreting relationships between two or more parameters. For example, an LCS representing characteristics of both rainfall and soil type provides an understanding of soil and water interrelationships. This integrated LCS is more useful for determining crop yields than a single parameter soil or rainfall LCS.

LCSs should be hierarchical in structure to increase their usefulness. Hierarchical LCSs group units of land into larger areas, based upon characteristics of the land. Hierarchical LCSs are very useful for summarizing data and developing concepts at the level needed by the user. A field biologist may need data for individual habitat types, whereas a regional or national wildlife planner may need data summarizing larger areas. A properly developed hierarchical LCS can provide useful data at many levels of resolution.

Wildlife Communities

Most LCSs used in wildlife management were not developed specifically for that purpose. They were based upon parameters such as soil, vegetation, climate, and topography, rather than the distributions of wildlife communities.

Distributional patterns of wildlife communities have been studied by biogeographers. Hagmeier (1966) and Udvardy (1963) mapped mammalian and avian regions, respectively, of North America. Species density of amphibians and reptiles in North America were examined by Kiester (1971), but he did not identify specific amphibian and reptilian regions. Many other authors (Van Dyke 1939, Miller 1951, MacArthur 1959, Simpson 1964, Cook 1969, Bock and Lepthien 1974, 1975, Bock et al. 1978) have researched the zoogeography of North American animals.

Field studies have demonstrated that wildlife communities change along environmental gradients. Climate and exposure are primary factors determining distributions of amphibians and reptiles (Porter 1972). Mammals are strongly influenced by vegetation and soil types (Dueser and Shugart 1978). Bond (1957) showed that southern Wisconsin bird communities responded to vegetation type. Smith (1977) and Noon (1981) found bird species distributed along moisture and altitudinal gradients, respectively. Generally, birds are associated with habitat structure (James 1971), which in turn is influenced by climate, soils, moisture, and topography. Since vertebrate distributions are apparently influenced by many of the environmental factors used for LCS development, it is appropriate to see if wildlife communities are correlated with the units of LCSs.

Study Area

A method of comparing LCSs to distributional patterns of wildlife communities is demonstrated for Colorado and Wyoming. The wildlife community, for our purposes, consists of the vertebrate classes: Amphibia, Reptilia, Aves, and Mammalia (excluding Chiroptera). The recent breeding distributions of these vertebrates were determined from latilong publications (Bissell 1978, Kingery and Graul 1978, Langlois 1978, Oakleaf et al. 1982, Bardwell and Thomas 1980, Baxter and Stone 1980, and Findholt et al. 1981. These publications contain data on the status of each species for each latilong in the study area. A latilong is an area of land one degree in latitude and longitude on a side (Bissell and Graul 1981).

Methods

We chose *Ecoregions of the United States* (Bailey 1976) to compare to wildlife communities because ecoregions are based upon parameters of importance to wildlife. In addition, ecoregions are organized into a hierarchical system, allowing evaluation at any level of the hierarchy. Ecoregions of the United States were determined by soil, vegetative, climatic, and topographic characteristics. We used the section level (level 4) of this nine-level hierarchy in our analysis.

Our approach required identification of wildlife communities, and then a comparison of the distribution of these communities to ecoregions. Wildlife communities of Colorado and Wyoming were identified with a statistical analysis of species' distributions. Breeding terrestrial vertebrates were identified for each latilong within the study area, using latilong publications. A coefficient of similarity was calculated between all pairings of latilongs. The similarity coefficient (Webb 1950) was:

$$SC = \frac{n_{12}}{n_1 + n_2 - n_{12}}$$

where

n_1 = number of species in latilong 1,
n_2 = number of species in latilong 2, and
n_{12} = number of species common to latilongs 1 and 2.

Similarity coefficients between all possible pairs of latilongs were arranged in a similarity matrix.

The similarity matrix was used in a hierarchical cluster analysis. The purpose of this analysis was to group latilongs into successively larger groups in a dendritic pattern, based upon similarities in vertebrate species composition indicated by the similarity coefficients. The Cluster Analysis of Variables procedure (Hartigan 1979) from the Biomedical Computer Program, P-Series (Dixon and Brown 1979) was used to group latilongs. The criterion used to combine clusters was the average distance between clusters.

The cluster analysis produced a dendrogram showing the interrelationships among latilongs based upon similarity in species composition. At any percentage similarity, a specific number of groups of latilongs (wildlife communities) could be mapped. Comparison of wildlife communities to LCSs necessitated that the number of wildlife communities equal the number of LCS units in the study area. To evaluate the section level of ecoregions in the study area, a vertical line was drawn through the dendrogram at the percentage similarity that defined the desired number of groups. These groups of latilongs (wildlife communities) were then mapped on an overlay of ecoregion sections for the study area.

Subjective comparison of the size and location of wildlife communities relative to ecoregion sections provided an indication of their similarity. An objective comparison, however, is needed if several LCSs are to be evaluated to determine the one most similar to wildlife communities. We used the methods of Inkley et al. (in prep.) to determine objectively the similarity between distributions of wildlife communities and ecoregion sections. Ecoregion sections and wildlife communities were associated in pairs on the basis of areal overlap. That is, an ecoregion section and wildlife community occurring over predominantly the same area were considered to be associated with each other. The areal overlaps of each paired ecoregion section and wildlife community were totaled and expressed as a percentage of the total area. This percentage objectively expressed the similarity between ecoregion sections and wildlife communities.

Results

Relationships among latilongs, as determined by the vertebrates breeding in each latilong, are diagrammed in Figure 1. The dendrogram permits examination of wildlife communities at any percentage similarity. For example, at 40 percent similarity, four clusters of latilongs are evident. Eight clusters of latilongs were selected because there are eight ecoregion sections in Colorado and Wyoming

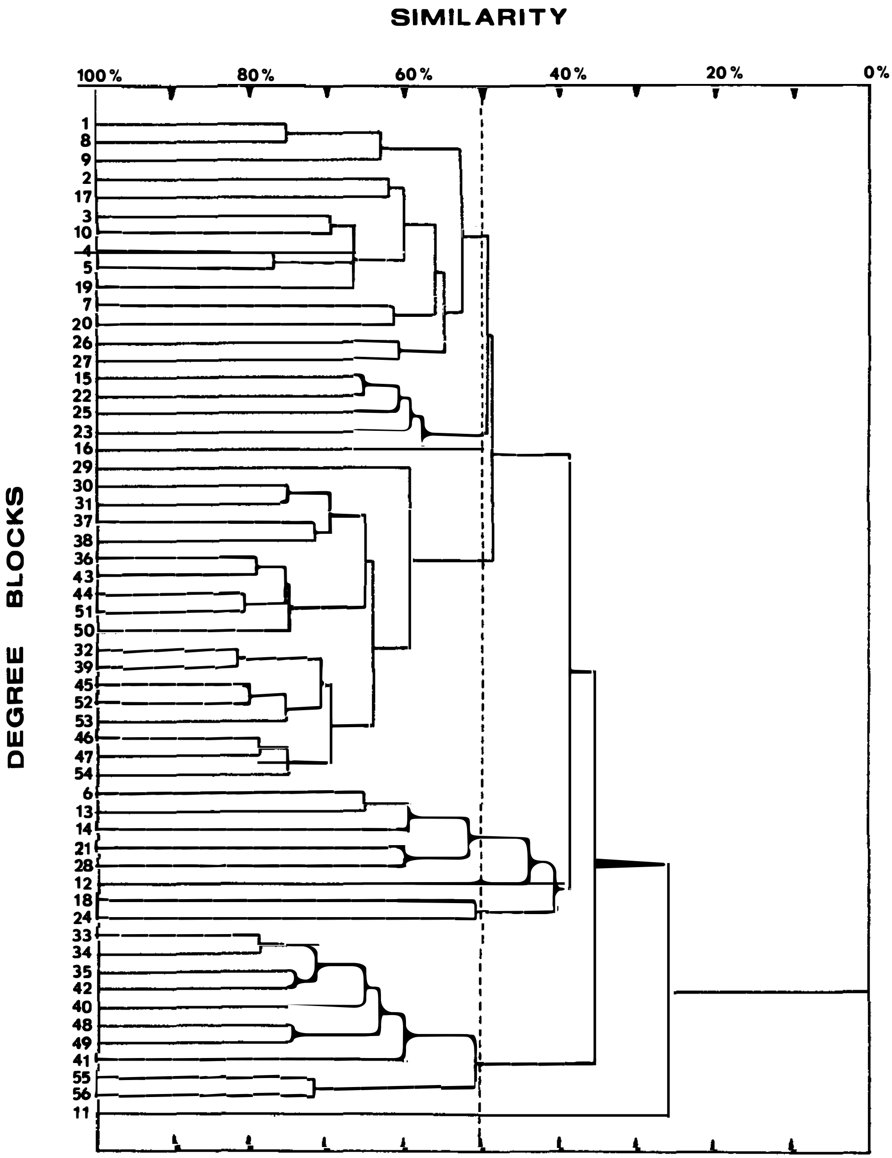
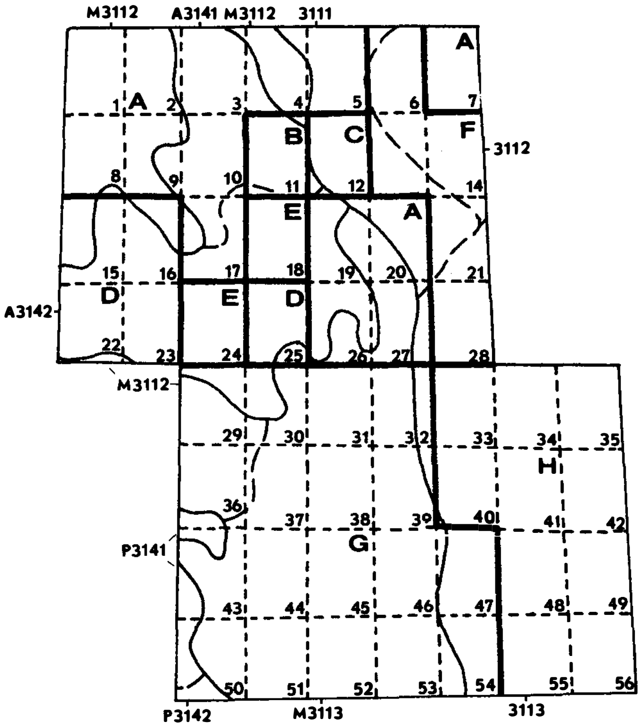


Figure 1. Dendrogram illustrating relationships among degree blocks based upon their similarities in breeding vertebrate species composition. Eight groups of degree blocks are evident at 50 percent similarity.

(P3142 excluded because of small area). These eight clusters of latilongs, or eight wildlife communities, were evident at 50 percent similarity. The locations of these eight wildlife communities, identified by letters *A* through *H*, are illustrated in

Figure 2. The methods of Inkley et al. (in prep.), established the relationships among individual ecoregion sections and wildlife communities (Table 1).

The mountains of Wyoming and Colorado were represented by wildlife communities *A* and *G,* and were associated with ecoregion sections M3112 and M3113 (Table 1), respectively. Representative breeding species of these two wildlife communities are the gray jay (*Perisoreus canadensis*), Gapper's red-backed vole (*Clethrionomys gapperi*), and the boreal toad (*Bufo boreas*). Wildlife communities *A* and *G*, though primarily in montane habitats, including six latilongs (3, 5, 7, 10, 47, and 54) that were predominantly within non-montane ecoregion sections (Figure 2). Latilongs 3, 5, 10, 47, and 54 were included in the montane wildlife community due to the presence of montane species at the peripheries of these



LEGEND

Ecoregion province boundaries
Ecoregion section boundaries
1 Degree block number
Degree block boundaries
3112 Ecoregion number
Wildlife group boundaries
A Wildlife group

Figure 2. Map of ecoregions and wildlife communities in Colorado and Wyoming.

Table 1. The associations between wildlife communities and ecoregions determined by map comparison procedures are presented in this table.

Ecoregion section	Wildlife community
3111	C
3112	F
3113	H
A3141	B
A3142	D
M3112	A
M3113	G
P3141	E

latilongs. Latilong 7 was in montane wildlife community *A* because of the fauna of the Black Hills. The clustering of latilongs 19, 20, 26, and 27 into wildlife community *A* was surprising because of their geographical proximity to wildlife community *G*. This boundary may have been a result of slightly different criteria used to determine breeding status in Colorado and Wyoming.

Ecoregion sections 3111, 3112, and 3113 were associated with wildlife communities *C*, *F*, and *H* respectively, and represented fauna of grassland habitats. Characteristic species are the Plains harvest mouse (*Reithrodontomys montanus*), red-headed woodpecker (*Melanerpes erythrocephalus*), Great Plains toad (*Bufo cognatus*), and Western hognose snake (*Heterodon nasicus*).

Ecoregion sections A3141 and A3142 of the Wyoming basins corresponded to wildlife communities *B* and *D*, respectively. Ecoregion section A3142 was sufficiently diverse to be split into wildlife communities *D* and *E*. Since wildlife community *D* had greater overlap with A3142, it rather than *E* was associated with A3142 (Table 1). By arbitrary assignment, wildlife community *E* was associated with ecoregion section P3141, with which it had no areal overlap. The overall similarity between the distributions of wildlife communities and ecoregion sections in Colorado and Wyoming, was 80 percent at the section level of analysis.

Discussion

The objective comparison of ecoregions at the section level indicated that ecoregions and wildlife communities are similar in size and location (80 percent similarity) in Colorado and Wyoming. Interpretation of similarity was partially obscured by low resolution wildlife data. Each degree block overlaps many potential natural vegetation types (Küchler 1964). This caused the similarity in species composition between latilongs to be high relative to what we would expect if each latilong covered only one or several vegetation types. In addition, a few latilongs were included in apparently the incorrect wildlife community because of the presence of species from another community at the periphery of the latilong.

Low resolution data does not preclude comparison of ecoregions and wildlife communities. Comparison may be done at the level of data resolution. Particularly indicative of the merits of these methods is the classification of latilong seven from ecoregion section 3112 of the Great Plains into a wildlife community (*A*) dominated by fauna of the Rocky Mountains. The wildlife community of latilong seven, the Black Hills area, is distinctly different from the surrounding Great Plains, although this is not represented at the ecoregion section level. Because of similarities in vegetative, topographic, and climatic characteristics, the Black Hills wildlife community is most similar to wildlife community *A* of the Rocky Mountains.

The high similarity between ecoregions and wildlife communities suggests that animals respond to the same or similar environmental factors (soil, vegetation, climate, and topography) that were used for establishment of ecoregions. Although the vertebrate community as a whole may show high correlation with ecoregions, individual species or groups of species may not be similarly correlated because different environmental factors influence each species, or the same environmental factors may influence each species differently.

Recommendations

We recommend further examination and improvement of methodologies for determining how well land classification systems represent the wildlife resource. We (Anderson et al., in prep.) have already developed evaluation procedures with the same objective, but with modifications to improve the analysis by incorporation of abundance data. This technique has been used only with birds because of the paucity of abundance data for other vertebrate classes.

We believe that evaluation of LCSs for their representation of wildlife communities should be conducted on a nationwide or at least regional scale. Development and utilization of a single LCS for wildlife in the United States will improve wildlife inventory, research, and management if the LCS represents the distribution of wildlife communities. The use of a single system will also facilitate exchange of data among agencies and scientists and minimize duplication of effort.

Our evaluation procedures can be improved by including the fisheries resource in evaluation methods. Inclusion of fish distributions will allow evaluation of LCSs for their representation of the complete fish and wildlife community. However, their inclusion may necessitate new methods of analysis because factors affecting fish distributions are markedly different than those for wildlife.

Analyses of LCSs to determine how accurately they reflect distributions of wildlife commmunities need to be applied at many levels of resolution. Through multi-level application of these methods, a complete evaluation of hierarchical LCSs may be done.

Only when LCSs have been evaluated to determine if they represent natural stratifications of a resource can they be used to implement effective and economical inventory, research, and management of that resource. We recommend evaluation, and modification if necessary, of any LCS before it is implemented for use.

It may be possible to examine objectively the distributions of other resources with modifications of the procedures presented here. We recommend similar analyses of vegetation, soils, and other natural resources to examine the relationships among them.

Summary

A method of identifying wildlife communities and comparing their distributions to units of various land classification systems was presented. Wildlife commmunities were identified using cluster analysis of the distributional patterns of mammals, birds, reptiles, and amphibians. The locations of these communities were compared objectively and subjectively to sections of *Ecoregions of the United States* (Bailey 1976). The similarity between ecoregion sections and wildlife communities in Colorado and Wyoming was high. An exception was the Black Hills, where vegetational, climatic, topographic and soil characteristics were not represented by *Ecoregions* as being distinctly different from the surrounding Great Plains. The wildlife community of the Black Hills had a higher similarity to the Rocky Mountain wildlife community than it did to the Great Plains wildlife community.

Recommendations were made to improve the methods by including abundance and fisheries data and performing the procedures at many hierarchical levels. Evaluations need to be done to select one national LCS suitable for wildlife. Before any LCS is used as a natural resource management tool, it should be thoroughly evaluated, and modified if necessary.

Acknowledgments

We thank Robert Oakleaf and Geoffrey Hammerson for providing data; Robert Bailey and Charles Cushwa for valuable suggestions; Jonnie Hoggan, Keith Lewis, Robin Sell, and Roberta Skinner for manuscript preparation; Kit Leung for computer programming; and William Krohn, Tricia MacLaren, Barry Noon, Hal Salwasser, and William Seitz for reviewing the manuscript. This research was funded by the Eastern Energy and Land Use Team, with logistic support provided by the Migratory Bird and Habitat Research Laboratory, and the Wyoming Cooperative Fishery and Wildlife Research Unit.

References Cited

Anderson, S. H., D. B. Inkley, and C. T. Cushwa. An approach to comparing land classifications and patterns of wildlife distribution. In preparation.

Bailey, R. G. 1976. Ecoregions of the United States (map). USDA Forest Service, Intermountain Region, Ogden, Utah.

Bardwell, L., and V. Thomas. 1980. Bird latilong update. Colo. Field Ornithol. 14: 66–69.

Baxter, G. T., and M. D. Stone. 1980. Amphibians and reptiles of Wyoming. Wyoming Game and Fish Dep., Cheyenne. 137 pp.

Bissell, S. J., ed. 1978. Colorado mammal distribution latilong study. Colorado Division of Wildlife, Denver. 20 pp.

Bissell, S. J., and W. D. Graul. 1981. The latilong system of mapping wildlife distribution. Wildl. Soc. Bull. 9: 185–189.

Bock, C. E., and L. W. Lepthien. 1974. Winter patterns of bird species diversity and abundance in the United States and southern Canada. Amer. Birds 28: 556–562.

———. 1975. Patterns of bird species diversity revealed by Christmas counts versus breeding bird surveys. West. Birds 6: 95–100.

Bock, C. E., J. B. Mitton, and L. W. Lepthien. 1978. Winter biogeography of North American Fringillidae (Aves): a numerical analysis. Syst. Zool. 27: 411–420.

Bond, R. R. 1957. Ecological distribution of breeding birds in the upper forests of southern Wisconsin. Ecol. Monogr. 27: 351–384.

Cook, R. E. 1969. Variations in species density of North American birds. Syst. Zool. 18: 64–84.

Dixon, W. J., and M. B. Brown, eds. 1979. Biomedical computer programs, P-series. University of California Press, Berkeley. 880 pp.

Dueser, R. D., and H. H. Shugart. 1978. Microhabitat configurations in a forest-floor small mammal fauna. Ecology 59: 89–98.

Findholt, S., R. Oakleaf, and B. Long, eds. 1981. Working draft of Wyoming mammalian atlas. Wyoming Game and Fish Department, Cheyenne. 25 pp.

Hagmeier, E. M. 1966. A numerical analysis of the distributional patterns of North American mammals II. Re-evaluation of the provinces. Syst. Zool. 15: 279–299.

Hartigan, J. A. 1979. Cluster analysis of variables. Pages 623–632 *in* W. J. Dixon and M. B. Brown, eds. Biomedical computer programs, P-series. University of California Press, Berkeley. 880 pp.

Inkley, D. B., S. G. Mankowski, L. L. McDonald, and S. H. Anderson. An objective method of comparing two maps. In preparation.

James, F. J. 1971. Ordinations of habitat relationships among breeding birds. Wilson Bull. 83: 215–236.

Kiester, A. R. 1971. Species density of North American amphibians and reptiles. Syst. Zool. 20: 127–137.

Kingery, H. E., and W. D. Graul, eds. 1978. Colorado bird distribution latilong study. Colorado Division of Wildlife, Denver. 61 pp.

Küchler, A. W. 1964. The potential natural vegetation of the conterminous United States. American Geographical Society Special Publication 361 (map).

Langlois, D., ed. 1978. Colorado reptile and amphibian distribution latilong study. Colorado Division of Wildlife, Denver. 18 pp.

MacArthur, R. H. 1959. On the breeding distribution pattern of North American migrant birds. Auk 76: 318–325.

Miller, A. H. 1951. An analysis of the distribution of the birds of California. University of California Publication in Zoology 50: 531–643.

Noon, B. R. 1981. The distribution of a guild along a temperate elevational gradient: the importance and expression of competition. Ecol. Monogr. 51: 105–124.

Oakleaf, R., H. Downing, B. Raynes, M. Raynes, and O. Scott, eds. 1982. Wyoming avian atlas. Wyoming Game and Fish Department and Bighorn Audubon Society, Cheyenne. 88 pp.

Patton, D. R. 1978. Run wild: a storage and retrieval system for wildlife habitat information. General Technical Report RM-51. USDA Forest Service, Fort Collins, Colo. 8 pp.

Porter, K. R. 1972. Herpetology. W. B. Saunders Company. Philadelphia. 524 pp.

Simpson, G. G. 1964. Species density of North American recent mammals. Syst. Zool. 13: 57–73.

Smith, K. G. 1977. Distribution of summer birds along a forest moisture gradient on an Ozark watershed. Ecology 58: 810–819.

Thomas, J. W., ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agr. Handb. No. 553. USDA For. Serv., Washington, D.C. 512 pp.

Udvardy, M. D. F. 1963. Bird faunas of North America. Pages 1147–1167 *in* Sibley, C. G., ed. Proceedings 13th International Ornithological Congress. American Ornithologists' Union. 1246 pp.

Van Dyke, E. C. 1939. The origin and distribution of the Coleopterous insect fauna of North America. Pages 255–268 *in* Proceedings of the 6th Pacific Science Congress of the Pacific Science Association. University of California Press, Berkeley. 993 pp.

Verner, J., and A. S. Boss. 1980. California wildlife and their habitats: western Sierra Nevada. General Technical Report PSW-37. USDA Forest Service, San Francisco. 439 pp.

Webb, W. L. 1950. Biogeographic regions of Texas and Oklahoma. Ecology 31: 426–433.

Habitat Evaluation: A Comparison of Three Approaches on the Northern Great Plains

William K. Seitz and Craig L. Kling[1]
Colorado Cooperative Wildlife Research Unit, Colorado State University, Fort Collins

Adrian H. Farmer
Habitat Evaluation Group, Western Energy and Land Use Team, Office of Biological Services, Fort Collins, Colorado

Introduction

The Fish and Wildlife Coordination Act of 1934 (16 U.S.C. 661–667), the Principles and Standards for Planning Water and Related Land Resources (U.S. Water Resources Council 1973), the National Environmental Policy Act of 1969 (42 U.S.C. 4321–4347), and the Forest and Rangelands Renewable Resources Planning Act of 1974 (16 U.S.C. 1601–1610) and other legislation and regulations either require the development of methods and procedures that will insure that wildlife are given appropriate consideration during decision-making or imply that standard procedures for evaluation of impacts to habitat already exist. The legislative requirements are necessary because of changes in the land's capabilities to produce wildlife brought on by increased use of resources. Methods of inventory and evaluation of wildlife habitat are necessary if biologists are to make intelligent recommendations and decisions on behalf of wildlife and people who use and enjoy it.

Several methodologies have been developed in recent years as a result of the demand for habitat evaluation techniques (Daniel and Lamaire 1974, U.S. Fish and Wildlife Service 1976, Whitaker and McCuen 1976, Flood et al. 1977, Bramble and Byrnes 1979, and others). The U.S. Fish and Wildlife Service (USFWS) developed and is refining the Habitat Evaluation Procedures (HEP) to provide uniform procedures for estimating impacts of various types of land and water development on fish and wildlife and their habitat. Williams et al. (1977) suggested that pattern recognition (PATREC) concepts and data organization, analysis, and information synthesis based on Bayesian statistical inference could be employed to estimate habitat suitability.

The USFWS, as part of one effort to improve HEP, funded a project in 1978 through the Colorado Cooperative Wildlife Research Unit (CCWRU) to evaluate habitat evaluation models from two approaches: (1) PATREC models (Williams et al. 1977) and (2) suitability index (SI) models (Giles 1978). The principal criteria for judging the models included: (1) accuracy with which the approach could predict suitability of an area for producing wildlife, as reflected by density, (2) acceptance and ease of application of the approach by biologists, and (3) costs to conduct the evaluation in the field. A non-structured habitat evaluation method, the personal opinion approach (POA), was the third procedure evaluated during the test.

SI models rely on transformation curves and life requisite equations to estimate

[1]Present address: Mariah Associates, Laramie, Wyoming 82070

habitat suitability (U.S. Fish and Wildlife Service 1981). PATREC models use information on the frequency with which specific habitat components occur among areas of known low density as well as comparable information on the frequency with which the same components occur among areas with high density populations of a particular species. This information is then used to calculate, based on Bayesian statistical theory, a probability that an area supports a high density given the observed pattern of habitat attributes found on the area (Williams et al. 1977, Kling 1980, U.S. Fish and Wildlife Service 1981).

Study Area

Personnel from the CCWRU and HEP Group, Western Energy and Land Use Team, USFWS, Fort Collins, Colorado, selected an area near Decker, Montana for the field test of the habitat evaluation models after a three-month search in seven western states for the best available data base (Figure 1). The area had been studied intensively by a USFWS research team from the Denver Wildlife Research Center. Wildlife and vegetation in this area had also been inventoried by several mining companies, environmental consultants, and university researchers. The Decker area was selected because density estimates of several wildlife species that had been produced there during the past two to three years were available for use as a measure of habitat suitability. There are problems with the use of density as

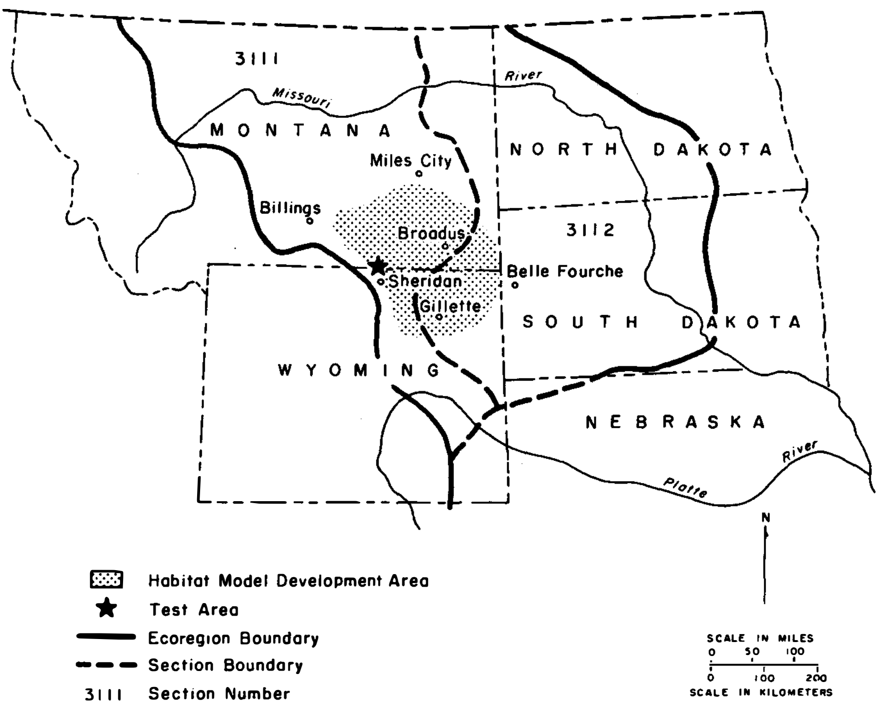


Figure 1. Location of test area used during summer 1979.

a measure of habitat suitability due to the interactions of habitat with other factors, such as predation or unusually mild or severe weather, which also influence density. We attempted to reduce the influence of these other factors by selecting an area where average density estimates over several years could be calculated. The region surrounding the test area (Northern Great Plains Ecoregion Sections 3111 and 3112 in Bailey 1976) served as the study area within which the background information for model development was gathered.

For the test, three sites within the Decker test area were chosen based on recommendations of the USFWS research team. The sites selected were those for which the most wildlife population data had been gathered and they represented a range from high to low populations for most of the wildlife species in the test. The authors and the test participants did not know the USFWS population estimates during the field test.

Methods

Terrestrial wildlife species were selected to represent wildlife exhibiting a range of characteristics: habitat generalists and specialists, mammals, birds, game and non-game, well known and lesser known species. The species were mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), sharp-tailed grouse (*Pediocetes phasianellus*), sage grouse (*Centrocercus urophasianus*), golden eagle (*Aquila chrysaetos*), and Brewer's sparrow (*Spizella breweri*).

The Field Test

A comparison of the two standardized models and POA under field conditions was conducted during the weeks of July 9 and 16, 1979. The criteria for comparison were (1) accuracy with which the model could predict the suitability of a site (or at least a relative ranking of sites) for producing wildlife, (2) acceptance and ease of application of the procedure, and (3) costs to conduct the evaluation in the field.

The test was divided into three parts: (1) accuracy with which the models estimated the density of each species for each site, (2) comparison of the models for repeatability of density estimates by teams, and (3) an assessment of the use and interpretation of the models by the volunteer participants. Area-wide habitat inventory data collected by environmental consultants, USFWS biologists, university researchers, and the authors were used to calculate density estimates for each model. These estimates were then compared to USFWS population estimates as a measure of model accuracy.

Teams of three to four biologists were used during testing to simulate actual field conditions. Eighteen people participated the first week; 16 assisted the second week. To assure that teams would be comprised of representatives of various agencies, participants were stratified according to their employer and teams were comprised of individuals drawn at random from the various strata.

Personnel of the HEP Group in Fort Collins prepared the material relating to SI models and C. Kling, CCWRU, prepared the PATREC material for the test. These materials included a short description of each of the models, instructions on how to use them in a field situation, and SI and PATREC models for each species.

Inventory information required for the two standardized models was similar enough so that it could be gathered at the same time, thereby reducing duplication of measurements and saving participants' time. SI models were constructed using literature reviews. PATREC models were based either on field data collected in the area around the Decker test area (Figure 1) or on literature. Other materials that were prepared for the test participants included USGS 7.5 minute topographic quads, vegetation map overlays, data forms, and sampling equipment.

Members of the HEP Group and CCWRU spent about four hours the first day briefing the participants about the models for the field test.

Each team devoted one day to both data collection and calculations for each site. After each site had been inventoried, the teams used the inventory information to perform model calculations and obtain an estimate for the expected density for all species except the golden eagle model, which expressed a probability of occurrence of an occupied site. Prior to performing model calculations, the teams were asked to provide their personal opinion estimate of the expected density for the site for each species. Teams used whatever information or basis they wanted for personal opinion estimates. Model calculations performed by each team were checked for arithmetic error and when errors were found, they were corrected.

Participants completed an appraisal form (Appendix C in Kling 1980) on the morning of the fifth day of the test period. The form was used to solicit information about models tested and the participants' reaction to various aspects of each. It also served as a means by which participants could formally comment, criticize, and make suggestions for improvement. A brief summary of the habitat evaluation estimates was presented followed by a general discussion of the test and the evaluation models.

Statistical Analysis

Crosstabs, an SPSS program (Nie et al. 1975), was used to summarize the responses to the appraisal form and to identify statistically significant relationships among (1) familiarity, experience, or prior use of either of the two standardized models and responses to other questions in the appraisal form and preference ranking of the methods, (2) level of familiarity with the species and ranking of the models, and (3) number of times the respondent evaluated habitat or used an evaluation done by someone else and the ranking of models.

Four factors of variation in the model estimates were analyzed: (1) variations in SI, PATREC, and POA evaluations, (2) corrected and recorded estimates by procedure, (3) sites and (4) teams. Data were analyzed by ANOVA using a factorial design. If F values were significant (0.05 level), LSD values (Snedecor and Cochran 1967: 272) were computed to identify the source of significant differences among the components comprising the factor.

Results and Discussion

Model Performance

Performance of the models as judged against observed densities was variable among sites, teams, and species (Table 1). These results are summarized herein; see Kling (1980) for a more detailed presentation, including graphical results for the six species on the three areas.

Table 1. Predicted density estimates for six species on the three test sites near Decker, Montana from 10 teams using PATREC, Suitability Index (SI), and personal opinion. Observed population densities are based on inventory studies during 1976–1978.

	Mule deer/ 2.6 km^2			Pronghorn/ 2.6 km^2			Sharp-tailed grouse/ 2.6 km^2			Sage grouse/ 2.6 km^2			Brewer's sparrow (pairs/40 ha)			Golden eagle (*p* of occupied area)		
	1[a]	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Observed population density	10	80	25	1.5	0.0	1.5	NA[b]	NA	NA	NA	NA	NA	42	24	4	Y[c]	Y	N
SI																		
$\bar{y}$—recorded[d]	73	45	38	6.0	7.0	6.0	15	12	8	32	35	42	11	20	6	0.41	0.58	0.52
$\bar{y}$—corrected	100	22	68	6.0	7.0	8.0	18	17	12	25	39	36	27	23	13	0.32	0.56	0.60
area-wide	87	73	20	8.0	9.0	9.0	18	19	20	29	66	83	30	21	11	0.36	0.67	0.68
PATREC																		
$\bar{y}$—recorded	85	30	14	3.0	4.0	4.0	23	3	12	16	21	92	38	30	19	0.56	0.78	0.47
$\bar{y}$—corrected	73	29	11	3.0	4.0	4.0	24	3	11	12	18	90	41	30	19	0.52	0.77	0.53
area-wide	150	20	10	1.0	1.0	1.0	29	2	3	10	14	99	50	6	5	0.96	0.96	0.62
Mean personal opinion	42	49	32	5.0	4.0	5.0	15	8	7	31	40	38	29	19	14	0.54	0.68	0.41

[a]1 = site 1, 2 = site 2, 3 = site 3.

[b]Inventory information for sharp-tailed grouse and sage grouse was number and location of leks and average number of displaying males/lek. Expected density estimates from the procedures were not directly comparable.

[c]Y = yes, site occupied by nesting golden eagles; N = no, site not occupied.

[d]"Recorded"—estimates the participants gave, "corrected"—estimates based on the same inventory information used by the participants after calculations were checked; "area-wide"—estimates based on information from an entire test area and which were used to check inherent accuracy of the procedure and models.

Both PATREC and SI models overestimated the expected density of mule deer on site 1 and underestimated it on the other two sites when area-wide structural habitat data collected by environmental consultants and others were used as input to the models (Table 1). The POA estimate, averaged for all teams, was higher than expected on sites 1 and 3, and lower on site 2. In all areas, the SI models were closer than PATREC to the USFWS population estimates. The ranking of sites, based on USFWS population estimates, was 2, 3, 1 (highest to lowest) (Table 2). Both PATREC and SI models ranked the sites in the following order: 1 (highest), 2, 3 (lowest). In searching for the major source of error, we learned that site 1 was on an Indian reservation and was subject to year-round harvest. In this instance, habitat was probably not limiting the mule deer population and, as a result, the model comparisons were misleading.

All three approaches produced pronghorn density estimates that were higher than USFWS estimates; however, the PATREC estimates were much closer than the SI models or POA (Table 1). No ranking comparison was attempted (Table 2) because the range of density estimates was not wide (Table 1). Time and travel constraints prohibited selection of two additional pronghorn test sites exhibiting a wider density range.

Population density data on sharp-tailed grouse was not available; therefore the standards used to judge model results were the personal opinions of the USFWS research team. They based their opinion on such data as the number and location of leks and the average number of displaying males on each lek. Their ranking for sharptails was 1, 3, 2 with site 1 relatively high, site 3 medium to low, and site 2 with few, if any, sharptails (Table 2). PATREC correctly ranked the sites. The SI model density estimates for all three sites were about the same so no ranking was possible (Tables 1 and 2). The POA correctly ranked site 1, but did not differentiate sites 2 and 3 (Tables 1 and 2).

Population information on sage grouse populations for each site was in the same form as for sharptails. PATREC and the SI models correctly ranked the three sites while the POA correctly ranked site 1 as the lowest, but did not distinguish between sites 2 and 3 (Table 2).

PATREC overestimated the density of Brewer's sparrows on site 1 by eight individuals, while the SI models and the POA underestimated it by 12 and 13, respectively (Table 1). All three approaches underestimated the USFWS population estimate on site 2, but the SI model estimates were closest (Table 1). All three approaches overestimated the expected density on site 3, but PATREC was the closest (Table 1). The sites were correctly ranked by SI and POA; PATREC correctly ranked the highest site but did not distinguish between the sites 2 and 3.

There were occupied golden eagle nests on sites 1 and 2 but none on site 3. The model output for PATREC and SI models was a probability; sites with probabilities greater than or equal to 0.5 were classed as occupied and less than 0.5 were classed as unoccupied. Only personal opinion evaluated the three sites correctly (Table 2). PATREC incorrectly evaluated site 3 while the SI models incorrectly evaluated sites 1 and 3.

The differences between the predicted and observed population densities are of paramount importance in the judgment of the models. It is likely that some of the density levels were the result of other factors in addition to those considered by the models. However, assuming that we measured the correct attributes, discrep-

Table 2. Ranking of the three test sites near Decker, Montana for six species based on observed population density and predicted density estimates from Suitability Index (SI) and PATREC models, and personal opinion, July 1979.

Habitat evaluation approach and inventory	Mule deer			Prong-horn			Sharp-tailed grouse			Sage grouse			Brewer's sparrow			Golden[a] eagle		
	H[b]	I	L	H	I	L	H	I	L	H	I	L	H	I	L	H	I	L
Observed population density	2	3	1		NA[c]		1	3	2	3	2	1	1	2	3	Y	Y	N
SI	1	2	3				NA[d]	NA[d]	NA[d]	3	2	1	1	2	3	N	Y	Y
PATREC	1	2	3				1	3	2	3	2	1	1	NA[d]	NA[d]	Y	Y	Y
Personal opinion	2	1	3				1	NA[d]	NA[d]	NA[d]	NA[d]	1	1	2	3	Y	Y	N

[a]Density estimates were stated as either presence (Y) or absence (N) of a nesting pair of golden eagles.
[b]H = ranked highest, I = ranked intermediate, L = ranked lowest; 1 = site 1, 2 = site 2, 3 = site 3.
[c]Ranking was not done because population estimates were so close.
[d]Ranking was not done because population estimates from the sites were close.

ancies between observed and predicted population densities were caused by improperly structuring the attributes in the model.

The number and complexity of mathematical calculations required by the models resulted in mathematical errors. The number of mathematical errors was higher with SI models than PATREC models. There were significant differences ($p \leq .05$) between the recorded and corrected estimates using SI models for all species except sage grouse and pronghorn. No significant differences between recorded and corrected estimates were found with PATREC. Inventory of habitat attributes was one of several factors influencing variability of the teams' results. Some variation should be attributed to the small number of samples the participants were allowed to take on a limited area. Natural variation in some of the attributes was considerable. The participant's interpretation of what was meant by the attribute and how to measure it was another source of error. Neither the PATREC or SI models had adequate descriptions for some of the attributes or measuring techniques. Ellis et al. (1979) reported that better documentation of the criteria would limit this type of variability. Experience and proficiency with field sampling procedures influences variability and will probably be present to varying degrees regardless of the method of habitat evaluation attempted.

Additional time was required to do the SI model calculations compared to PATREC calculations. Not counting the time to do the inventory, time required for SI model calculations for all six species ranged from 3 to 9 ($\bar{y} \pm s = 5.0 \pm 1.5$) person-hours/site while PATREC calculations required from 1 to 4 ($\bar{y} \pm s = 2.2 \pm 0.8$) person-hours/site. Time required for SI model calculations averaged 140 percent greater than required for PATREC based on the average of times for individual teams.

Participants' Appraisals of the Three Approaches

Participants' appraisals of the three approaches may not be representative of a wide spectrum of biologists because the respondents had to be at least interested enough in habitat evaluation to participate in the field test. We believe the sample was representative of people who had an interest in habitat evaluation methods and their use, and who could provide valuable information as well as suggestions for improvements of the approaches (Table 3).

More than half of the 34 participants had helped develop or implement SI models prior to the field test (Figure 2). In contrast, less than 20 percent were familiar with PATREC models and no one had used it in the field prior to the test (Figure 2). We checked for possible relationships between responses to the questions on familiarity or prior use of models (statements a, b, and c in Figure 2) with responses to other questions because the disproportionate sample having familiarity with SI models may have biased responses to the questions. Cross tabulations between these variables indicated that definite relationships existed between familiarity with method and responses to a few of the other questions (Figure 2). Few questions elicited responses that indicated a major difference between participants' opinion on PATREC and SI approaches (Figure 2). Better instructions, fewer data forms, better explanations of terms, and more clearly defined model variables were items participants identified for improvement for both procedures.

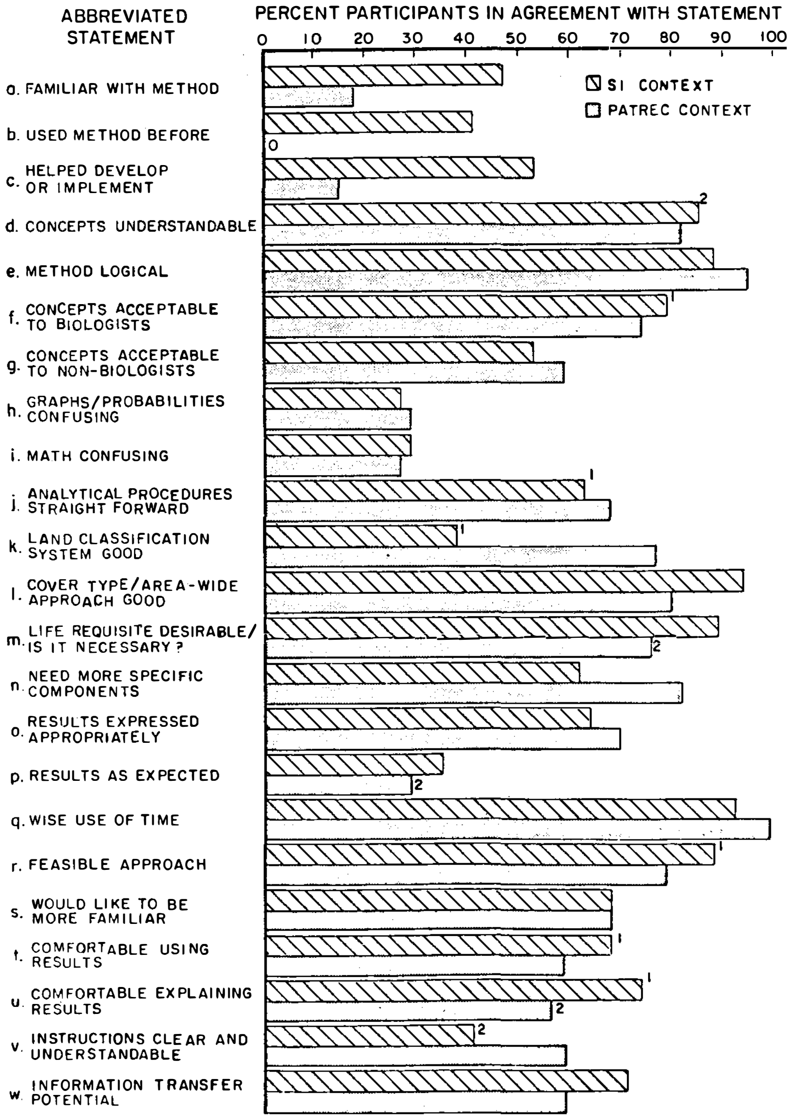
There were mixed feelings regarding the use of habitat models that yield habitat

Table 3. Biographical data from 34 participants in the field test of habitat evaluation procedures, Decker, Montana, July 1979. One participant is equivalent to about three percent of the sample.

	Percent
Education completed:	
Bachelor's degree	41[a]
Master's degree	35
Doctorate degree	24
Years of professional experience:	
1 or less	15
2–5	38
6–10	20
10–20	15
More than 20	12
Position:	
Administration	6
Management	21
Research	12
Technical support	47
Other	15
Number of times per year they evaluate habitat:	
Never	38
Less than 1	12
1–5	35
More than 5	15
Number of times per day they use results of habitat evaluation done by someone else:	
Never	53
Less than 1	15
1–5	26
More than 5	3
Percent who have explained or justified results of habitat evaluation:	
To other biologists	71
To sympathetic nonbiologists	62
To antagonistic nonbiologists	41
In hearings or court	9

[a]Totals in each category may not total 100 percent due to rounding error.

quality ratings expressed as units of potential animal density. Some expressed concern that model output units of potential animal density might be interpreted (or misinterpreted) as actual density estimates. Some participants preferred results to be expressed in more abstract terms such as habitat quality indices, while others indicated such indices were too nebulous to be of much use.



[1] Indicates significant relationship with response to the first statements related to SI.

[2] Indicates significant relationship with response to the first statements related to PATREC.

Figure 2. Responses to statements about characteristics of the Suitability Index (SI) models and Pattern Recognition (PATREC) models from 34 participants in the July 1979 field near Decker, Montana.

Preference ranking of PATREC and SI models by the participants varied among species evaluated in the test but the average overall species was equal (Table 4). Both of the standardized models were generally preferred over personal opinion for evaluation of habitat of species in the test. Variability in preference for models was also shown relative to responses to more general questions (Table 4). POA was preferred for familiar species but PATREC and the SI models were equally ranked if the participant was not at all familiar with the species. SI models were preferred over the other two approaches if the participant was going to use results of an evaluation done by someone else or if a standardized method was required. None of the factors of familiarity with species, number of times per year they conducted habitat evaluations, or number of times they used results of evaluation conducted by someone else had enough influence on the way the participants ranked the models to show significance ($p \leq 0.1$). Participants indicated that a major factor that influenced ranking of models was the performance (or malfunction) of a particular model for the species relative to the participant's perception of (1) the appropriateness of the model's habitat attributes, (2) relative weights assigned to the attributes, and (3) similarity between results of the model and their expectation of what should be on the area.

Conclusions

When the results of the study were analyzed in light of the three principal criteria for judging model performance we established before the field test, (1) the two structured approaches performed better than POA, and (2) neither PATREC or SI

Table 4. Participants' ranking, expressed as the percentage of participants first choice, of the three approaches for conducting habitat evaluations in 11 situations.

Situation	SI	PATREC	POA	Other
Habitat evaluations conducted for:				
Mule deer	29	26	18	12[a]
Pronghorn	36	26	12	15
Sage grouse	41	26	9	12
Sharp-tailed grouse	29	29	12	18
Brewer's sparrow	26	40	6	15
Golden eagle	24	35	18	12
Species $\bar{x}$	31	31	12	14
Familiar species	12	29	42	9
Unfamiliar species	38	38	9	15
Evaluation done by someone else	46	30	3	12
Standardized method required	46	30	0	0

[a]Differences between sums of rows and 100 percent were those who did not respond to the question on the appraisal form.

performed well enough for us to recommend one over the other. The accuracy with which the models predicted suitability of an area for producing wildlife was variable. None of the models were able to rank more than two areas correctly. There were significant differences between the recorded and corrected estimates using SI models but not PATREC models. POA was unable to produce average estimates that were significantly different among the three areas. When looking at ease and acceptance of application of the approach by the participants, the results were also mixed. Both structured models were generally preferred over POA but there was variability in preference when familiarity with species was considered. Costs to choose the study area, build the PATREC models, conduct the test, and analyze the results totalled near $50,000. Costs to build the SI models were not available. In terms of time, SI model calculations required 140 percent more time than PATREC.

The fundamental characteristics of a model are determined by the information it contains and the intended use for which it was developed. The PATREC and SI models evaluated in this study contained very similar information, i.e., environmental attributes that were measured, so perhaps it is not surprising that overall performance in predicting observed wildlife densities was similar. The variation in performance as illustrated by the inconsistency in area rankings between PATREC and SI models were likely the result of different perceptions on the part of model builders resulting in different mathematical relationships for manipulating habitat information.

Perhaps in the final analysis the test of a model's "goodness" is the degree to which it improves a land-use decision (Thesen 1974). The decision made regarding the way a tract of land is used is the important thing, and habitat evaluation models are only important in how they help during the decision-making process. Whether anyone should use the models discussed depends on whether the models can help in making a better decision for wildlife. If biologists consciously consider what they are doing during habitat evaluations, then approaches like PATREC or SI models will help identify important habitat attributes, increase our understanding of what constitutes good habitat, and improve our ability to communicate that understanding. This increased understanding and improved communication should improve our ability to make intelligent decisions and recommendations when managing wildlife.

There are several considerations for further studies involving the field verification of habitat models. We feel the objective of field verification efforts is to improve the reliability of a model and, in turn, define the limits of model credibility. Reliability of a habitat model is judged by how well the kind and amount of population associated with land use changes can be predicted. A substantial amount of additional effort would be required to begin defining the bounds within which the model can be expected to give reliable predictions. The ideal, but perhaps not the most cost effective approach to model verification, is for a specific application. The model also must be constructed for the particular habitat area and land use development using the following criteria: (1) the habitat models must contain habitat attributes that are likely to be limiting populations that occupy the habitat to be evaluated, and (2) the model must be structured so that it is sensitive to changes in these habitat attributes. In the end, the model user must face the fact that habitat models built on structural and floristic habitat attributes may be hard to verify even under ideal conditions because of a lack of knowledge about relationships to observed populations. Biologists do not have extensive sources of information regarding the type and number of relationships between habitat attributes and observed populations to construct habitat models for a wide array of species that will provide accurate and reliable population density predictions for large biological/geographical areas such as ecoregions. We feel the ecological knowledge gained from the conduct of well-designed quantitative studies of species-habitat relationships will move model builders a big step closer to building habitat evaluation models that will provide accurate and reliable outputs. Perhaps better communication between biologists, land managers, and researchers will identify and foster a more complete understanding of the constraints and limitations of building, verifying, and using habitat evaluation models to aid in land-use decisions.

Acknowledgments

We thank the personnel of the USFWS team in Sheridan, Wyoming for their help in providing the population data for the test area and obtaining trespass permission for the study participants. Mr. Art Allen, USFWS, provided much useful help and preparation of the SI models. Special thanks to William Krohn, Kenneth Russell, Spencer Amend, and Doug Inkley for reviewing the paper and providing helpful comments.

References Cited

Bailey, R. G. 1976. Ecoregions of the United States (map). USDA For. Serv. Intermtn. Reg., Ogden, Utah. Scale 1:7,500,000.

Bramble, W. C., and W. R. Byrnes. 1979. Evaluation of the wildlife habitat values of rights-of-way. J. Wildl. Manage. 43(3): 642–649.

Daniel, C., and R. Lamaire. 1974. Evaluating effects of water resource developments on wildlife habitat. Wildl. Soc. Bull. 2(3): 114–118.

Ellis, J. A., J. N. Burroughs, M. J. Armbruster, D. L. Hallett, P. A. Korte and T. S. Baskett. 1979. Appraising four field methods of terrestrial habitat evaluation. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 369–379.

Flood, B. S., M. E. Sangster, R. D. Sparrowe, and T. S. Baskett. 1977. A handbook for habitat evaluation procedures. Resour. Bull. 132. U.S. Fish and Wildl. Serv., Washington, D.C. 77 pp.

Giles, R. H., Jr. 1978. Wildlife management. W. H. Freeman and Company, San Francisco, California. 416 pp.

Kling, C. L. 1980. Pattern recognition for habitat evaluation. M.S. Thesis. Colorado State Univ., Fort Collins. 244 pp.

Nie, N. H., C. H. Hall, J. G. Jenkens, K. Steinbrenner, and D. H. Bent. 1975. Statistical package for the social sciences (SPSS), second edition. McGraw-Hill Book Company, New York.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. Iowa State Univ. Press, Ames, Iowa. 593 pp.

Thesen, A. 1974. Some notes on systems models and modeling. Int. J. Systems Sci. 5(2): 145–152.

U.S. Fish and Wildlife Service. 1976. Habitat evaluation procedures: for use by the Division of Ecological Services in evaluating water and related land resource development projects. U.S. Fish and Wildl. Serv., Washington, D.C. 30 pp. Multilith.

———. 1981. Standards for development of habitat suitability index models. U.S. Fish and Wildl. Serv., Washington, D.C. 103 ESM. 176 pp.

U.S. Water Resources Council. 1973. Principles and standards for planning water and related land resources. Federal Register 38(174): Part 3.

Whitaker, G. A., and R. H. McCuen. 1976. A proposed methodology for assessing the quality of wildlife habitat. Ecol. Modelling 2: 251–272.

Williams, G. L., K. R. Russell, and W. K. Seitz. 1977. Pattern recognition as a tool in the ecological analysis of habitat. Pages 521–531 *in* Classification, inventory, and analysis of fish and wildlife habitat—the proceedings of a national symposium. Phoenix, Ariz. U.S. Fish and Wildl. Serv., Office of Biological Services, Washington, D.C.

Validating Habitat Quality Assessment: An Example

Richard A. Lancia
Forestry Department, North Carolina State University, Raleigh

S. Douglas Miller
Institute for Wildlife Research, National Wildlife Federation, Washington, D.C.

David A. Adams and Dennis W. Hazel
Forestry Department, North Carolina State University, Raleigh

Introduction

Rational management of fish and wildlife resources necessitates an ability to predict, accurately and quantitatively, future consequences of proposed management plans. Federal legislation and regulations mandate appraisal of current environmental conditions and require forecasting future conditions.[1] To meet these demands, numerous models to evaluate habitat quality for fish and wildlife have been developed (e.g., Schamberger and Farmer 1978, Flood et al. 1977, Boyce 1977, 1978, Adams 1980, U.S. Army Corps of Engineers 1980, Lines and Perry 1978, Asherin et al. 1979).

This proliferation of habitat quality prediction models attests to the ease with which models can be constructed. However, the crucial test—whether a model accurately predicts habitat quality—rarely is done. When attempted, approaches to model validation fall into three major categories. In all cases, the model should be developed with one data set and then be evaluated with new data collected at another time or in a different area.

1. Species authorities are asked to examine model predictions and to judge whether, in their opinion, the model performs satisfactorily. This approach is highly subjective, circular, and of limited value because, presumably, species authorities were consulted during model development. In any event, the animals, not humans, are the appropriate subjects for model validation.
2. Several independently-developed models, purported to evaluate habitat quality for the same species, are compared to one another. The assumption is that if the models are predicting the same thing, then their results should be comparable. However, results typically are widely discrepant (Whelan et al. 1979). Habitat evaluation models also have been tested to determine the replicability among observers (Ellis et al. 1979), but this is not a test of the ability of the models to evaluate habitat quality accurately.
3. Models are evaluated by the ability to predict population density or some other correlated population attribute, e.g., Shannon-Weaver Index or number of species. However, using density estimates to validate models is risky because

[1]Examples of legislation and regulations are: Fish and Wildlife Coordination Act of 1934, National Environmental Policy Act of 1969, Endangered Species Act of 1973, Forest and Rangelands Renewable Resources Planning Act of 1974, National Forest Management Act of 1976, and Principles and Standards for Planning Water and Related Land Resources (Water Resources Council 1973)

the size of species populations is a function of innumerable factors—previous history, weather, disease, environmental pollutants, exploitation, etc.—many of which may operate entirely independent of habitat conditions on a particular study area. Using habitat parameters (independent variables) to explain variability in density (dependent variable) is a valid technique to describe habitat preferences (e.g., Sturman 1968, James 1971), but a model developed this way should not be expected to predict density accurately. Furthermore, density estimates are difficult to make, and this approach is not applicable to rare species, except over very large areas.

In summary, we believe that these methods are not the last word in attempts at model validation. In the remainder of the paper we explore another approach to validate habitat assessment based on habitat use by individuals residing on a study area.

Study Site

The study site, 12 by 12 km (144 km^2) [7.46 by 7.46 miles, 55.6 mi^2], is located in the Coastal Plain physiographic province adjacent to the White Oak River on the Croatan National Forest, Carteret County, North Carolina. The vegetation typifies the southeastern evergreen region (Braun 1950) and is characterized by level topography, scattered pocosins, and bottomland hardwood forests along rivers and creeks. The U.S. Forest Service manages the forest for multiple use with timber harvesting on sawlog rotations. Clearcuts, the typical silvicultural system, are artificially regenerated to loblolly (*Pinus taeda*) or longleaf pine (*P. palustris*).

Methods

The Model

We used a slightly modified version of Habitat Evaluation Procedures (HEP) currently being developed and refined by the U.S. Fish and Wildlife Service (Fort Collins, Colorado) as the conceptual framework for our model. Using literature descriptions of bobcat (*Lynx rufus*) habitat, we calculated a Habitat Quality Index (HQI) from 0.0 to 1.0 (1.0 being optimal) based on quantitative estimates of food, cover, and reproduction life requisites for each habitat type on the study area. These estimates could be derived from functions depicting the relationships between measurable habitat parameters and Habitat Suitability Indices (HSIs) for each life requisite in each habitat type. HSI values were combined within each habitat to yield Life Requisite Suitability Indices (LRSIs) for each habitat type. The LRSIs were averaged with a measure of habitat juxtaposition and interspersion to estimate habitat quality, which was displayed, using a grid-cell system (SYMAP, Harvard University), as an overlay for the habitat-type map. All calculations using grid-cell values were done with the Statistical Analysis System (SAS) (Helwig and Council 1979).

We evaluated the predictive capability of our model by comparing maps of habitat quality with the frequency of use of habitats by bobcats. Habitat use was determined empirically by tracking radio-marked individuals on the study area. A flow diagram (Figure 1) illustrates this approach.

Habitat Map

A habitat-type map of the Croatan study site was prepared by manually delineating habitats on 1:24,000 U.S. Geological Survey orthophotoquads using photointerpreted, large-scale, oblique photos; U.S. Forest Service stand condition maps; and ground truth data. Nine habitat types were identified: agriculture, pocosin, bottomland, and upland hardwoods, mixed pine-hardwoods, mature pine, young pine plantations, tidal fresh water marsh, and open water. The completed map was digitized and incorporated into the SYMAP grid-cell analytical system. Each grid cell represented 1.25 ha (3.1 acres).

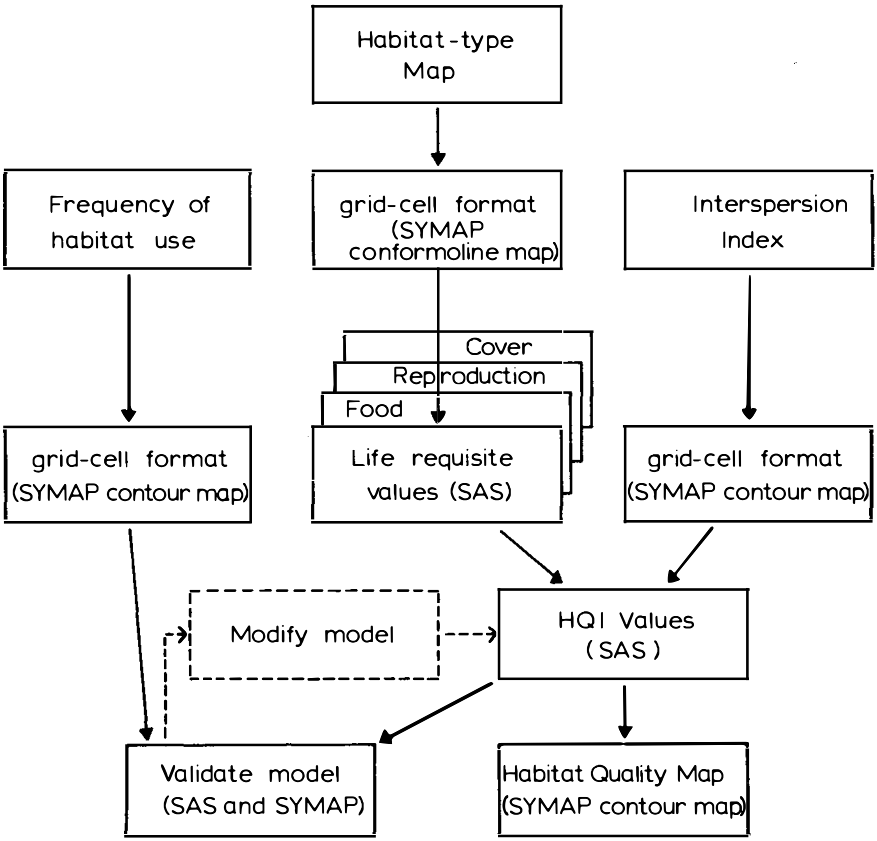


Figure 1. Flow diagram of the steps used to develop a model predicting Habitat Quality Index Values (HQIs) and to evaluate the model with frequency of radio fixes as an empirically-determined measure of habitat quality.

Life History

Derivation of the life requisites for each habitat type is based on the following description of the life history of bobcats in the Southeast. This description is supported by factual data and, where gaps exist, by our best guesses.

Bobcats principally prey upon small mammals, particularly rabbits (*Sylvilagus* spp.) and cotton rats (*Sigmodon hispidus*), so plant communities supporting these prey species are essential habitat components (Miller and Speake 1978). Because small mammals are most abundant in preforest or early successional stages and generally decline in numbers and biomass as succession proceeds, early seral stages, such as old fields and young pine plantations, should be preferred foraging grounds for bobcats. However, these cats are opportunistic predators, and other habitats should also provide some prey items. Preferences for prey species (determined during another facet of this study) and availability of preferred prey species (Golley et al. 1965) were used to predict the ability of each habitat type to provide prey items.

Although the precise manner in which bobcats use cover is unknown, cover certainly provides concealment, allows protection from weather, and is also an important component for successfully stalking prey. In general, if cover is adequate for a prey species, then we assume it is also adequate for the stalk-hunting style of bobcats.

In the Coastal Plain, daytime resting cover may include bramble patches (*Rubus* spp.), ericaceous shrub thickets, canebreaks, and densely-vegetated windrows. Hardwoods along streams provide travel lanes between open-canopy cover types. Large, hollow trees and root masses of uprooted trees are common den sites, frequently occurring in hardwood drainages, river bottoms, and mixed pine-hardwood habitat types.

Bobcats use a variety of habitats to meet daily, seasonal, and yearly needs. Habitat quality is reflected in the spatial arrangement of various habitats and the ability of these habitats to provide needed life requisites. We therefore include in our calculation of HQI an interspersion term relating the distance between habitats to LRSIs for all nearby habitat types (see below).

Life Requisite Suitability Indices. Life Requisite Suitability Indices (LRSIs) were calculated for each life requisite—food, cover, and reproduction—in each habitat type (Table 1), based on relationships between habitat characteristics and a Habitat Suitability Index (HSI) (Schamberger and Farmer 1978:280) (Figure 2). Then food, cover, and reproduction LRSI values corresponding to each habitat type were assigned to every grid cell using the conformolines map elective of SYMAP. We subjectively downgraded food values for pocosin and marsh habitats because we thought high water would reduce habitat suitability for prey species.

Interspersion Index. An interspersion index was calculated for sample points arbitrarily located at the intersections of 1,000 m (1,093.6-yard) UTM grid lines ($N = 169$). These intersections were chosen for ease in identification; however, any random or systematic sampling scheme could be used. The sampling intensity will vary with the complexity of the habitat.

At each sample point, distances to the nearest edge of all other habitat types were measured and converted to an HSI value derived from a distance:HSI function (Figure 3, Appendix I). Derivation of the function assumed that as distance

Table 1. Life Requisite Suitability Indices (LRSIs) for habitat types identified on the Croatan study site used to estimate habitat quality for bobcats.

	Life requisite suitability indices		
Habitat type	Food	Cover	Reproduction
Agriculture	0.8	0.2	0.0
Young pine plantation	1.0	1.0	0.4
Mature pine	0.4	1.0	0.4
Mixed pine-hardwoods	0.3	1.0	0.6
Bottomland hardwoods	0.4	1.0	1.0
Upland hardwoods	0.4	1.0	1.0
Marsh	0.2	1.0	0.0
Pocosin	0.2	1.0	0.0

to adjacent habitats increases, availability and hence the ability to provide life requisites decreases.

Calculation of the interspersion value combined the LRSI values of all habitats adjusted for distances between habitat types (for details see Lancia et al. In press). Because of the additive algorithm, LRSI values for a sample point could only be improved by nearby habitats. Thus, the index indicated the ability of the sample point and adjacent habitat types to meet life requisite requirements.

SYMAP created a contour map of interspersion based on sample point interspersion values and assigned an interspersion index value to every grid cell. Interpolation among sample points created a continuous "interspersion surface" that superceded discrete habitat boundaries and, we believe, depicted habitat interspersion and juxtaposition.

Habitat Quality Index. A Habitat Quality Index (HQI) value was calculated for each grid cell as the average of the geometric mean of the LRSI values and the interspersion index:

$$\mathrm{HQI} = \frac{\left(\prod_{j=1}^{n} \mathrm{LRSI}_j\right)^{1/n} + \begin{array}{c}\text{Interspersion}\\ \text{index}\end{array}}{2}$$

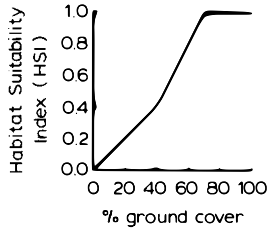
The geometric mean of the LRSIs was zero when any life requisite was zero, corresponding to a limiting factor effect. Averaging the geometric mean with the interspersion index permitted more suitable conditions in adjacent habitats to ameliorate deficiencies in a particular habitat type.

Habitat Use

Bobcats captured in 1979 and 1980 were equipped with radio-transmitter collars (Wildlife Materials, Carbondale, Illinois) and released at the capture site. Each year trapping began in early spring near the peak of the reproductive season. We attempted to live-trap as many individuals using the study area as possible, with

FOOD

V_1 : % Ground Cover



HABITAT TYPES

agriculture

young pine plantations

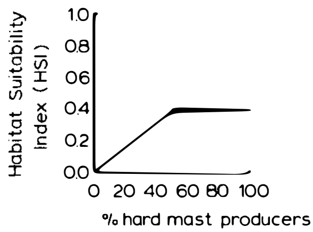
mature pine

mixed pine-hardwoods

pocosin

coastal marsh

V_2 Canopy in Hard Mast Producers



HABITAT TYPES

bottomland hardwood

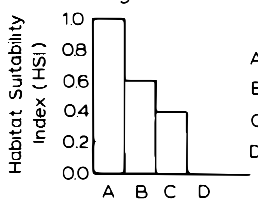
upland hardwood

mixed pine-hardwoods

$LRSI_{food}$ for each habitat is V_1 or V_2 as appropriate, except for mixed pine-hardwoods where $LRSI_{food} = \frac{2(V_1) + V_2}{2}$

REPRODUCTION

V_3 · Den Sites



A = Abundant

B = Moderate

C = Scarce

D = None

HABITAT TYPES

all

$LRSI_{repro} = V_3$

COVER

Because cover requirements for bobcats are so general, all habitat types provide good cover except for agricultural fields

$LRSI_{cover} = 1.0$; except agriculture where $LRSI_{cover} = 0.2$ (seasonally)

Figure 2. Graphical relationships for food, reproduction and cover life requisites used to estimate Life Requisite Suitability Indices (LRSIs) for each habitat type on the study area.

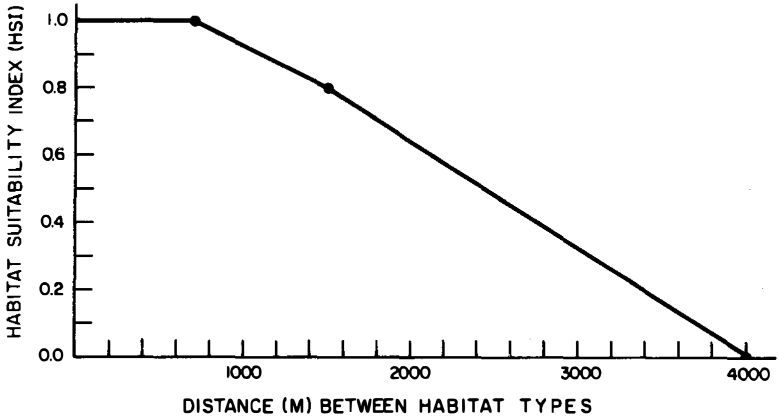


Figure 3. Relationship between the habitat suitability index and the distance between habitat types (see Appendix I for derivation) used to calculate an interspersion index.

trap locations concentrated in areas having the most abundant sign. We began monitoring locations of the cats in late spring and continued monitoring most individuals until late summer. On every other day we attempted to locate individuals twice during the nocturnal activity period, once at sunrise and sunset, and once during the diurnal rest period, but it frequently was not possible to monitor this intensively.

A 14-element, vehicle-mounted, yagi antenna was used to determine telemetry azimuths. Intersections of azimuths were recorded using UTM grid coordinates to the nearest 100 m (109.4 yards). We considered locating animals within a 100 m by 100 m square to be within the accuracy limit of our telemetry system. All radio fixes within a 1 km^2 (0.4 mi^2) UTM cell for all cats were used in developing a SYMAP contour map. The contour map created a smoothed distribution of frequency of use values (i.e., number of radio fixes) and assigned a frequency value to every grid cell.

Validating the Model

To test the predictive capability of our model we evaluated the relationship between our map of habitat quality and a contour map of the frequency of radio locations. For this evaluation, frequent use of an area was considered prima facie evidence that it provided necessary life requisites. However, the converse was not necessarily true. Some areas may have been unused for a variety of behavioral or ecological reasons, or we may have been unable to detect use of some areas.

A contingency table of HQI values versus the frequency of radio locations for grid cells having one or more radio fixes was used to evaluate the predictive capability of the model. For the table, HQI values and radio locations were grouped into quintiles. Only grid cells with one or more radio fixes were used to assure that radio-marked bobcats had an equal opportunity to visit all evaluated cells. An interpretation based on cells that were not used would be ambiguous because we could not distinguish between little or no use by radio-marked cats and use by unmarked cats. In the latter case, use by radio-marked cats would not be a good evaluator of habitat quality.

The contingency table was divided into three interpretive zones based on an aggregation of quintile groups: (1) Zone I—equivalent use and HQI or use and HQI within one of agreement; (2) Zone II—relatively high use and relatively low HQI; and (3) Zone III—relatively low use and relatively high HQI. Using SYMAP, we mapped these zones of predictive ability as point conformolines.

Results and Discussion

Habitat-Type Map

The habitat-type map based on SYMAP output is shown in Figure 4. Areas of interest for subsequent discussion are the large pocosin in the northeastern corner; the dominance of agricultural fields in the west-central portion, the southwestern corner, and the south-central portion; the band of bottomland hardwoods transecting the site from the northwest corner to the south-central portion; and, just slightly to the east and west of center, two areas with highly-interspersed, small blocks of varied habitat types. The small triangle in the extreme southwestern corner was not classified because it was outside the ranges of all monitored bobcats.

Habitat Quality Index

HQI ranged from 0.05 to 0.78, reflecting the distribution of LRSI values for each habitat type: agriculture, marsh and pocosin ranked lowest (0.05–0.40); mixed pine-hardwoods and mature pines, intermediate (0.54–0.67); and upland and bottomland hardwoods and young pine plantations highest (0.68–0.78). The habitat quality map (Figure 5) approximated the distribution of these three groups; however, in areas where the poorest habitat types were in relatively small patches, overall habitat quality was higher due to the effect of the interspersion term (e.g., central portion of the map). Areas with large blocks of poor habitat produced a low HQI ranking (e.g., the pocosin in the northeast corner).

The HQI map was displayed with the SYMAP contour map elective using a 0.5 by 0.5 km matrix of HQI values. A more widely-spaced input matrix resulted in an inadequate resolution of HQI patterns, while a denser input matrix added little to clarity. Calculations using HQI values were made for every grid cell, regardless of the matrix spacing used for displaying the HQI map.

Habitat Use

Six bobcats (three in 1979 and three in 1980) were captured on the study area and radio-marked (Table 2). Activity was monitored between mid-March and early October of each year, with a total of 1,436 radio fixes recorded for the two years. Home range size was smallest for an adult female that raised a litter on the study area and was largest for two adult males that had enlarged ranges apparently in response to the reproductive season. The cats monitored in 1979 concentrated activity on the west side of the study area, but those monitored in 1980 used the east side more intensively. Figure 6 depicts the frequency of radio fixes as a gray-

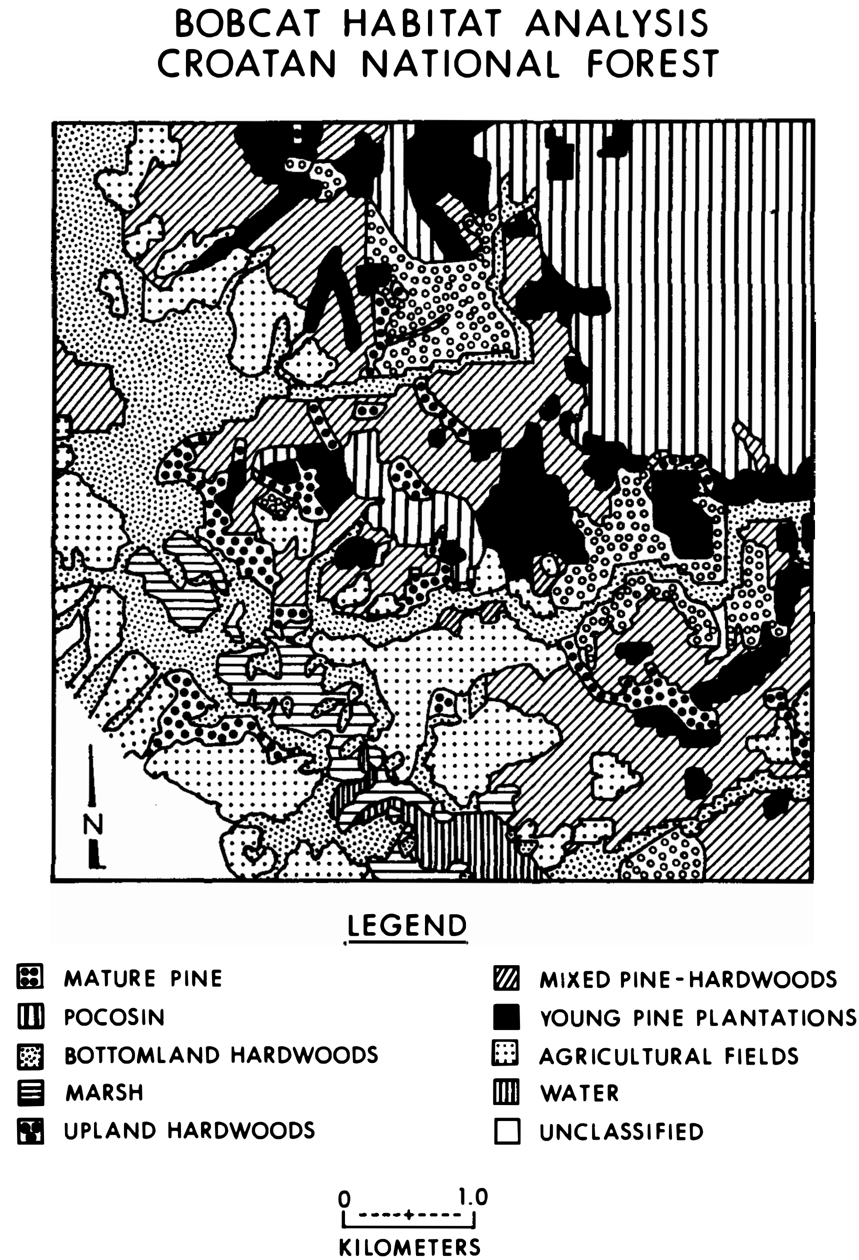
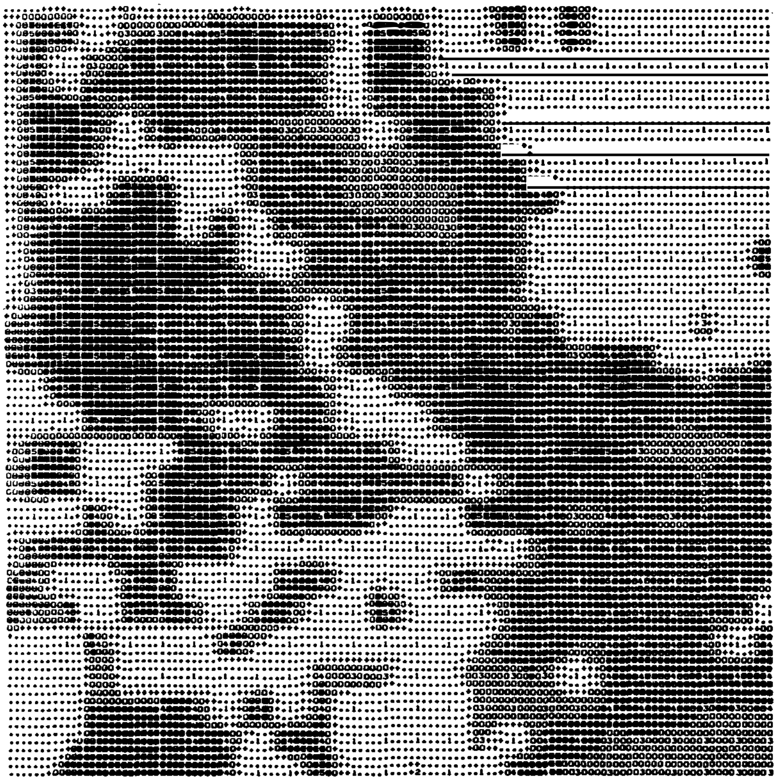


Figure 4. Habitat-type map of the study area.



HABITAT QUALITY INDEX

Figure 5. A gray-scale map of Habitat Quality Indices (HQIs) produced with the contour map elective of SYMAP. Dark areas represent the higher HQI values.

scale map. The general spatial pattern was two intensively-used cores surrounded by progressively less intensively-used bands. Core areas were located just east and west of the center of the study area. This spatial distribution possibly reflected similar habitat use among groups of socially compatible cats, such that several activity centers were located in the same area.

Habitat Quality Model Validation

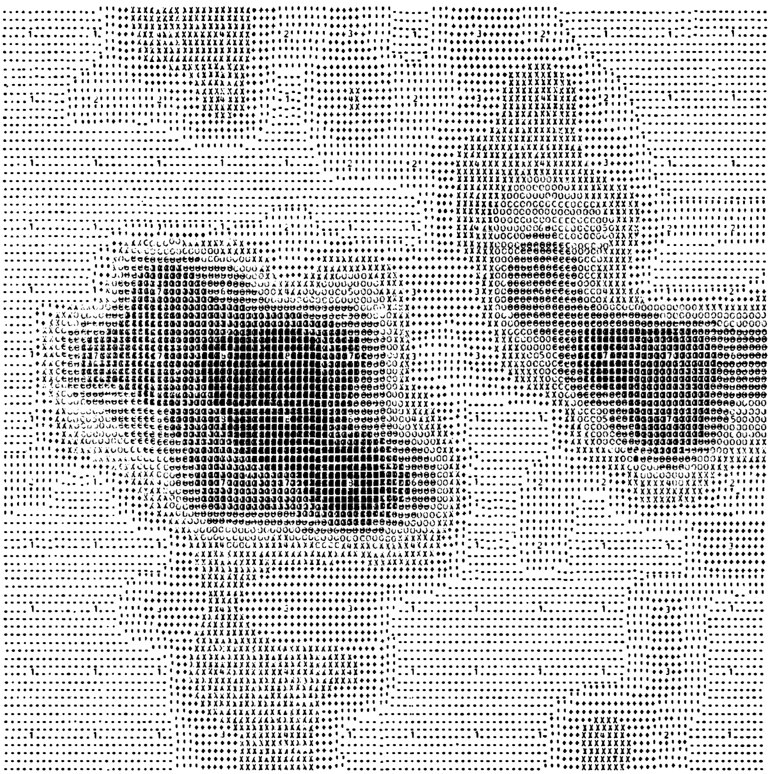
The distribution of grid cells within quintile groups of the contingency table (Table 3) was tested for independence of HQIs and the frequency of radio fixes, and the null hypothesis was rejected ($x^2 = 920$, d.f. $= 16$). Therefore, we assumed a relationship between HQIs and the frequency of radio fixes.

If the quintile ranks for all grid cells based on HQI values and frequency of radio fixes matched exactly, then our model predictions would be perfect. However, only 21.26 percent of the grid cells had identical ranks. If cells with ranks within

Table 2. Summary of radio-location data for 6 bobcats on Croatan National Forest, 1979 and 1980.

Animal number	Sex	Age class	Date: Radio marked	Date: Last observation	Total fixes	Home[a] range (ha)
1	M	adult	04/15/79	05/31/79	136	1,666
2	F	adult	04/24/79	10/03/79	418	1,237
3	F	immature	05/14/79	10/11/80	372	2,475
5	M	adult	03/12/80	06/02/80	74	4,973
6	F	adult	03/12/80	08/17/80	301	2,927
8	M	adult	03/21/80	07/13/80	135	5,035

[a]Home range determined by Mohr's minimum home range method using the TELEM (Koeln 1980) computer program.



FREQUENCY OF RADIO FIXES

Figure 6. A gray-scale map of the frequency of radio fixes produced with the contour map elective of SYMAP. Darker areas represent more frequently used areas.

Table 3. Contingency table of percentages of 6,377 grid cells with one or more radio fixes grouped by approximate quintiles of frequency of radio recoveries and HQI values (1 lowest, 5 highest).

Habitat Quality Index values (grouped by quintiles)	Frequency of radio fixes (grouped by quintiles) 1	2	3	4	5
1	3.40	3.09	1.87	0.67	0.00
2	6.01	2.82	5.22	5.55	2.41
3	5.22	2.59	1.49	2.27	1.69
4	10.96	4.58	3.59	4.16	5.91
5	6.18	1.93	3.39	5.60	9.39

Zone II

Zone III   Zone I

Zone I	55.54%
Zone II	12.19%
Zone III	32.26%
	99.99%

one of agreement were included with those in agreement, then 55.54 percent of the grid cells fell within this group (Zone I in Table 3).

Cells with high frequency of radio fixes but low HQI values (Zone II in Table 3) accounted for 12.19 percent of the total number of cells. An error of this type indicated an inability to recognize all components of good habitat—a serious fault in most models. However, the smallest percentage of cells fell in this category. A large number of these cells were in the pocosin habitat type possibly indicating an underestimation of LRSI values.

A large percentage of the cells, 32.36 percent, had a low frequency of radio fixes and a high HQI value. This type of error may not indicate a general weakness in our approach. For example, most of these cells surrounded intensively-used activity centers (Figure 7), perhaps reflecting a geometric effect of increasing distance from an activity center. If habitats of equivalent quality on the edges of cat ranges were not used intensively because of behavioral, population or geometric effects, then prediction errors of this type from a model incorporating only habitat parameters are not surprising. Furthermore, field observations of bobcat sign and interviews with trappers indicated that the infrequent telemetry fixes in some areas of Zone III may have been due to occupation of those areas by uninstrumented cats.

Conclusions

The test of single-species habitat preference models is not what species authorities believe, not what model comparisons reveal, nor how well estimates of

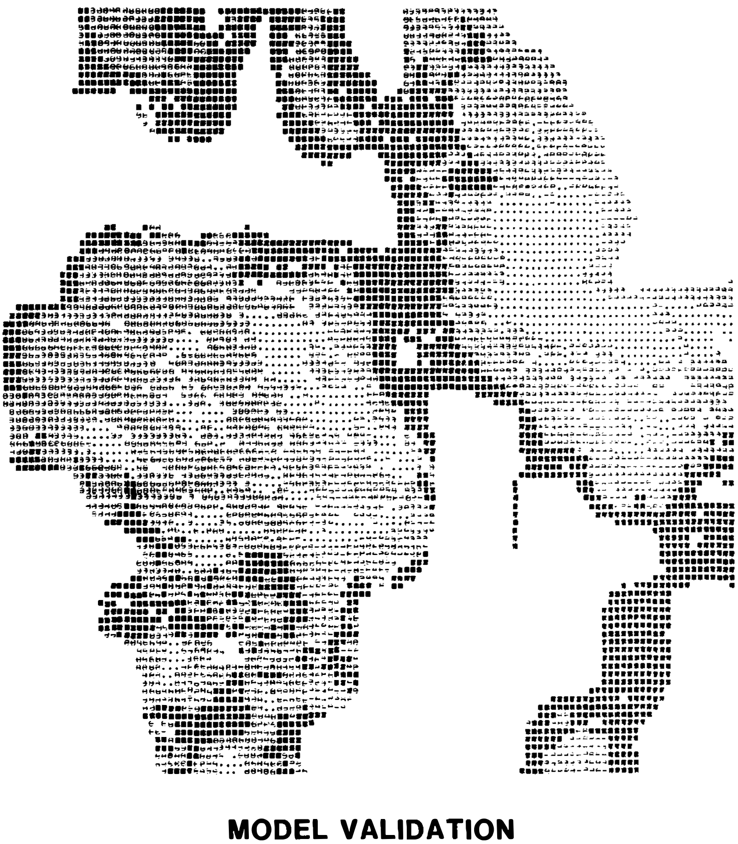


Figure 7. A plot of interpretive Zones I, II and III (see Table 3) used in model validation. Symbols are Zone I— θ, Zone II—., and Zone III—■ overprint.

population density agree, but rather how closely model predictions reflect habitat selection by the species being modeled. Our use of empirically-determined habitat preferences of individual animals is a fundamentally new approach to habitat model validation—one we believe has potential for assessing our ability to model habitat requirements of individual species.

The lack of complete agreement between model predictions and actual habitat use by bobcats suggests a need for refinement of the model. However, of greater significance is the relatively high correspondence we did find. When one considers the enormous range of sensory input available to an animal when selecting habitat preferences, the agreement we found by including only a few habitat variables suggests we may have chosen major determinants used by bobcats for habitat selection. Fine tuning is needed, but the coarse adjustment appears correct.

We could argue our Zone III errors are irrelevant. We attempted to predict potential habitat quality, not where individual animals actually located their home ranges. Predicting how individual animals distribute themselves within adequate habitat goes beyond the sophistication necessary to make management decisions. Even at this crude stage of development, our model has merit for assessing habitat quality for bobcats.

Appendix I

To develop a distance versus Habitat Suitability Index (HSI) function, we assumed that as the distance from the center of a home range increased, the probability of use decreased. A concentration of movements of adult cats within established home range or territory supports this contention. This relationship would not apply to transient or dispersing animals. To simplify calculations, we also assumed bobcat ranges were circular.

Miller (1980) reviewed the literature on bobcat ranges in the Southeast and found they vary from about 150–3,000 ha. This variation may represent differences in sex and age groups, seasonal range use, habitat distribution, and bobcat population densities. In our study, ranges varied from about 1,200 to 5,000 ha (Table 2); however, these data were not used in deriving the HSI:distance function.

To construct the curve, we calculated radii corresponding to ranges of 150 to 3,000 ha. Plotting these radial distances on the abscissa against HSI values (ordinate), we constructed a curve to represent the probability distribution of a cat using areas at increasingly greater distances from the center of its home range. We identified a threshold of approximately 700 m below which distance was not a factor in habitat use. Beyond 700 m, HSI values declined until reaching 0.0 at about 4000 m.

Acknowledgements

Funding was provided by the U.S. Fish and Wildlife Service's Endangered Species Program through the North Carolina Wildlife Resources Commission. Other support provided by the University Systems Analysis and Control Center, the Computing Center, and the School of Forest Resources, North Carolina State University; the North Carolina Division of Forestry; Champion International Timberlands; the USDA Forest Service; the North Carolina Forestry Foundation; Betty Moore; David Woodward; Larry Petrovick; and Consie Powell. R. Powell, G. Blank, and H. Devine reviewed drafts of the manuscript.

Literature Cited

Adams, D. A. 1980. Wildlife habitat models as aids to impact evaluation. The Environmental Professional 2: 253–262.

Asherin, D. A., H. L. Short, and J. E. Roelle. 1979. Regional evaluation of wildlife habitat quality using rapid assessment methodologies. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 404–424.

Boyce, S. G. 1977. Management of eastern hardwood forests for multiple benefits (DYNAST-MB). USDA For. Serv. Res. Pap. SE-168, SE For. Exp. Sta., Asheville, N.C. 116 pp.

______. 1978. Management of forests for timber and related benefits (DYNAST-TM). USDA For. Serv. Res. Pap. SE-184, SE For. Exp. Sta., Asheville, N.C. 140 pp.

Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Publ. Co., New York. 596 pp.

Ellis, J. A., J. N. Burroughs, M. J. Armbruster, D. L. Hallet, P. A. Korte, and T. S. Baskett. 1979. Appraising four field methods of terrestrial habitat evaluation. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 369–379.

Flood, B. S., M. E. Sangster, R. D. Sparrowe, and T. S. Baskett. 1977. A handbook for habitat evaluation procedures. Resour. Publ. U.S. Fish and Wildl. Serv., Washington, D.C. 132 pp.

Golley, F. B., J. B. Gentry, L. D. Caldwell, and L. B. Davenport, Jr. 1965. Number and variety of small mammals on the AEC Savanna River Plant. J. Mammal. 46(1): 1–18.

Helwig, J. T. and K. A. Council, eds. 1979. SAS user's guide. SAS Institute, Inc., Raleigh, N.C. 494 pp.
James, F. C. 1971. Ordinations of habitat relationships among breeding birds. Wilson Bull. 83(3): 215–236.
Koeln, G. T. 1980. A computer technique for analyzing radio telemetry data. Pages 262–271 *in* J. M. Sweeney, ed. Proceedings of The 4th Nat. Wild Turkey Symp. Arkansas Chapt., The Wildlife Soc. 292 pp.
Lancia, R. A., D. W. Hazel, S. D. Miller, and J. D. Hair. In Press. Computer mapping of potential habitat quality for bobcat based on digital LANDSAT imagery. Proceedings of Inplace Resource Inventories National Workshop Orono, Maine.
Lines, I. L., Jr., and C. J. Perry. 1978. A numerical wildlife habitat evaluation procedure. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 284–301.
Miller, S. D., and D. W. Speake. 1978. Prey utilization by bobcats on quail plantations in southern Alabama. Proc. Southeast. Assoc. Game and Fish Commissioners 32: 100–111.
Miller, S. D. 1980. Ecology of the bobcat in South Alabama. Unpubl. Ph.D. Thesis. Auburn University, Auburn, AL. 156 pp.
Schamberger, M., and A. Farmer. 1978. The habitat evaluation procedures: Their application in project planning and impact evaluation. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 274–283.
Sturman, W. A. 1968. Description and analysis of breeding habitats of the chickadees, *Parus atricapillus* and *P. rufescens*. Ecology 49(3): 418–431.
U.S. Army Corps of Engineers. 1980. A habitat evaluation system for water resources planning. Lower Miss. Valley Div., Vicksburg, MS. 89 pp.
Water Resources Council. 1973. Principles and standards for planning water and related land resources. Federal Register 38(174): Part 3.
Whelan, J. B., A. R. Tipton, J. F. Williamson, P. R. Johansen, J. P. McClure, and N. D. Cost. 1979. A comparison of three systems for evaluating forest wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 392–403.

HEP as a Planning Tool: An Application to Waterfowl Enhancement

Scott C. Matulich and Jeffrey E. Hanson
Department of Agricultural Economics, Washington State University, Pullman

Ivan Lines
Soil Conservation Service, U.S. Department of Agriculture, Spokane, Washington

Adrian Farmer
U.S. Fish and Wildlife Service, U.S. Department of the Interior, Fort Collins, Colorado

Introduction

To many, the principal role of wildlife agencies in public and private resource development has been that of impact mitigation. With known or pending habitat damage, biologists have to develop mitigation or compensation plans. Unfortunately, once in a mitigation framework, they are in a no-win situation, seeking remedial action at best. Yet, the potential exists for cooperative project planning, thereby facilitating mitigation of impacts *before* they occur, and enhancement of environmental amenities through project development. In fact, such planning is mandated by federal legislation (e.g., National Environmental Policy Act, Fish and Wildlife Coordination Act, Outdoor Recreation Act, etc.).

In the spirit of these legal mandates, the biological profession must recognize and fulfill its role in planning; rarely have biologists been effective in incorporating fish and wildlife habitat improvement into project designs. Presently, environmental quality and enhancement often are regarded as obstacles to development, partly because quantitative information that can be easily integrated into the planning process is lacking. However, through proper biological planning, these tradeoffs can be recognized and complementary benefits incorporated into project design. Moreover, such an integrated planning process would be an immense aid to more efficient management of state, federal and even private fish and wildlife resources.

Two factors dominate the planning process: (1) biological or habitat models linked to specified management activities, and (2) economic choice criteria to evaluate tradeoffs and/or complementary benefits between biological and other project purposes. Biological models can provide measures of change in environmental conditions and the response of a wildlife species to these habitat changes. Inability to quantify this potential response has been a significant deterrent to cooperative planning. However, an additional modeling framework is necessary to link the biological model and attendant management activities to an economic choice criterion. It is this linkage that will aid decision makers in the evaluation of alternative project plans, and is the focus of this paper.

Scientific Paper #6163, Agricultural Research Center, College of Agriculture, Washington State University. This research was supported by the U.S. Bureau of Reclamation, Project 1-07-10-50281; the Office of Water Research and Technology, Project B-086-WASH, Agreement 14-34-0001-9160.

The Habitat Evaluation Procedures (HEP) can serve as the requisite biological model (U.S. Fish and Wildlife Service 1981). The remainder of this paper demonstrates how HEP can be linked to an optimization framework that explicitly models the continuum of biological responses to various management or enhancement practices available to wildlife managers. Cost effectiveness or cost per unit of habitat or wildlife produced can be estimated. Decision makers can then select the management programs that provide the greatest increase in habitat/wildlife for a given dollar expenditure. This general framework is applied to mallard (*Anas platyrhynchos,* Linneaus) habitat management in a proposed 400,000-acre (162,000 ha) Bureau of Reclamation irrigation project in Washington's Columbia Basin.

Analytical Overview

HEP as a Biological Model

HEP was developed by the U.S. Fish and Wildlife Service for use in impact assessment and planning (see Schamberger and Farmer 1978, for the historical development of HEP).[1] While the HEP modeling process is discussed in considerable detail elsewhere (U.S. Fish and Wildlife Service 1981), a brief overview is provided here. This overview is intended to draw attention first to the level of detail required for a credible habitat model, and secondly, to illustrate the linkage between habitat models and management practices designed to alter habitat.

The HEP modeling process quantifies overall habitat suitability as a dimensionless value ranging from zero to one, the Habitat Suitability Index (HSI). HSI represents the capacity of a given habitat to support or produce a target species. The logic of an HSI model is illustrated in Figure 1, "A Breeding Habitat Suitability Index Model for the Common Mallard (*Anas platyrhychos,* Linneaus)."

Levels I through IV trace the relationship between overall habitat suitability and the measurable environmental variables needed to characterize the habitat potential of a given environmental setting. Overall habitat suitability for mallard breeding habitat (Level I) depends on the suitability of life requisite needs (Level II), i.e., nesting habitat, submersed food, and brood-rearing habitat. Each life requisite may be supplied by several different cover types (Level III). Since each cover type is different, a separate set of measurable environmental variables (Level IV) is required to define the adequacy of each cover type. Although the same environmental variable may be related to different cover types, e.g., vegetation density, separate measurement of the variable for each cover type satisfying a particular life requisite need is required to define the overall suitability of each cover type. For a detailed description of this specific mallard habitat model and supporting literature, see Hanson and Matulich (1982).

Aggregation and spatial interspersion of the measurable environmental variables into an HSI embodies the complexity of the environment being modeled. The more complex the environment, the greater the number of elements needed to define the system and the more intricate the linkages between the elements. By definition,

[1]Both the intent and application of HEP in planning appears to have been in developing mitigation strategies for known or anticipated habitat damage.

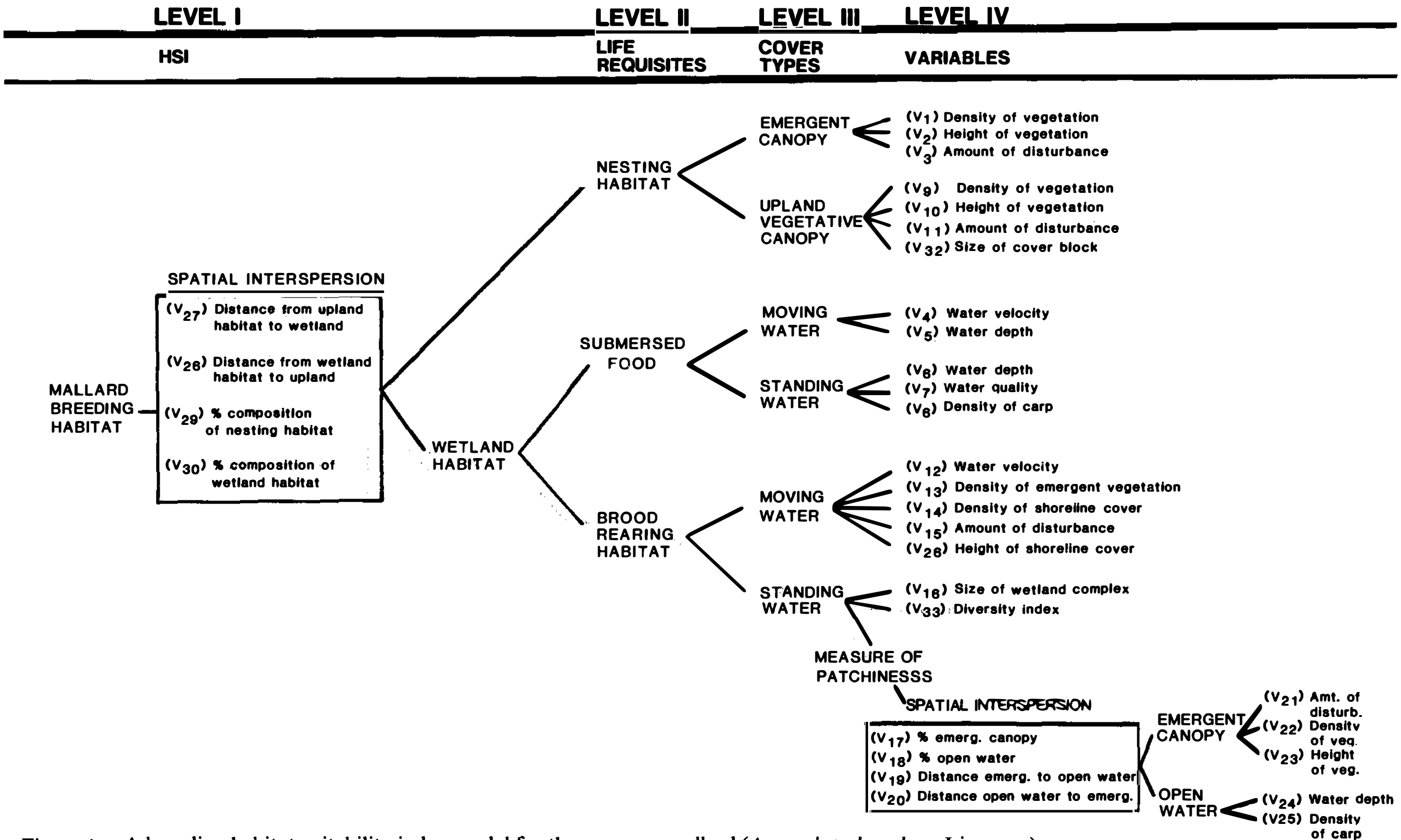


Figure 1. A breeding habitat suitability index model for the common mallard (*Anas platyrhynchos*, Linneaus).

all models are simplifications of reality. But to be useful in a predictive or planning sense, all dominant environmental factors and interactions should be incorporated. Figure 1 demonstrates the implication of modeling complex environmental systems. The complexity of this process is further demonstrated later in this paper when the mathematical representation of one part of this model is presented.

The HSI model depicts elementary habitat production relationships that serve as the basis for measuring responsiveness to habitat manipulation. A set of management activities now must be defined and linked to this framework.[2] It is through this linkage that management activities explicitly influence overall habitat suitability. Thus, expansion of the HSI modeling framework to incorporate the influence of management activities on habitat suitability enables planners and wildlife managers to measure expected biological outcomes.

Economic Choice Criterion

The final step is to incorporate an economic choice criterion that enables decision makers to select economically efficient and rational management activities. In a classic sense, this problem embraces both costs and benefits of these activities. By establishing the costs per unit of management activity, the total cost of the management plan can be readily calculated. On the other hand, benefit valuation poses a difficult problem. Not only is this valuation process conceptually difficult, but it has left biologists in a powerless position when confronting the proponents of economic development. It is here that difficulties in valuing non-market wildlife resources emerge. Non-market valuation techniques may be useful in measuring one dimension of wildlife resources, their recreational value, but no consideration is given to their ecological value. At best, the valuation process is partial.

An alternative choice criterion to maximizing net benefits is minimization of costs per unit of habitat or wildlife produced, i.e., cost effectiveness. This alternative avoids the non-market valuation process altogether. Admittedly, cost effectiveness analyses give the decision maker greater discretionary influence over the final choice. However, the ultimate choice will be determined by several factors: (1) the monetary resources available for program implementation, (2) the anticipated biological output response, and (3) the success of lobbying efforts by interested parties. Thus, the cost effectiveness approach offers the biological profession defensible and useful information to help decision makers choose among least cost management plans associated with different levels of wildlife output (HSI).

The remainder of this paper presents an example of the expanded HEP model in a cost effectiveness framework. Specifically, this framework is applied to the East High Irrigation Project. Because the model is extremely complex, only a synopsis is presented here (for full details see Hanson 1982).

A Planning Model for Mallard Management

A problem confronting planners in Washington's East High Irrigation Project is the determination of optimal management levels for the entire irrigation project.

[2]The relevant management activities should be defined by a team of experts familiar with species' needs and the particular area to be managed. Biologists from the Soil Conservation Service, U.S. Fish and Wildlife Service, and Washington Department of Game identified the set of potentially relevant management activities and their impact on measurable environmental variables.

Numerous options exist for developing this area as mallard breeding habitat, ranging from passive management (the no action alternative), to intensive habitat development. This synopsis describes the procedures required to formulate a mathematical programming model to determine cost effectiveness.[3] Since the model is designed to formulate the optimum level of mallard management activities, the objective is to minimize the costs of habitat maintenance/development subject to the basic biological model, a minimum level of biological productivity (HSI), and other resources that may be limiting.

Figure 2 illustrates the linkage between the HSI model and the management activities for a single measurable environmental variable—vegetative density in the emergent zone.[4] This particular linkage isolates the portion of the model addressed here. Keep in mind, management activities (Level V of the expanded tree diagram) represent the array of choice available to the planner. Each activity can be employed in different amounts, and each incurs different costs. In turn, each activity has a different impact on habitat quality (suitability). The set of equations required to define the linkages illustrated in Figure 2 are discussed below.

Collectively, all management activities combine to define non-linear relation-

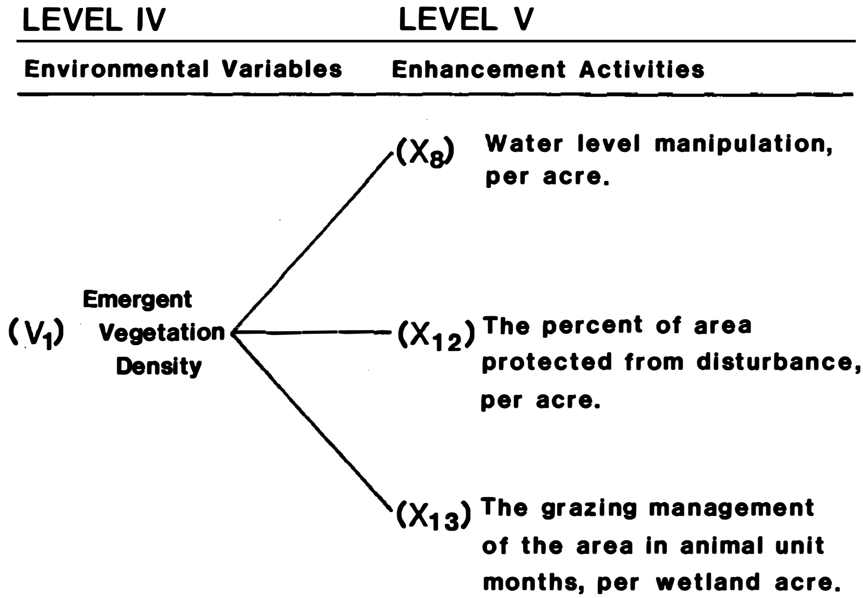


Figure 2. Linkage of management activities to measurable environmental variables.

[3]All constrained optimization problems fall under the generic heading of mathematical programming; the most common of which is linear programming. For further reference see Beale (1968), Hadley (1962, 1964), Hillier and Lieberman (1980), Pfaffenberger and Walker (1976), or Wagner (1975).

[4]Specifically, Figure 2 illustrates the role of emergent vegetation density as related to overwater nesting. This example was chosen despite the fact that overwater nesting is not common behavior for mallards. It is reported in the literature (Krapu et al. 1979) and is included in this general HSI model for completeness.

ships within the HSI model. Consequently, a non-linear programming technique is required to model these relationships. In particular, separable programming is used to estimate cost effective management plans.[5]

Formulation of the separable programming example is divided into two parts. First, a general model description of the linkage between habitat suitability—the constraining biological production criterion—and emergent vegetation density is presented. This description portrays how each management activity influences emergent vegetation density, the overall relationship between the management activities in combination, and habitat suitability of the emergent vegetation density. The second section is a detailed derivation of the specific example equations. Due to the non-linear form of several of the relationships, separable, piecewise linear approximations are formulated.

A General Description of Model Linkages

Modeling the linkage between emergent vegetation suitability and specific management activities is a complex process involving a number of functional relationships nested one into the other. Emergent vegetation suitability, for example, is directly influenced by the percentage of canopy coverage, i.e., density of the emergent vegetation as measured by Daubenmire's technique (1959). This relationship between emergent vegetation suitability and vegetation density is illustrated in Levels III and IV of Figure 1. It is also shown that emergent vegetation suitability is influenced by vegetation height and amount of disturbance, but these two environmental variables will not be discussed here. Rather, the only nested functions described here are those linking emergent vegetation suitability, as defined by vegetation density, to the management activities that impact that density.

Suitability of emergent vegetation depends on vegetation density (Figure 3). Density, in turn, is directly affected by three management activities: (1) water level manipulation per acre of pond (X_8), (2) the percentage of area protected from disturbance (X_{12}), and (3) grazing management of the area measured in animal unit months per wetland acre (X_{13}). Each management activity influences emergent vegetation differently, as shown in figures 4–6, and described in detail below.

On a per acre basis, vegetation management can be undertaken at different time intervals. The longer the interval, the less impact there is on vegetation density given constant management intensity (Figure 4).

Animal grazing and human disturbance affect the density of emergent vegetation by trampling areas where emergents grow. Although emergent species are not a preferred food, livestock will graze on this vegetation if upland food is unavailable or unpalatable. Because cattle do not selectively thin when they feed, any grazing is likely to create open patches in the emergent canopy. Thus, the percentage of wetland which is protected from animal disturbance will impact the overall emergent vegetation density (Figure 5).

[5]Separable programming is a method for optimizing non-linear objective functions and constraints. By transforming non-linear expressions into piecewise linear approximations, modified linear programming algorithms can be used to solve the constrained optimization problem. For further discussion on separable programming see Hadley (1964).

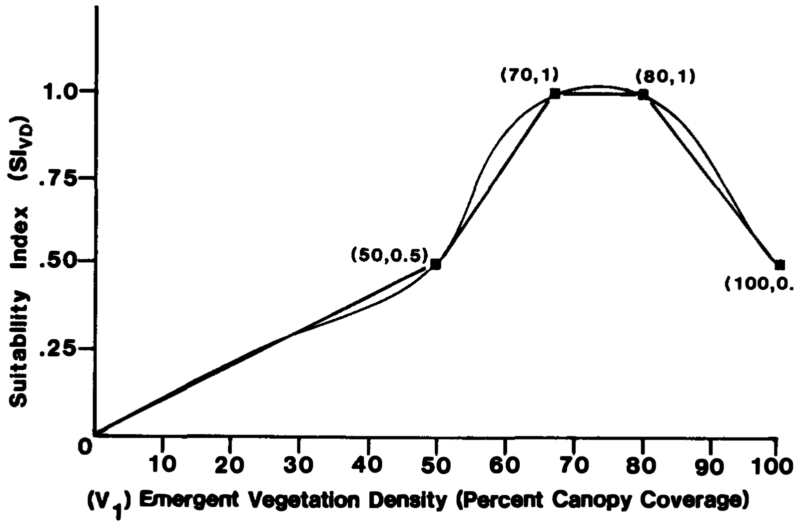


Figure 3. Emergent vegetation density suitability index curve for overwater nesting.

A separate activity monitoring the grazing plan of the wetland is needed, not because of the disturbance factor, but because grazing leases provide an option for generating revenues from these lands. These funds can be used to help offset the mallard management costs. The extent to which grazing can be allowed depends on the tradeoffs between habitat suitability, costs of vegetation maintenance, and revenues generated from grazing leases. The programming model serves to analyze both the cost/revenue relationships, and the impacts of each activity on emergent density and its attendant suitability. The fewer animal unit months per wetland acre of grazing allowed, the greater the vegetation density and thus, the higher the habitat suitability (Figure 6).

Before discussing the specific form of each activity/vegetation density relationship, one final functional linkage must be presented. The role of each management activity, in terms of its vegetational influence, must be linked with the others to determine an overall vegetation influence. This composite value for vegetation density is linked to the overall density suitability index (Figure 3).

The relationship between these three management activities and overall emergent vegetation density is compensatory. A high level of fencing offers protection from grazing disturbance. This protection offsets the need for grazing management, which is presumed to be beneficial only in generating revenues. These two management practices, in turn, tradeoff with the water level manipulation activity. The functional form of this relationship is given in equation (1).

(1) $V_1 = \frac{1}{2} V_{D8} + \frac{1}{2} (V_{D12} * V_{D13})^{1/2}$

Overall emergent vegetation density (V_1) is the average of vegetation densities (V_{D_i}) resulting from the three management practices: the water level manipulation

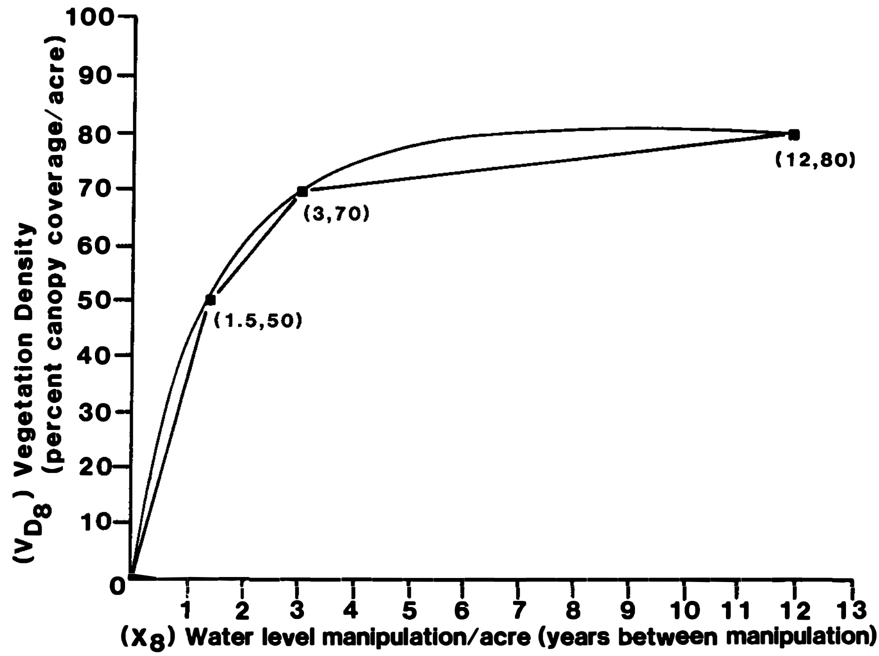


Figure 4. Relationship between water manipulation and emergent vegetation density.

activity (X_8) and the protection and grazing management activities (X_{12} and X_{13}). The percentage of area protected from grazing and grazing management are both required if either is employed. Thus, a geometric mean serves to aggregate the associated vegetation densities, V_{D12} and V_{D13}. If the percentage of the area protected is low, a strict grazing control policy would offset the potential impact of insufficient fencing on the vegetation density, and vice versa. The next step is to specify the functional forms representing these linkages. Readers uninterested in the specific mathematical derivations may skip the next section with little loss in continuity.

Mathematical Formulation of the Specific Example Equations

Functional representation of emergent vegetation suitability clearly involves both linear and non-linear relations as evident from figures 3 through 6. The non-linear functions portrayed in figures 3 and 4 may be approximated directly as separable, piecewise linear equations. However, aggregation of V_{D12} and V_{D13} in equation (1) involves a somewhat more complex non-linearity because the product of V_{D12} and V_{D13} must be transformed into separable linear combinations of the two variables. Each of the necessary equations can provide a fully equivalent, yet separable expression of the relationship between V_{D12} and V_{D13}. Two common methods exist to achieve separability: (1) log transformation, and (2) the difference

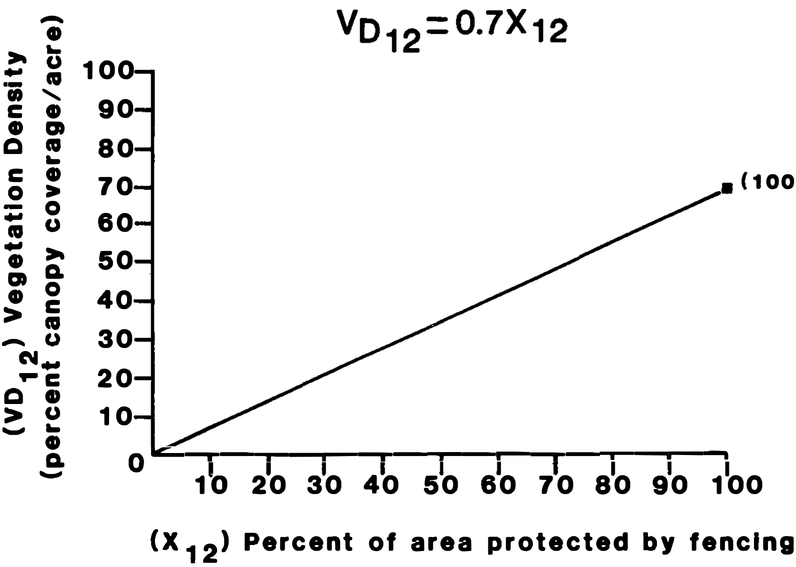


Figure 5. Relationship between percentage of area protected by fencing and emergent vegetation density.

of two squares transformation. For the sake of simplicity, the first of these methods is employed here.

The first step in formulating the mathematical model involves deriving the equations relating management activities to their respective influences on emergent vegetation density. Secondly, these three density expressions must be aggregated into a single, overall density expression. The final linkage relates overall density to emergent vegetation suitability. This process is developed below for each functional relationship in this synopsis of the HSI model.

A set of grid points that define the piecewise linear approximation to the nonlinear function(s) must be selected to closely approximate that function(s). These grid points are the endpoint coordinates of the line segments defining the linear approximation. In this example, the grid points designating the values of V_1, and thus the V_{D_i}'s correspond to 0, 50, 70, 80, and 100.[6] These values closely approximate the suitability index curve in Figure 3.

The relationship between the water manipulation activity (X_8) and emergent vegetation density (V_{D8}) is convex and non-linear (see Figure 4). The vegetation density/management activity curve is piecewise linearly approximated by selecting (0,0), (1.5, 50), (3, 70), and (12, 80) as the grid points. Table 1 demonstrates the

[6]In cases where the upper bound of the relationship is achieved before vegetation density reaches 100 percent, fewer grid points may be selected, as with X_8. Figure 4 illustrates that emergent vegetation density, as influenced by water manipulation, reaches its maximum value at 80 percent. Thus, 100 percent vegetation density cannot be attained and no corresponding value of X_8 can be specified.

Table 1. Linearizing variable coefficient derivation: X_8 and V_{D8}.

Variables				Coordinate values			
X_8	0.0		1.5		3.0		12.0
V_{D8}	0.0		50.0		70.0		80.0
Slope components							
ΔX_8		1.5		1.5		9.0	
ΔV_{D8}		50.0		20.0		10.0	
Linearizing variable				Coefficients			
$\frac{\Delta V_{D8}}{\Delta X_8}$		33.3		13.3		1.1	

derivation of the slope coefficients in the linear approximation of Figure 3. Letting α_i represent the special "linearizing" variable, the relationship between the water manipulation activity (X_8), and emergent vegetation density (V_{D8}) can be approximated by equations (2) through (6):

(2) $V_{D8} = 33.3\alpha_1 + 13.3\alpha_2 + 1.1\alpha_3$

(3) $X_8 = \alpha_1 + \alpha_2 + \alpha_3$

(4) $\alpha_1 \leq 1.5$

(5) $\alpha_2 \leq 1.5$

(6) $\alpha_3 \leq 9.0.$

The percentage of area fenced (X_{12}) is shown in Figure 5 to be linearly related to emergent vegetation density (V_{D12}). Thus, a single linear expression can serve to constrain the optimizing model in terms of this management activity:

(7) $V_{D12} = 0.7\ X_{12}.$

As Figure 6 illustrates, the relationship between grazing management and vegetation density is also linear. The amount of livestock grazing (X_{13}) is inversely proportional to emergent vegetation density (V_{D13}):

(8) $V_{D13} = 70 - 35\ X_{13}.$

Aggregation of these three independent relationships as defined by equations (2) through (8) now may be formulated. Use of the geometric mean to aggregate V_{D12} and V_{D13} in equation (1) requires writing the product term

$$\tfrac{1}{2}(V_{D12} * V_{D13})^{1/2}$$

in terms of separable functions. To do this, first add an equation defining a new varible (Z):

(9) $Z = \tfrac{1}{2} \ln V_{D12} + \tfrac{1}{2} \ln V_{D13}.$

It follows that the geometric mean, $(V_{D12} * V_{D13})^{1/2}$ can be written as:

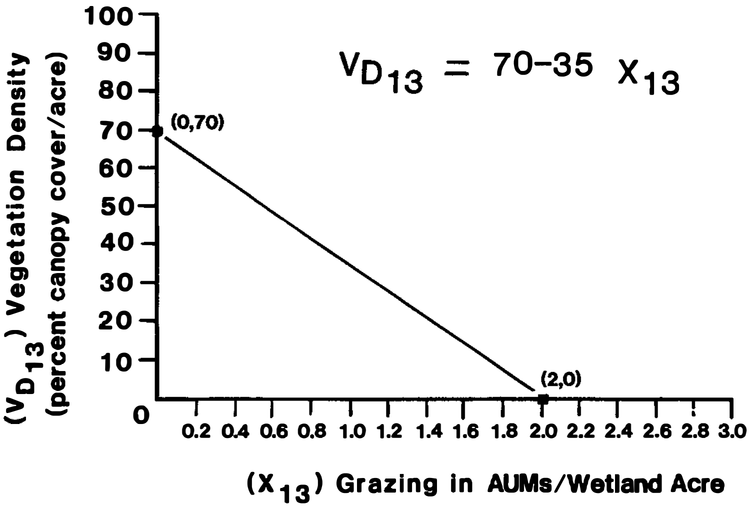


Figure 6. Relationship between grazing plan and emergent vegetation density.

(10) $U = e^Z$.

This equation, along with (9) is added to the model. Finally, equation (1) is restated as:

(11) $V_1 = \frac{1}{2} V_{D8} + \frac{1}{2} U$.

Equation (11) takes the place of equation (1) in the constraint structure. The resulting equations capture the original restrictions on the problem and involve *only* separable, non-linear functions, ln V_{D12}, ln V_{D13} and e^Z.

Further explanation of equations (9) through (11) is warranted to provide clarity. The objective is to define V_1 (overall vegetation density) as a linear combination of the separable functions. Since the log transformation is used to "separate" V_{D12} from V_{D13} in equation (1), several steps are required to link each V_{D_i} with the overall vegetation density. Logarithms of V_{D12} and V_{D13} are used to define a new variable Z. Once Z is defined (V_{D_i}'s have been transformed), an anti-log is required to return the geometric mean back to non-log scale (equation (10)). This defining equation insures that the final answer will be in units compatible with the input data. In summary, equation (9) defines the log of the geometric mean in terms of separable functions of V_{D12} and V_{D13}, and equation (10) relates the log of the geometric mean back to the geometric mean. The end result is a system involving only separable functions which relate the management activities to the overall emergent vegetation density. Equations (9) to (11) now can be cast in the separable programming framework.

Figure 7 illustrates the relationship betweeen vegetation density (V_{D12}) to one half its log. In approximating the curve with grid points, V_{D12} values of one and

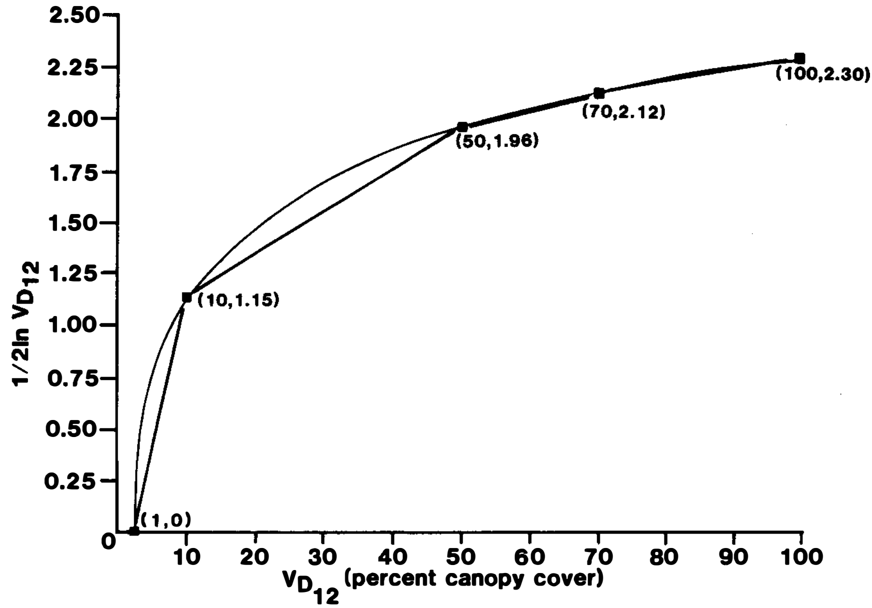


Figure 7. Relationship between V_{D12} and ½ ln V_{D12}.

ten are chosen to accurately estimate the left-hand segment of the curve. Points representing 50, 70, and 100 are selected, as before, to correspond to the grid points of the density/suitability index curve. The linearizing equations are presented below as formulated in Table 2. Using β_i as the special "linearizing" variable for V_{D12}, V_{D12} and ½ ln V_{D12} can be represented as in equations (12) through (17):

(12) $\frac{1}{2} \ln V_{D12} = 0.128\beta_1 + 0.020\beta_2 + 0.008\beta_3 + 0.006\beta_4$

(13) $V_{D12} = \beta_1 + \beta_2 + \beta_3 + \beta_4$

(14) $\beta_1 \leqslant 9$

(15) $\beta_2 \leqslant 40$

(16) $\beta_3 \leqslant 20$

(17) $\beta_4 \leqslant 30$.

Using δ_i as the linearizing variable, V_{D13} and ½ ln V_{D13} are defined with equations (18) through (23):

(18) $\frac{1}{2} \ln V_{D13} = 0.128\ \delta_1 + 0.020\ \delta_2 + 0.008\ \delta_3 + 0.006\ \delta_4$

(19) $V_{D13} = \delta_1 + \delta_2 + \delta_3 + \delta_4$

(20) $\delta_1 \leqslant 9$

(21) $\delta_2 \leqslant 40$

(22) $\delta_3 \leqslant 20$

(23) $\delta_4 \leqslant 30$.

The right-hand sides of equations (12) and (18) are then substituted for ½ ln V_{D12} and ½ ln V_{D13} respectively in equation (9), thereby defining Z.

Table 2. Linearizing variable coefficient derivation: V_{D12} and ½ ln V_{D12}.[a]

Variables				Coordinate values					
V_{D12}	1		10.0		50.0		70.0		100.0
½ ln V_{D12}	0		1.15		1.96		2.12		2.30
Slope components									
ΔV_{D12}		9.0		40.0		20.0		30.0	
Δ½ ln V_{D12}		1.15		0.81		0.16		0.18	
Linearizing variable				Coefficients					
$\dfrac{\Delta ½ \ln V_{D12}}{\Delta V_{D12}}$		0.128		0.020		0.008		0.006	

[a]The same derivation applies to V_{D13} and ½ ln V_{D13}.

Figure 8 illustrates the relationship between the anti-log function "e", and the sum of the log transformed V_{D_i}. A greater number of grid points are required to allow for the various combinations of each V_{D_i} that might result in significant alterations in overall suitability. The coefficients for the linearizing variables, λ_i, are presented in Table 3. Relevant constraint equations are defined by equations (24) through (32):

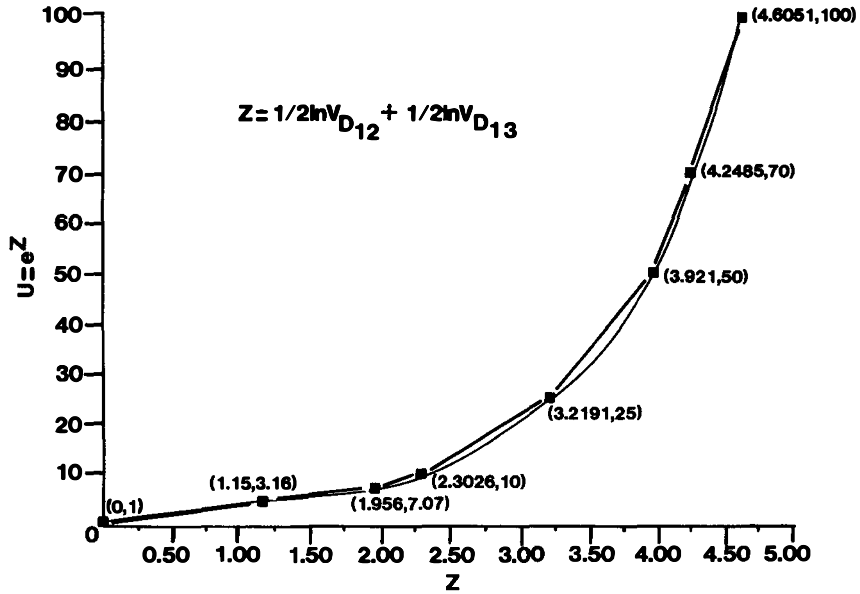


Figure 8. Relationship between Z and U.

Table 3. Linearizing variable coefficient derivation: Z and U.

Variables								Coordinate values							
Z	0.0		1.15		1.96		2.30		3.22		3.92		4.25		4.60
U	1.0		3.16		7.07		10.00		25.00		50.00		70.00		100.00
Slope components															
ΔZ		1.15		0.81		0.34		0.92		0.70		0.33		0.35	
ΔU		2.16		3.91		2.93		15.00		25.00		20.00		30.00	
Linearizing variable								Coefficients							
$\frac{\Delta U}{\Delta Z}$		1.878		4.851		8.444		16.376		35.612		60.975		84.034	

(24) $U = 1.878\lambda_1 + 4.851\lambda_2 + 8.444\lambda_3 + 16.376\lambda_4 + 35.612\lambda_5 + 60.975\lambda_6 + 84.034\lambda_7$

(25) $Z = \lambda_1 + \lambda_2 + \lambda_3 + \lambda_4 + \lambda_5 + \lambda_6 + \lambda_7$

(26) $\lambda_1 \leq 1.15$

(27) $\lambda_2 \leq 0.806$

(28) $\lambda_3 \leq 0.347$

(29) $\lambda_4 \leq 0.916$

(30) $\lambda_5 \leq 0.702$

(31) $\lambda_6 \leq 0.328$

(32) $\lambda_7 \leq 0.357.$

The final step is to link, mathematically, overall emergent vegetation density to emergent vegetation suitability. Coefficients for the linearizing variables are listed in Table 4. SI_{VD} is the overall suitability index value for emergent vegetation density. The constraint set consists of the following system of linear equations, with γ_i as the linearizing variable for V_1:

(33) $SI_{VD} = 0.010\ \gamma_1 + 0.025\ \gamma_2 - 0.025\ \gamma_4$

(34) $V_1 = \gamma_1 + \gamma_2 + \gamma_3 + \gamma_4$

(35) $\gamma_1 \leq 50$

(36) $\gamma_2 \leq 20$

(37) $\gamma_3 \leq 10$

(38) $\gamma_4 \leq 20.$

In summary, a series of nested relationships (some linear, some non-linear) are transformed into a system of linear equations. With these constraints and defining relationships, it is possible to use separable programming to determine the cost effective level of each management activity to achieve a given emergent vegetation density suitability of overwater nesting habitat. It is important to remember that this formulation results in a single environmental variable suitability index. The overall model consists of numerous indexes which must be aggregated and spatially interspersed to generate HSI in much the same fashion as above.

By fixing the level of HSI, optimization of the mathematical programming model yields the least cost set of management activities that achieve the specified HSI value. Parametric variation of HSI traces out a cost effective frontier from which decision-makers can choose a desired plan. See Hanson (1982) for the complete model.

Summary, Conclusions, and Implications

The HSI model framework can serve as a planning tool in resource development. However, the basic framework needs expansion to include the influence of potential management practices, and an economic choice criterion to choose among alternative management plans. This expansion is accomplished in a step-wise manner and requires the use of mathematical programming methods to determine optimal (cost effective) management strategies. The cost effectiveness framework provides a decision-making tool that avoids the tenuous non-market resource valuation process.

Modeling environmental relationships may be a complex procedure. When an

Table 4. Linearizing variable coefficient derivation: V_l and SI_{VD}.

Variables				Coordinate values					
V_l	0		50.0		70.0		80.0		100.0
SI_{VD}	0		0.5		1.0		1.0		0.5
Slope components									
ΔV_l		50.0		20.0		10.0		20.0	
ΔSI_{VD}		0.5		0.5		0.0		−0.5	
Linearizing variable					Coefficients				
$\frac{\Delta SI_{VD}}{\Delta V_l}$		0.01		0.025		0.0		−0.025	

environmental model is used as a planning device, sufficient detail must be incorporated to accurately depict biological responses from management activities. There appears to be a tendency among most wildlife managers to opt for overly simplistic models comprised of few variables. These models may fail to adequately portray the biological system, and thus, may be incapable of systematically tracing out the integrated responses of a given management option.

The need for selecting *optimal* plans further aggravates the complexity of this analysis. Once the habitat model is formulated and linked to an array of management activities, it must be cast in a mathematical programming framework. The specific example presented in this paper illustrates the relationship between only three management activities and one segment of the biological production model. Thirty-eight equations are needed to characterize this relationship in the separable programming framework. Specification of the complete model requires many more equations.

The high degree of biological and mathematical sophistication required to develop cost effective plans necessitates collaboration of several experts: field biologists, research biologists, mathematical modelers and resource economists. The research biologists, modelers and resource economists must work together to formulate a viable analytical framework. Availability of a library of general wildlife habitat models would expedite this process. These models should be sufficiently detailed to be adaptable to different environmental scenarios. Management experience of the field biologist is needed to frame the problem in a particular application, and to validate the resultant model. Failure to collaborate is likely to perpetuate the role of biologists as impact mitigators rather than as partners in planning.

References Cited

Beale, E. M. L. 1968. Mathematical programming in practice. John Wiley and Sons, New York, 195 pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northw. Sci. 33: 43–64.

Hadley, G. 1962. Linear programming. Addison-Wesley Publishing Co., Menlo Park, Ca. 520 pp.

______. 1964. Non-linear and dynamic programming. Addison-Wesley Publishing Co., Reading, Ma. 484 pp.

Hanson, J. E. 1982 (forthcoming). Bioeconomic analysis of waterfowl enhancement in the East High Irrigation Development Project, Washington. Department of Agricultural Economics, Master's thesis. Washington State Univ., Pullman, Wa.

———, and S. C. Matulich. 1982. A breeding habitat suitability model for the common mallard (*Anas platyrhynchos,* Linneaus) in the eastern Columbia Basin, Washington. Program in Environmental Science and Regional Planning Bulletin 82-1, Washington State Univ., Pullman, Wa.

Hillier, F. S., and G. J. Lieberman. 1980. Introduction to operations research. Holden-Day Inc., San Francisco, Ca. 829 pp.

Krapu, G. L., L. G. Talent, and T. J. Dwyer. 1979. Marsh nesting by mallards (*Anas platyrhynchos*). Wildl. Soc. Bull. 7: 104–110.

Pfaffenberger, R. C., and D. A. Walker. 1976. Mathematical programming for economics and business. Iowa State Univ. Press, Ames, Ia. 462 pp.

Schamberger, M., and A. Farmer. 1978. The Habitat Evaluation Procedures: their application in project planning and impact evaluation. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 274–283.

U.S. Fish and Wildlife Service. 1981. Standards for the development of Habitat Suitability Index models. 103 ESM. USDI Fish and Wildl. Serv., Div. of Ecol. Serv., Washington D.C.

Wagner, H. M. 1975. Principles of operations research with applications to managerial decisions. Prentice Hall Inc., Englewood Cliffs, N.J. 1039 pp.

Project Applications of the Forest Service Rocky Mountain Region Wildlife and Fish Habitat Relationships System

Judy L. Sheppard and Dale L. Wills
Forest Service, U.S. Department of Agriculture, Denver, Colorado

James L. Simonson
Forest Service, U.S. Department of Agriculture, Delta, Colorado

Wildlife and Fish Habitat Relationships (WFHR) is a Forest Service system for integrating wildlife and fish information and assessment data into interdisciplinary land and resource management. WFHR is a comprehensive organization of information in a format useful for managing wildlife through the management of their habitats. The WFHR System assists the Forest Service in meeting its goal of managing wildlife and fish habitats, both for species diversity as well as for individual species of management concern.

The Rocky Mountain WFHR System (USDA Forest Service 1981a) organizes information on 853 vertebrate animal species occurring on National Forest System lands in the five-state Rocky Mountain Region (Colorado, Kansas, Nebraska, South Dakota, and Wyoming). It provides an information base from which field inventories, assessments, and management plans can be developed. The system is usable on a District project, Forest, or Regional level. It is being coordinated with other Forest Service data inventory systems, as well as with other resource agencies' systems.

The System is based on a similar Forest Service Regional System in California (Hurley and Asrow 1980, Verner and Boss 1980). The data in the Rocky Mountain WFHR System were compiled by Forest Service wildlife and fisheries biologists throughout the Rocky Mountain Region. Overall coordination of the system was provided by the Forest Service Regional Office. Verification of the information compilation was made by wildlife professionals outside the Forest Service. The data have not been field validated.

The system can be used manually or with the Qwick Qwery (CACI 1975) data base management system.[1] The computerized system can be used two ways: for simple retrieval by specific data elements and to carry out analytical computations.

Retrieval by data elements can list species which might be present in given habitat conditions, and can be used to help determine indicator species or other species of special interest. The computational capability of the system can be used to evaluate the impacts of alternative vegetation modification proposals, to predict future impacts with and without modification, and to assist in determining when and what kinds of modifications need to be made in an area to meet given objectives.

[1]The use of a trade, firm, or corporation name does not constitute an official endorsement of or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.

This paper will briefly outline the contents of the data base and will discuss two applications of the evolving system—an analysis of a timber sale, and an analysis of a mining project.

Contents of the Data Base

The Rocky Mountain WFHR System contains data in three formats: narratives, habitat relationships matrices, and status matrices. Narratives contain life history information as it relates to the habitat needs of each species. The following information is in each species narrative: Status (legal and management), distribution by habitat, reproduction, special habitat requirements, food habits, territory/home range, references, and other management information. The narrative information, although not computerized, is used manually to supplement the matrix information and to provide references.

The second format, habitat relationships matrices, differs for terrestrial species and aquatic species. Matrices for terrestrial species provide information on the use of 24 vegetation types (10 forested, 14 non-forested) and 10 special habitat needs (e.g., snags, talus slopes, etc.). The forested types are divided into five structural stages, based on growth characteristics of dominant plants: grass/forb, shrub/seedling, young, mature, and old growth. The young and mature stages of each vegetation type are further subdivided by three categories of canopy closure: less than 40 percent, 40 to 70 percent, and greater than 70 percent. Non-forested types include grasses, with one structural stage, and shrubs with both a grass/forb and a shrub stage.

Importance of each vegetation type and structural stage to a terrestrial species is related to the biological functions of reproduction, feeding, and resting (i.e., cover). Season of use is also included.

Within each cell of a matrix, a value is assigned for the species association with the particular vegetation type and structural stage for each biological function (Figure 1) (USDA Forest Service 1981a). This value, referred to as a habitat capability rating, is based on current literature and professional knowledge. The values range, in whole numbers, from 1 to 3. A habitat capability rating of 1 indicates the habitat is optimum (it contains all of the required elements, with none being limiting) for that biological function. A habitat capability rating of 2 is acceptable habitat for a particular biological function, but some elements might be limiting the population from reaching its optimum density. A habitat capability of 3 is marginal. In this case, the habitat might be used by the species, but there are some required elements that are missing or limited.

A final value, the habitat capability coefficient (HCC), is calculated for each vegetation type and structural stage (USDA Forest Service 1981b). The HCC is an aggregated, weighted value based on the habitat capability ratings for reproduction, feeding, and resting. These values can range from 0.00 to 1.00. The HCC, then, provides an overall subjective numerical rating of the value to a species of a vegetation type and structural stage, or of a special habitat need.

Habitat relationships matrices for aquatic species do not contain habitat capability ratings or coefficients, nor do they denote season of use. These matrices have a variety of aquatic habitat and micro-habitat elements; and use of an element is shown as "required for survival," "not required for survival," or "unknown."

Species Common Name	Biological Function[a]	Lodgepole Pine[b]								
		1	2	3A	3B	3C	4A	4B	4C	5
GRAY-HEADED JUNCO	B			2	2	3	1	2	3	1
	F	1	2	2	2	3	1	2	3	1
	R	2	2	2	2	3	1	2	3	1
	S[c]									
	HCC[d]	0.50	0.33	0.50	0.50	0.20	1.00	0.50	0.20	1.00

Figure 1. Habitat relationships matrix for the Gray-headed Junco (*Junco caniceps*) in lodgepole pine (*Pinus contorta*).

[a]Biological function: B = reproduction; F = feeding; R = resting (cover)

[b]Structural stages: 1 = grass/forb; 2 = shrub/seedling; 3A = young with <40% canopy closure; 3B = young with 40–70% canopy closure; 3C = young with >70% canopy closure; 4A = mature with <40% canopy closure; 4B = mature with 40–70% canopy closure; 4C = mature with >70% canopy closure; 5 = old growth

[c]Season of use (S) indicated by shading: summer / spring / fall / winter

[d]Habitat capability coefficient (HCC): 1 = optimum; 0.50 = intermediate; 0.20 = marginal

The final data format is status matrices. These matrices contain information on life form; Federal classification as threatened or endangered; State status as threatened or endangered; protected or unprotected nongame; and hunted, trapped, or fished. They also indicate species' occurrence (introduced or native) on each National Forest and National Grassland in the Rocky Mountain Region.

All of the information in the matrices has been computerized. The following two examples use computer analysis to different degrees, but both use the data base as the primary input for the analysis.

Project Applications

Application of the WFHR System to a Timber Sale

The purpose of this application of the WFHR System is to analyze the consequences to wildlife of various alternatives of proposed timber sales. Index formulation and application to timber sale planning are based on the work of Hurley (1978), and Barrett and Boss (1978). The analysis can be performed on an entire sale area, or on individual cut and uncut stands within a sale, depending on the resource inventory data available and the needs of the user or decision maker. The analysis can cover immediate effects on wildlife, and/or can assess the change over time in the capability of an area to support wildlife. All species of wildlife for which the particular forest type provides habitat can be analyzed, or the analysis can be applied only to selected species.

Information required for the analysis includes: acres of various forested types and structural stages prior to treatment, as well as those expected to result from each of the alternative treatments, and the habitat capability coefficient for each wildlife species in each vegetation type and structural stage.

The method used in analysis of alternative timber sale treatments assesses the impacts of vegetation change on all species, using the pre- and post-treatment structural stages of the forested types involved.

Some assumptions underlying this analysis include:

1. Vegetation types are relatively uniform over the sale area;
2. HCC represents the overall importance of a vegetation type to a species;
3. All habitat remains available to wildlife; none is "lost" to large roads or impoundments, etc.;
4. The sale is comprised primarily of single-storied stands (although the analysis can be applied in a limited manner to multi-storied stands);
5. Juxtaposition of acreages of the same vegetation type is not critical to a species' survival; and
6. Water for terrestrial species is adequately distributed throughout the unit.

Analysis of the effect of vegetation change is done in the following way:

1. A raw habitat capability index, pre-treatment ("RAW HCI, PRE"), is calculated for each species as the sum of the products of: HCCs of the given vegetation types and structural stages times the number of pre-treatment acres of each of those vegetation types and structural stages:

$$\text{RAW HCI}_{\text{pre}} = \sum_{i=1}^{j} \text{HCC}_i \times \text{Area}_{\text{pre}(i)}$$

(where i = distinct stands of the same vegetation type and structure)

2. A "RAW HCI, POST" is calculated in the same manner, using the projected number of post-treatment acres in each vegetation type and stage:

$$\text{RAW HCI}_{\text{post}} = \sum_{i=1}^{j} \text{HCC}_i \times \text{Area}_{\text{post}(i)}$$

3. An HCI is then calculated for both pre- and post-treatment by dividing the "RAW HCI" by the total number of acres in the sale area or in an individual stand, and then multiplying by 100:

$$\text{HCI, PRE} = (\text{RAW HCI}_{\text{Pre}} \div \text{Total Area}) \times 100$$

$$\text{HCI, POST} = (\text{RAW HCI}_{\text{post}} \div \text{Total Area}) \times 100$$

4. The change in habitat capability indices is the difference between Post- and Pre-HCI:

$$\text{Change in HCI} = (\text{HCI, POST}) - (\text{HCI, PRE})$$

5. Steps 2, 3, and 4 are repeated for each alternative treatment.

This type of analysis was applied to the 2,000-acre (810-ha) Divide Timber Sale area on the Gunnison National Forest in Colorado. Two alternative treatments were proposed for the sale. Alternative 1, a partial cut, would remove 35 to 40 percent of total basal area by patch cuts of 1 to 5 acres (0.4 to 2.0 ha) each, and group tree selection of one-half to 1 acre (0.2 to 0.4 ha) each over the sale area. Alternative 2 proposed 40-acre (16.2-ha) clearcuts over 35 to 40 percent of the area containing mature trees with greater than 40 percent canopy closure. The acreages of the three forested types and structural stages prior to treatment and those projected from each alternative are displayed in Table 1.

The Rocky Mountain WFHR System allows the user to specify which wildlife species will be analyzed. In the Divide Timber Sale, the selection criteria were that the species occur, according to the status matrices, on the Grand Mesa, Uncompahgre, and Gunnison national forests (a single administrative unit) and use, according to the relationships matrices, any of the pre- or post-treatment vegetation types and structural stages on the sale area. Other combinations of criteria are also possible. Table 2 is a partial list resulting from the WFHR analysis on the Divide Timber Sale. The full report from this analysis listed 163 species that might use the area in its present or future condition.

The columns—habitat capability prior to treatment (''Habitat capabililty pre''), habitat capability with an alternative (''Habitat capability alt. X''), and the associated change in habitat capability (''Post-pre change in capability'')—indicate the relative changes in the overall value of the 2,000-acre (810-ha) area for meeting the reproduction, feeding, and cover requirements of each species. A positive ''change in capability'' implies the proposed changes would benefit the species; a

Table 1. Pre- and projected post-treatment acres by vegetation type and structural stage in the Divide Timber Sale, Gunnison National Forest, Colorado for partial cut and clearcut treatments.

Vegetation type	Structural stage	Canopy closure	Acres (pre)	Acres (post)	
				Alt. 1	Alt. 2
				(partial cut)	(clearcut)
Lodgepole pine	Grass/forb		0	0	391
	Young	<40%	10	10	10
		40–70%	56	56	56
		>70%	202	202	202
	Mature	<40%	60	285	60
		40–70%	643	563	418
		>70%	416	271	250
Spruce/fir	Grass/forb		0	0	176
	Young	40–70%	8	8	8
	Mature	<40%	87	115	87
		40–70%	102	235	66
		>70%	351	190	211
Aspen	Grass/forb		0	42	7
	Young	40–70%	45	18	45
	Mature	40–70%	20	5	13
Total acres			2,000	2,000	2,000

Table 2. Partial list of the wildlife analysis for the Divide Timber Sale. Alternative 1 was a partial cut; Alternative 2 was a clearcut. Figures might not add, due to rounding.

Common name	Habitat capability pre	Habitat capability Alt. 1	Post-pre change in capability	Habitat capability Alt. 2	Post-pre change in capability
Golden-mantled ground squirrel	6.00	18.00	12.00	20.00	14.00
Nuttall's cottontail	4.00	11.00	7.00	18.00	14.00
Pine marten	52.00	59.00	7.00	39.00	−13.00
Mule deer	25.00	31.00	5.00	29.00	4.00
Western jumping mouse	35.00	40.00	5.00	54.00	19.00
Prairie falcon	56.00	59.00	3.00	66.00	10.00
Northern pocket gopher	0.00	2.00	2.00	24.00	24.00
Mountain vole	2.00	3.00	1.00	6.00	5.00
Common elk	49.00	49.00	0.00	52.00	3.00
Red-tailed hawk	54.00	54.00	0.00	47.00	−8.00
Western toad	40.00	40.00	0.00	40.00	0.00
Common merganser	48.00	48.00	0.00	40.00	−9.00
Heather vole	62.00	62.00	0.00	62.00	0.00
Evening grosbeak	73.00	73.00	0.00	50.00	−24.00
Turkey vulture	82.00	82.00	0.00	78.00	−5.00
Tiger salamander	77.00	77.00	0.00	59.00	−18.00
Northern leopard frog	92.00	92.00	0.00	69.00	−23.00
Black bear	53.00	52.00	1.00	47.00	−6.00
Goshawk	74.00	71.00	−3.00	57.00	−16.00
Porcupine	66.00	60.00	−6.00	46.00	−20.00
Pine grosbeak	57.00	51.00	−6.00	37.00	−20.00
Bald eagle	47.00	39.00	−8.00	30.00	−16.00
Hammond's flycatcher	59.00	47.00	−12.00	47.00	−12.00

negative number implies adverse effects. For example, the turkey vulture (*Cathartes aura*) has a pre-treatment habitat capability index of 82.00 (out of a possible 100). Under Alternative 1, that capability would remain the same; under Alternative 2, the capability would be reduced.

Habitat capabiliity index (HCI) is not directly related to animal population densities. The post-pre change in capability represents an estimated change in the "ability of a land area to support a given species," rather than a direct change in numbers of individuals of that species. Thus, a 10-percent increase in HCI for a species under a given treatment does not mean the species' population will increase by 10 percent. It does, however, mean that the land should be slightly more capable of producing or maintaining that species than under the pre-treatment condition. The alternative that provides the greatest increase in the HCI would presumably benefit the species most.

Habitat capability indices for different species are not linearly related to one another. The change in HCI can be compared among species to identify those that will be most affected by a proposed activity. However, a change of -10 for one species is not necessarily twice as much as a change of -5 for a different species. It implies a greater adverse impact, but not necessarily one twice as great.

The analysis for the Divide Timber Sale (Table 2) shows that, for most raptors—particularly the goshawk (*Accipiter gentilis*)—the partial cut (Alternative 1) provides better habitat than the clearcut (Alternative 2). For most small mammals, the clearcut results in greater habitat capability. Amphibians and waterfowl, in general, are not benefitted by either alternative because of their dependence on aquatic and wetland conditions. Both alternatives show a negative impact on porcupines (*Erethizon dorsatum*). If a decline in porcupine population is a desired goal of the sale, the analysis shows that the clearcut should initially be more beneficial in achieving the goal than the partial cut.

The same analysis used to assess the effect of vegetation change can be used to assess the effect of proposed changes in special habitat needs created by specific treatment, such as snags or edge. The HCC for the special habitat need is used in place of that for vegetation type and structural stage. A quantification of the pre- and post-treatment special habitat condition, such as number of snags or linear feet of edge, is used. The quantification can be in any units, as long as post- and pre-treatment measurements are in the same units.

If applying the analysis to determine the effects of vegetation changes over time on wildlife species, estimates would have to be made on the structural stages of vegetation types for intervals throughout the given time span. This application is useful in determining when the next entry into a stand should be made in order to meet specific wildlife habitat objectives.

Application of the WFHR System to a Mining Project

This application of the WFHR System analyzes the general impacts of various alternatives of a proposed mining project on all wildlife species that might be present in the given area. Unlike the timber sale application, this analysis considers the impacts on wildlife of "acres lost," not acres converted from one structural stage or vegetation type to another.

The information required to perform the analysis includes: total HCC for each species in each vegetation type or special habitat need occurring in the project area; percentage of total project area occupied by each vegetation type or special habitat need; and number of acres of each vegetation type or special habitat need affected by each alternative.

The method used in the analysis of alternatives was to weight the final index by the number of species using the habitat of a certain HCC value and multiply by the scarcity of that habitat in relation to the total project area.

The methodology was developed specifically to analyze alternatives of the Mount Emmons Mining Project on the Gunnison National Forest in Colorado. During the initial stages of the Draft Environmental Impact Statement, a public issue surfaced that, in a broad context, impacts on all wildlife should be considered. The procedure was developed to respond to this issue. The following assumptions were made in developing the procedure (USDA Forest Service 1982):

1. All habitat has inherent value for wildlife, and changes in the relative quantities of various habitats can be compared.
2. Available data bases (WFHR) would be adequate to evaluate impacts of project alternatives on wildlife.
3. HCC represents the relative importance of a given habitat type to each species listed.
4. All species are analyzed without bias to social value.
5. Habitats that are in short supply have a relatively greater value than proportionately abundant habitats.
6. A "worst case" analysis is used which assumes that all disturbed areas will be unavailable for 30 to 50 years. In all probability, with reclamation, some habitats could be available for use by some wildlife species at a much earlier time.

Analysis of the impacts of alternatives is conducted as follows:

1. A list of species for the area is compiled from the WFHR System along with each species' total HCC for all structural stages of each vegetation type on the project area in which the animal occurs. The total HCC equals the sum of the HCCs of the structural stages of a vegetation type. The range of values of the total HCC could vary from 0 (not suitable) to 9 (optimum) for forested types (a maximum) value of 1.0 for each of 9 structural stages, and from 0 to 1.0 for non-forested and special habitat needs. Table 3 is a partial list of the species that might occur on the Mount Emmons Mining Project and their total HCCs.
2. A species influence factor (SIF) based on combined HCCs of the structural stages of each vegetation type, is an intermediate calculation that allows the derivation of an impact index value for each vegetation type. The SIF is calculated by taking each of the possible values of total HCC for a vegetation type occurring on the area and dividing by the maximum total HCC (as noted above) for that vegetation type. This is done to make the range of values of total HCC of forested types equivalent with the range for non-forested and special habitat needs. The total is multiplied by 100 and divided by the decimal value of the proportion of the study area on which the vegetation type occurred (P). A log transformation is applied to the equation to linearize the data:

$$\mathrm{SIF} = \mathrm{Log}_{10} \frac{(\text{Total HCC/Max. HCC}) \times 100}{P}$$

For example, Table 4 shows the calculations for sagebrush habitat on the

Table 3. Partial list of species that might occur on the Mount Emmons mining project area, Gunnison National Forest, Colorado. Total habitat capability coefficients are listed by vegetation type. Figures have been rounded.

	Total habitat capability coefficient by vegetation type								
			Mtn. meadow						
Common name	Alpine	Sagebrush shrubland	Wet	Dry	Riparian	Aspen	Lodgepole pine	Spruce/ fir	Douglas fir
Mountain chickadee	0.00	0.00	0.00	0.00	1.00	6.00	2.00	6.00	6.00
Prairie falcon	1.00	1.00	1.00	1.00	1.00	3.00	7.00	4.00	6.00
Goshawk	0.00	0.00	0.00	0.00	1.00	6.00	5.00	3.00	4.00
Ruby-crowned kinglet	0.00	0.00	0.00	0.00	1.00	2.00	6.00	6.00	4.00
Townsend's solitaire	1.00	1.00	0.00	0.00	0.00	4.00	4.00	6.00	7.00
Least chipmunk	0.00	1.00	0.00	0.00	0.00	2.00	2.00	2.00	2.00
Mule deer	0.00	1.00	0.00	0.00	1.00	9.00	4.00	3.00	6.00
Common elk	1.00	1.00	1.00	1.00	1.00	8.00	5.00	5.00	5.00
Pine marten	0.00	0.00	0.00	0.00	0.00	0.00	3.00	5.00	1.00
Red squirrel	0.00	0.00	0.00	0.00	0.00	0.00	6.00	7.00	4.00

Table 4. Wildlife impact index calculations for sagebrush habitat on the Mount Emmons mining project. Sagebrush constitutes 36.03 percent of the surveyed area.

Total HCC	No. species[a]	SIF[b]	No. species × SIF
1.00	16	2.44	39.04
0.83	6	2.36	14.16
0.66	10	2.26	22.60
0.50	11	2.14	23.54
0.40	3	2.04	6.12
0.33	10	1.96	19.60
0.30	4	1.92	7.68
0.23	1	1.80	1.80
0.20	2	1.74	3.48
0.16	4	1.65	6.60
0.13	2	1.56	3.12
0.06	1	1.22	1.22
	70		149.96

Impact Index Value 149.96 ÷ 100 = 1.49

[a]No. species = number of species using this habitat and for which biologists have assigned a habitat capability coefficient as shown in the first column.

[b]Species Influence Factor (SIF) = $\text{Log}_{10} \dfrac{(\text{Total HCC/Max. HCC}) \times 100}{P}$

where P = proportion of surveyed area with subject habitat (as a decimal), and
Max. HCC = Maximum total Habitat Capability Coefficient possible (9.0 for forested types, and 1.0 for non-forested types and special habitat needs).

Mount Emmons project. The total HCC for intermediate habitat is 0.50; the maximum HCC for sagebrush is 1.00; and the proportion of the study area containing sagebrush is 36.03 percent. Thus:

$$\text{SIF} = \text{Log}_{10} \frac{(0.50/1.00) \times 100}{.3603} = 2.14$$

3. An impact index value is determined by multiplying the SIF by the number of species of a given total HCC in that vegetation type. This provides a weighting of the SIFs by numbers of species and by HCCs.
4. The sum of the impact index values for each total HCC is divided by 100 to obtain a value that, when multiplied by the number of impacted acres, would be on the order of magnitude of the acres affected.

Once the impact index values are calculated for each vegetation type or special habitat need, the impacts of each alternative can be evaluated. Table 5 shows impact index values calculated for each of the nine vegetation types in the Mount Emmons project area.

Application of this technique to the Mount Emmons mining project was based on sample data from an area representative of the total project area. Vegetation types and proportions of project area covered by a specific type were derived from information gathered on the area.

Table 5. Wildlife impact index values for vegetation types occurring on the Mount Emmons mining project. Lodgepole pine results in a relatively high index value due primarily to the low proportion of its occurrence over the surveyed area.

Habitat	Index value
Rockland/talus	0.33
Sagebrush	1.49
Alpine	1.51
Dry mountain meadow	1.67
Wet mountain meadow	1.70
Spruce-fir woodland	1.78
Aspen woodland	2.11
Lodgepole pine	2.67
Riparian	3.61

The Mount Emmons Mining Project Draft Environmental Impact Statement (USDA Forest Service 1982) explored seven alternatives. The alternatives incorporated different combinations of mine and mill sites, ore haulage and worker access routes, production rates, land exchange, and mitigation measures. The impacts of each mine site, mill site, and ore haulage route, in terms of acres of vegetation type disturbed, were calculated. A "worst case" analysis of wildlife impacts from subsidence of Mount Emmons was also calculated. For each site or route, the acres of a specific vegetation type disturbed were multiplied by the appropriate index value (from Table 5) to give an index of wildlife impact for that vegetation type. The indices were then summed for all of the vegetation types on a mine site or haulage route. The general wildlife impact for a given alternative was determined by summing the impact indices for the combination of mill and mine sites and haulage routes that made up that alternative and adding the impact index of subsidence. The seven alternatives could then be compared as to their general impacts on wildlife.

Figure 2 shows the final aggregated wildlife impact indices for each proposed alternative of the Mount Emmons Mining Project. Higher impact indices represent greater adverse impacts. Alternatives 2, 3, and 4 would occur in the same general vegetation types. One reason for developing Alternative 7 was that it would occur in sagebrush habitat; and it was perceived that, in this vegetation type, impacts to wildlife would be minimized. What was not accounted for, however, was that the gentler terrain associated with Alternative 7 would require the use of more surface acres for the same volume of tailings than would the steeper terrain in Alternatives 2, 3, and 4. The analysis reflects the wildlife impacts resulting from the increased acres required.

There are several characteristics of this type of analysis. First, the focus is on wildlife species as the primary unit of importance, yet the process allows comparison of alternatives based on the degree of disturbance of habitat conditions. Second, all vertebrate species potentially occurring in the project area are considered equally without a bias toward economics, values, animal size, taxon, etc. The Mount Emmons application of this technique was the Forest Service response to

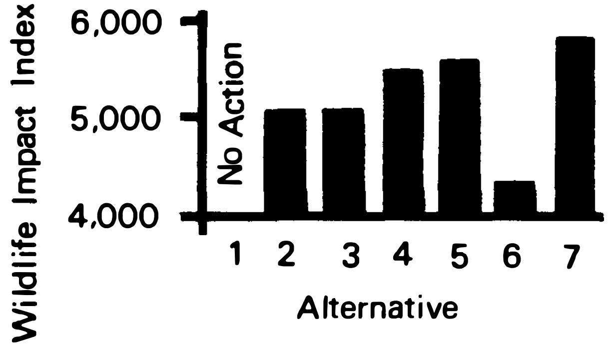


Figure 2. Aggregated wildlife impact indices for each proposed alternative of the Mount Emmons Mining Project (USDA Forest Service 1982:29). Higher index values represent greater adverse impacts.

a public issue that requested unbiased consideration of wildlife. The third characteristic of this analysis is that it takes into account the value of a vegetation type as species habitat, as well as the possible importance of relatively scarce vegetation types in limiting wildlife distribution. Fourth, the wildlife impact index values are specific in relation to the species considered and the local vegetation composition. Finally, this analysis considers the importance of each vegetation type to all species groups, rather than keying to species of special interest.

Interpretation of this analysis is limited by the same conditions as the timber sale analysis: the impact index value for each alternative is not directly related to animal population densities, and larger index numbers mean greater reduction in the capability of the habitat to support wildlife (but an index of 400 is not necessarily four times as great as an index of 100; nor will it necessarily mean a four times greater decrease in animal populations).

Discussion and Conclusions

The two applications of the Rocky Mountain WFHR System differ in several ways:

1. The mining application uses "acres lost," not acres converted to a different structural stage.
2. The final index value in the timber sale example is linked directly with one species. This allows evaluation of impacts on a single-species basis. The index value in the mining project example combines the impacts to individual species into one value for each alternative. This allows evaluation of impacts by alternatives.
3. The mining project analysis takes into consideration the scarcity of a vegetation type within the project area. The timber sale analysis could be modified to account for habitat scarcity within a sale area, but presently does not do so.
4. The mining project takes into account the value of vegetation types to different species, as well as the number of species that use a given vegetation type at a given capability rating.

Each application provides an analysis of project effects on wildlife, but uses the basic WFHR data in different ways. These analyses as well as the species narratives are intended to provide additional information for the decision maker. No single analysis will provide "the answer." Frequently, several levels (e.g., a project, or acres within a project) or types (e.g., assessment of effects on big game, or on endangered species) of analyses must be done to provide a more complete picture of potential effects on wildlife. The analyses presented in this paper are not meant to take the place of field knowledge. Field expertise is critical in the interpretation of the analysis and necessary in order to spot potentially important impacts of project proposals. Analyses using the Rocky Mountain WFHR System have a shortcoming in not being able to account for juxtaposition of vegetation types. Indirect or secondary impacts, particularly from a mining project, are also not included in these analyses; nor are impacts on fish populations. Again, this is where field knowledge is irreplaceable.

Currently in the Forest Service Rocky Mountain Region, use of the WFHR System via computer has not been extensive. The System is, however, being used creatively, and for a variety of purposes. While the applications presented in this paper are developmental, they are currently being used and evaluated. As needs arise, new types of applications of the system will be developed and old applications will be refined. As the basic information in the system is used, it will be validated and refined. Until the basic data in the system and the applications of that data are field validated, caution must be exercised in their use and interpretation. It is hoped that at some point in the future a link will be developed between values in the data base and habitat capability expressed in population numbers or percentage increase or decrease in populations.

In conclusion, the Rocky Mountain Region WFHR System contains a systematic organization of management and life history data on wildlife species on National Forest System lands in the Forest Service Rocky Mountain Region. Various levels of analysis can be performed with the System. Two uses of the System allow analysis of the effect of habitat modifications on a range of wildlife species or allow a resource manager to focus on the effect of habitat modifications on a specific group of species, such as big game or threatened or endangered species. While the Forest Service does not have a specific statutory mandate to analyze effects on all wildlife species, there is a multiple use mandate for management of the National Forest System for uses including wildlife, and the National Forest Management Act regulations (36 CFR 219, Subpart A) require that "fish and wildlife habitats will be managed to maintain viable populations of all existing native vertebrate species. . . ." It seems imperative, then, that techniques be used which will analyze projects and planning direction to determine consequences to all species of wildlife. In doing this type of analysis, it is possible that effects on a species not previously considered would be seen.

As Dr. Jack Ward Thomas said (Swanson 1981), "We can't wait 25 years for information on wildlife—forest management will keep moving on without it. Biologists must learn to come on with the information and skills they have and refine them as they go. It's better than waiting, and being too late." Application of the WFHR System to planning, projects, and in other ways is limited only by our own creativity.

References Cited

Barrett, B., and A. Boss. 1978. A practical application of the wildlife habitat guidelines. 9 pp. Unpublished paper.

CACI. 1975. QWICK QWERY User's Manual. Consolidated Analysis Centers Inc., Los Angeles, Cal. 267 pp.

Hurley, J. 1978. Western Sierra wildlife relationships Qwick Qwery file documentation. 11 pp. Unpublished draft.

——— , and E. Asrow. 1980. Western Sierra wildlife/habitat relationships computer use manual. *In* H. Salwasser, tech. ed. WHR applications note 80-1. USDA For. Serv. Pacific Southwest Region, San Francisco, Cal. 155 pp.

Swanson, D. 1981. Planning the habitat with the harvest. Wildl. Rev. 10(8): 21–23.

USDA Forest Service. 1981a. Wildlife and fish habitat relationships, Volume I—Narratives; Volume II—Matrices. Rocky Mountain Region, Denver, Colo. Vol. I: 886 pp.; Vol. II: 331 pp.

——— . 1981b. Wildlife and fish habitat relationships draft user's guide. Rocky Mountain Region, Denver, Colo. 160 pp.

——— . 1982. Mount Emmons Mining Project Draft Environmental Impact Statement. Grand Mesa, Uncompahgre and Gunnison National Forests, Delta, Colo. 430 pp.

Verner, J., and A. Boss, tech. coord. 1980. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. Pacific Southwest Forest and Range Exp. Stn., USDA Forest Service, Berkeley, Cal. 439 pp.

Solving the Habitat Dispersion Problem in Forest Planning

Stephen P. Mealey
USDA Forest Service, Fort Collins, Colorado

James F. Lipscomb
Colorado Division of Wildlife, Denver

K. Norman Johnson
Colorado State University, Fort Collins

Introduction

The National Forest Management Act (NFMA) of 1976 (16 U.S.C. 1600) requires that each National Forest, by 1985, prepare one integrated management plan that provides for multiple use and sustained yield for goods and services (36 CFR 219). Such plans must, by inference, emphasize single resources only to the extent that thresholds or minimum legal conditions for all other resources are always provided (Clawson 1975). The goal for wildlife to be met by each forest plan is: manage wildlife habitats to maintain viable populations of all existing native vertebrate species in the planning area (the forest) and maintain and improve habitat of management indicator species (MIS) [36 CFR 219.12(g)]. To meet this goal, wildlife habitat objectives representing threshold or minimum legal habitat conditions must be stated in forest plans to assure adequate consideration of the wildlife resource in all integrated management alternatives. Objectives representing the most desirable (optimum) habitat conditions must also be stated to provide direction for management emphasizing wildlife.

In specific portions of forested ecosystems to be determined in individual plans, planners are encouraged to establish wildlife habitat objectives stating threshold and most desirable levels of: (1) forest vegetation age class distributions and (2) habitat dispersion (USDA Forest Service, in prep.). In this paper, age class distribution refers to specific proportions of forest vegetation age classes or successional stages needed by wildlife. Habitat dispersion refers to spatial distribution or scattering of age classes needed by wildlife within a geographic area.

Recent planning efforts have been relatively successful integrating into forest plans habitat objectives stating age class distributions needed by wildlife. Such habitat objectives provide the quantity of habitats required by dependent vertebrates, but they do not necessarily assure needed habitat dispersion that provides cover and edges. Efforts to develop and quantitatively express habitat dispersion objectives in resource integration models have not been very successful. This problem, to be described later as the "dispersion problem," results from uncertainty among planners about what habitat dispersion objectives can or should be, and also reflects some limitations of current resource integration models to accommodate dispersion objectives.

This paper: (1) presents a synopsis of some past work on procedures to ensure on a forest the continual presence of different age classes needed by wildlife and explains why such procedures are insufficient to ensure that habitat dispersion objectives will also be met; (2) discusses the legal requirements for habitat dispersion in integrated planning; (3) describes the dispersion problem; (4) sets out a theoretical basis for developing wildlife habitat dispersion objectives for forested ecosystems; and (5) presents a process for incorporating such objectives into Forest Service planning models.

The questions of when, where, and how much of a national forest to subject to habitat dispersion objectives are not addressed in this paper. Neither is the question of other resource considerations (e.g., visual, watershed, and timber) in developing multiple use dispersion objectives. Such questions are to be resolved through an interdisciplinary team process that draws on applicable local, regional and national public issues and multiple use management concerns. The theory presented in this paper for developing wildlife habitat dispersion objectives is intended to serve as one of the considerations in developing dispersion objectives for national forests.

Ensuring Age Class Distribution Without Ensuring Habitat Dispersion

Mealey and Horn (1981) documented the integration into a forest plan of wildlife habitat objectives, stating acreages of vegetation age classes needed by wildlife through time. For the forest and some subdivisions of it, the linear programming timber harvest scheduling model was constrained to ensure that minimum acreages existed in each key age class in each period.

The general case of this example is represented as follows: assume the harvest of an area composed of two types of stands (young growth and old growth) is being planned. The net value from cutting the timber over two periods is to be maximized, subject to an even-flow constraint and a requirement that some minimum acreage of mature timber be left in each period after harvest. Old growth acres harvested in period 2 meet the requirement for period 1. Old growth acres left uncut can meet the requirement in both periods, and young growth acres left uncut after the second period also will be old enough to meet the requirement in the second period. The following linear program represents this decision problem.

Maximize: $P_{o1}o_1 + P_{o2}\,o_2 + P_{y1}\,y_1 + P_{y2}\,y_2$

Subject to:

Acreage control constraints

$$o_1 + o_2 + r_o \leqslant A_o$$
$$y_1 + y_2 + r_y \leqslant A_y$$

Inventory acreage constraints

$$o_2 + r_o \geqslant T_1$$
$$r_o + r_y \geqslant T_2$$

Even-flow constraint

$$-V_{o1}o_1 + V_{o2}\,o_2 - V_{y1}\,y_1 + V_{y2}\,y_2 = 0$$

where: i = any period

o_i = acres of old growth cut in period i

y_i = acres of young growth cut in period i

r_o = acres of old growth left uncut after period 2

r_y = acres of young growth left uncut after period 2

P_{oi} = net return from cutting an acre of old growth in period i

P_{yi} = net return from cutting an acre of young growth in period i

V_{oi} = volume/acre of old growth cut in period i

V_{yi} = volume/acre of young growth cut in period i

A_o = acres of old growth

A_y = acres of young growth

T_i = minimum number of acres of mature timber that must be left uncut in period i

The expression being maximized (often called the objective function) is composed of four terms. Each term provides the net value/acre cut times the acres cut for one of the four decision variables (acres of old growth cut in period 1, acres of old growth cut in period 2, acres of young growth cut in period 1, and acres of young growth cut in period 2). Summing these four terms gives the total net value from cutting the two stand types over the two periods. This expression is maximized subject to the constraints specified on the solution.

Three types of constraints appear in the problem. Acreage control constraints ensure that the total number of acres in period 1 and period 2 plus the acres left uncut do not exceed the total number of acres in each stand type. Inventory acreage constraints ensure that the acres of mature timber left uncut in each period is equal to or exceeds some amount. Even-flow constraints ensure that the timber harvest in period 1 ($V_{o1}o_1 + V_{y1}y_1$) equals the timber harvested in period 2 ($V_{o2}o_2 + V_{y2}y_2$).

In problems formulated this way, each stand type is usually composed of stands from across very large areas and sometimes from the entire forest. Old growth from the north end of a large area is combined with old growth from the south end and so on. Location of individual stands, their size and their spatial location in relation to other stand types (here young growth) are lost in the aggregation process. Constraints on minimum acreages in key age classes assure the presence of needed habitat within the planning area, but do not assure that the habitat can be spatially arranged throughout the area in a manner needed by wildlife.

Legal Requirement for Habitat Dispersion

As indicated, the term *habitat dispersion* refers to the distribution or scattering of cutting units and associated wildlife habitats within a geographic area. The NFMA implicitly establishes the legal requirement for habitat dispersion by setting maximum size limits for areas to be regeneration harvested in one operation (Sec. 6(g)(3)(F)(iv)) and by requiring that such cuts be carried out in a manner consistent with the protection of soil, watershed, fish, wildlife, recreation and esthetic resources, and the regeneration of the timber resource (Sec. 6(g)(3)(F)(vi)). Maximum size limits on cuts require that some portions of some harvestable stands remain uncut. This imposes some degree of scattering of harvest blocks among uncut areas. Compatibility of such cuts with the protection of wildlife resources demands a certain amount of edge and retention of cover which are necessary for wildlife.

Effective edge and cover in timber harvest areas result from adequately scattering cuts through uncut areas.

The Problem

The "dispersion problem" can be stated as follows: *Habitat dispersion objectives reflecting timber stand harvest rates compatible with requirements for maximum cut size and wildlife cover and edge have been lacking. As a result, forest planning models (such as the linear program given above) used to schedule timber harvests produce harvest schedules that may be impossible to achieve without violating explicit cut size limits and implicit wildlife cover and edge requirements of the NFMA Regulations (36 CFR 219).*

Solution requires: (1) a theory supporting dispersion objectives leading to specification of proportions of cut to uncut timber to be maintained in stands over time to meet cut size limits and wildlife cover and edge requirements; and (2) a process for incorporating such objectives in multiple use timber harvest scheduling models.

Timber harvest scheduling models lacking incorporation of dispersion requirements may schedule "too much" of a stand or adjacent stands for harvest during a decade (Baglien 1981, Mitchell 1981). For example, assume that a single stand of 100-year-old lodgepole pine (*Pinus contorta*) occurs on 1,200 acres (480 ha) of highly productive land. One harvest prescription applicable only to this stand requires clearcutting with a rotation age for future stands of 100 years. During the first decade, all 1,200 acres are available to the prescription. If the prescription contributes the most to the objective being maximized and there are no constraints on the stand's rate of harvest, all 1,200 acres might be assigned to the prescription. If that happened, the entire 1,200-acre stand would be scheduled for clearcut in one decade. Harvest according to this schedule would not be consistent with any reasonable maximum cut size or wildlife cover and edge requirements. As pointed out previously, even-flow or acreage inventory constraints specifying age class distributions cannot be relied upon to solve such a problem because constraints would apply only to total acres of large areas or entire forests. They would not constrain the harvest rates of individual stands.

This example characterizes the way many national forest timber harvest scheduling models have functioned. In fact, Johnson (1981) indicates that, in the past, Forest Service timber harvest scheduling was concerned primarily with forest-wide assessments of the biological sustainability of timber harvest over multiple rotations rather than with the spatial implications of timber harvesting, including considerations of habitat dispersion needs of wildlife on sub-units of the forest. Such an approach tends to overstate timber harvest capability when additional multiple use objectives for watershed and soil, recreation and visual, and wildlife and fish resources must be met.

Solution

Theory For Developing Dispersion Objectives

As indicated earlier, alternative sets of dispersion objectives must be developed that allow different land use emphasis. Two emphases are considered: the first favors rapid timber production while meeting minimum legal habitat conditions for wildlife (e.g., conditions for minimum populations of wildlife in a specified area). The second favors wildlife habitat (most desirable habitat conditions) with timber production a consequence.

Timber Production Emphasis—Minimum Legal Wildlife Conditions. In this case, dispersion objectives must be developed which specify the minimum time in which stands or groups of stands can be regeneration harvested and still retain edge and cover required by minimum populations of wildlife during the regeneration period. The principal theoretical assumption is: *the length of time required for regenerated vegetation to grow to become cover for large animals (e.g., elk [Cervus elaphus]) is the primary factor in development of threshold habitat dispersion objectives. Size and shape of cuts are other major factors. Rotation ages of stands are not factors.*

An example (Figure 1A) will help illustrate the way in which vegetation growth rate influences development of objectives. This example is based on clearcuts with a two-decade opening life. Two-decades of vegetation growth provide marginally effective cover in this case.

Figure 1A represents 18 cutting units in one mature stand. The number of decades necessary for stand regeneration, assuming the stand must be harvested each decade, is determined by scheduling individual units for harvest so there is at least a 20-year vegetation age difference between all adjacent units. In this case, the required vegetation age class differences cannot be achieved if more than 20 percent of the stand is cut in any decade and the stand is regenerated in less than 50 years. The timber harvest schedule for the stand, conveying the harvest rate compatible with requirements for maximum cut size and wildlife cover and edge, must meet the dispersion objectives that no more than 20 percent be harvested per decade and that the stand be totally regenerated in no less than five decades.

If the stand need not be harvested each decade, it could be divided into a checkerboard pattern with alternate blocks scheduled for harvest in decades 1 and 3. An even flow of timber could be achieved in the area by pairing the stand to another stand with cuts scheduled in decades 2 and 4. This pattern is shown in Figure 1B. The harvest schedules for the stands would permit 50 percent of each stand and 25 percent of the total area to be harvested each entry with 20 years between entries. The area could be totally regenerated in four decades. It would not be possible to provide the desired 20-year age difference between all adjacent cutting units along any common boundary of the two stands. Dispersion is minimal in this case since only two age classes occur in each stand. This condition may not be acceptable for large stands where greater diversity is necessary.

If rows 1, 2, and 3 in Figure 1A each represented different stands (e.g., different species) with similar ages and growth rates for regenerated vegetation, the indicated harvest schedule would be valid for the entire area since minimum age of cover and cut size are the primary determinants of dispersion objectives. If rows 1, 2, and 3 each represented stands differing in age but with similar growth rates, then a coordinated timber harvest schedule for the area would be necessary. The coordinated schedule would specify the harvest dates of individual cutting units such that the vegetation age of adjacent units would always differ by 20 years. A coordinated schedule for Figure 1A is shown in Table 1. The harvest date for each unit in stand 1 (row 1) follows the schedule established in Figure 1A which assures

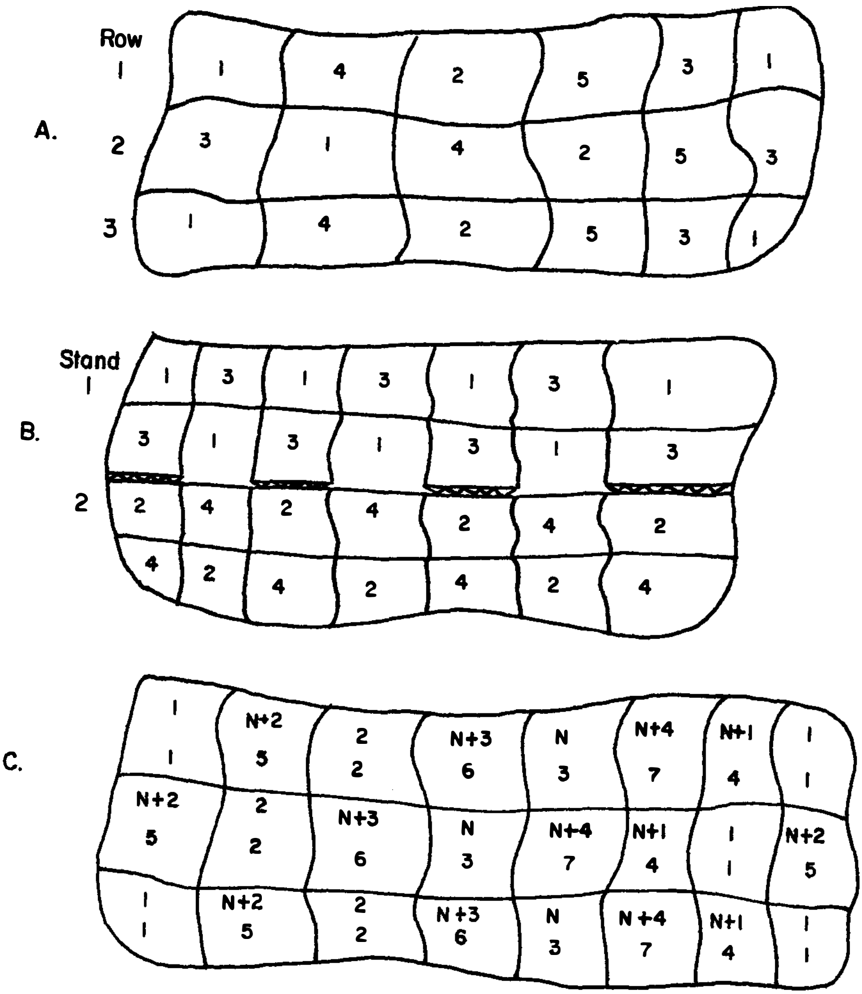


Figure 1. Patterns for laying out regeneration cuts to maintain adequate age differences along edges while regenerating stands rapidly. Numbers in each cutting unit indicate the decade of regeneration for the unit. *A* illustrates the pattern where stands are harvested each decade and age differences along edges must be at least two decades, *B* illustrates another pattern where stands need not be harvested each decade and two decade vegetation age differences are maintained along most edges, *C* applies a general rule to an example where the number of decades (*N*) required to establish wildlife cover following regeneration is 3.

at least two decades of vegetation age difference between adjacent cutting units. Stand 2 will not be ready for regeneration until the fourth decade (e.g., three decades after regeneration of stand 1 has begun). In order to maintain the habitat dispersion pattern begun in stand 1, regeneration of stand 2 begins with unit 4. Regeneration of stand 3 begins with unit 3 since it is ready for regeneration in the third decade.

Table 1. Example of a coordinated timber harvest schedule based on Figure 1A where row 1 represents a 100-year old stand, row 2 is a 70-year old stand, row 3 is an 80-year stand and rotation age for all stands is 100 years.

Stand		Decade of regeneration by cutting unit number				
Current age	Row number	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
100	1	1985	1995	2005	2015	2025
70	2	2035	2045	2055	2015	2025
80	3	2035	2045	2005	2015	2025

A general rule for establishing dispersion objectives that assures opportunity for the desired age difference between all adjacent cut units and some variety of age classes within an area follows: *The fraction of a stand to be regeneration harvested in any decade may not exceed 1/(2N+1); where N is the number of decades required to establish wildlife cover following regeneration.*

Figure 1C demonstrates how the general rule may be applied. The area is first divided into strings of cutting units $2N+1$ long. The end units of each string are scheduled for harvest in decades 1 and $N+1$. Units scheduled in decades 2 through N are spaced evenly in the string between units scheduled in decades 1 and $N+1$. The unit to the right of unit 1 is scheduled for decade $N+2$, the unit to the right of unit 2 is scheduled for decade $N+3$, etc. A new string begins to the right of unit $N+1$. Adjacent strings (e.g., the rows in Figure 1A) must be offset by at least one unit to assure edge contrast. The total number of units in the string $(2N+1)$ equals the regeneration period in decades. The reciprocal of that number $(1/(2N+1))$ represents the proportion of the stand area to be regeneration harvested per decade. Figure 1C shows that if $N=3$ decades, the minimum time to regenerate the stand is seven decades and, therefore, the maximum cut is 14 percent per decade. Similarly, if $N=4$, the minimum time to regenerate the area would be nine decades and the maximum cut per decade is 11 percent.

A general rule for establishing dispersion objectives that provides opportunity for age class differences between some adjacent cut units, and at least two age classes within an area, as shown in Figure 1B, follows: *The fraction of a stand to be regeneration harvested in any decade may not exceed ½ and the remainder may not be regenerated for N decades.*

If the above rule is used, cutting units will be laid out in a checkerboard pattern (Figure 1B) for each stand. If a relatively constant amount of area is to be harvested each year, there must be N stands of approximately equal size. Figure 1B shows that if N is 2, one stand will be regenerated in decades 1 and 3 and another in decades 2 and 4. Similarly if N is 3, one stand will be regenerated in decades 1 and 4, the second in decades 2 and 5, and the third in decades 3 and 6. Under these conditions, the fraction of the total area (including all N stands) that will be regenerated is $1/2N$.

Wildlife Habitat Emphasis—Most Desirable Habitat Conditions. In this case, dispersion objectives must be developed that assure the desired age difference between all adjacent cut units providing for optimum wildlife populations. Objectives also provide for the maximum variety and scattering of age classes within an area. The principal theoretical assumption is: *Desired stand rotation age is the primary factor in development of most desirable habitat dispersion objectives. Size and shape of cuts are other major factors.*

A general rule for establishing dispersion objectives under this emphasis follows: *The fraction of a stand to be regenerated in any decade equals 1/R where R equals the desired stand rotation age in decades.*

Harvest schedules can be determined as before, except the number of units in strings equals the number of decades in stand rotation ages (Figure 2). The end units of each string are scheduled for harvest in decades 1 and $N+1$. Units scheduled for harvest in decades 2 through N are spaced evenly between units 1 and $N+1$. Individual units are scheduled as before (Figure 2A); however, if the rotation length is more than $2N+1$ decades, additional cutting units must be fit into the scheduling pattern. This is accomplished by continuing the pattern pre-

A.

B.

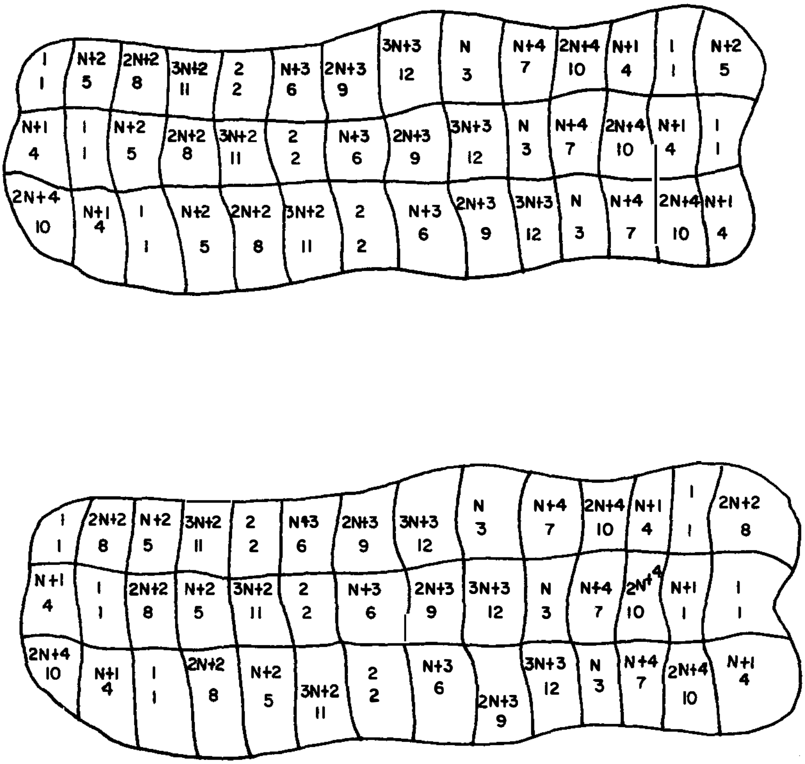


Figure 2. Application of the general rule for laying out clearcuts to the case where the number of decades required to establish wildlife cover following regeneration (N) is 3 decades, rotation length is 12 decades and openings are to be scattered as widely as possible at all times. *A* illustrates the general rule while *B* illustrates the modified rule which improves scattering when rotation length exceeds $3N+1$.

viously established (e.g., the unit to the right of unit $N+2$ is scheduled for $2N+2$, the unit to the right of $N+3$ is scheduled for $2N+3$, etc.). If the number of decades in the rotation exceeds $3N+1$, it is possible to improve the pattern by switching the scheduling of units scheduled for decades $N+2$ and $2N+2$ (Figure 2B). This will provide for better scattering of openings, particularly when units scheduled in decades $N+1$ and $N+2$ are both in openings.

Cut units are more widely scattered under the wildlife habitat emphasis (Figure 2) as compared with the timber production emphasis, and age class distribution as well as high quality habitat dispersion are assured. Also, under the wildlife emphasis, age class variety would continue throughout the rotation, whereas under the timber emphasis, age class variety would be minimal between decade $2N+2$ and rotation age. As a consequence, habitat diversity under the wildlife emphasis would be much greater.

Size and Shape Considerations. Dispersion objectives applicable to both emphases must also address size and shape of cutting units because size and shape impacts the effectiveness of the patterns discussed above. In most cases if size and shape of cutting units are governed by the needs of elk and deer, the opportunity for meeting the needs of other species within these units will be provided. The objectives recommended here are therefore based on elk and deer needs. If indicator species in a specific area include a species whose needs cannot be met under these conditions, more restrictive standards should be applied.

In cases where regeneration is to be completed rapidly (less than $3N+2$ decades), some or all cutting units must serve as cover areas surrounded by openings at some point in the regeneration period. If we assume that, on the average, a cover patch must be at least 600 feet (180 m) wide to be effective for big game (Thomas et al. 1979), the minimum size cutting unit should be about 10 acres (4 ha) and any unit this small should be approximately square. Because big game animals use recently regenerated areas to obtain forage, but generally do not use such areas if they are more than 600 feet from cover, cutting units should be no more than 1,200 feet (360 m) wide. This means that any unit over 30 acres (12 ha) in size should be longer than it is wide, and units approaching 60 acres (24 ha) should be two to five times as long as they are wide.

Optimum cutting units, especially for big game species, would probably fall in the range of 20 to 30 acres (8 to 12 ha) and would be one-and-one-half to two times as long as they are wide. In any case, cutting unit widths should fall between 600 and 1,200 feet (180–360 m). This standard will be met if average length to average width ratios fall within the range indicated by the shaded area in Figure 3. Higher length to width ratios are acceptable if regeneration is to take place over $3N+2$ or more decades, since in these cases cover areas will always be two units wide.

The minimum cutting unit size of 10 acres (4 ha) implies a minimum stand size for application of dispersion objectives. For the timber production emphasis case where stand harvest is required each decade, the minimum stand size equals $10 \times (2N+1)$. For example, if the number of cutting units in a string $(2N+1)$ is 5, then minimum stand size equals 50 acres (20 ha). For the case where stand harvest is not required every decade, the minimum stand size equals 20 acres (8 ha). For the wildlife habitat emphasis case, the minimum stand size equals $10 \times$ Rotation Age. Scheduling of stands smaller than the minimums should be coordinated with adjacent stands.

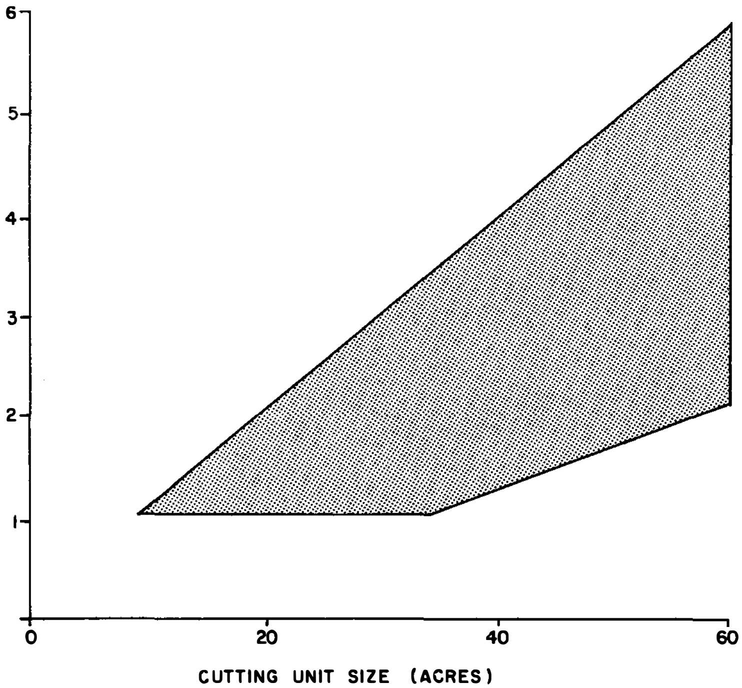


Figure 3. Relationships between size of cutting units and the corresponding shape factors (ratio of average length to average width) that are desirable for big game habitat. Shape factors within the shaded area are desirable where a large stand is to be regenerated in less than $3N+2$ decades (where N is the number of decades required to establish wildlife cover following regeneration).

Required Changes In Multiple Use Timber Harvest Scheduling Models

Inclusion of habitat dispersion objectives in multiple use timber harvest scheduling models used on most large forests requires either a substantial increase in model constraints or a restructuring of model components (i.e., decision variables).

Times of harvest (decision variables) could be developed for each stand, as opposed to grouping similar stands for harvest as was done in the linear program given above, and explicit constraints could link the harvest timing of adjacent stands. Thompson et al. (1973) demonstrated such an approach on the Pocomoke State Forest in Maryland. They recognized "66 separate and essentially homogeneous stands" and augmented a linear program of the type given above with constraints on maximum size of harvests in each stand in each period and the maximum size of harvests in adjacent stands in each period.

This approach has the advantage of making all habitat dispersion requirements explicit, thus enabling measurement of their cost. It has the disadvantage of possibly creating a problem too large to solve. The model created by Thompson et al. had 630 constraints to coordinate the harvest of 60 stands—a fairly large linear program. Most national forests contain 5,000–15,000 separate and distinct stands. Use of the Thompson et al. formulation could easily result in a problem containing 50,000–150,000 constraints. This would result in a linear program too large to solve on currently available computers.

A second approach fundamentally redefines the model's decision variables. In the timber harvest scheduling model given at the beginning of this paper, basic decision variables were defined as the number of acres of a particular stand grouping (old growth or young growth) to be cut in each period. Except as constrained by even-flow or inventory acreage constraints, the decision of how much old growth to cut in a period was independent of how much young growth was cut and could not assure consideration of habitat dispersion. The second approach defines decision variables as complete harvest schedules (as in Table 1) that contain habitat dispersion objectives for all stands in specific areas or locations. Each decision variable reflects a management emphasis-harvest timing combination over the entire planning horizon. Choices among decision variables become choices among alternative harvest schedules.

Mathematically, this decision problem can be represented (for two watersheds each with two harvest scheduling choices) as:

Maximize: $P_{w1} w_1 + P_{w2} w_2 + P_{x1} x_1 + P_{x2} x_2$

Subject to:

Inventory acreage constraints

$$Z_{w11} w_1 + Z_{w21} w_2 + Z_{x11} x_1 + Z_{x21} x_2 \geqslant T_1$$

$$Z_{w12} w_1 + Z_{w22} w_2 + Z_{x12} x_1 + Z_{x22} x_2 \geqslant T_2$$

Even-flow constraint

$$V_{w1} w_1 + V_{w2} w_2 + V_{x1} x_1 + V_{x2} x_2 = 0$$

where: j = any schedule
i = any period
w_j = proportion of watershed w assigned to harvest schedule j
x_j = proportion of watershed x assigned to harvest schedule j
P_{wj} = net return from assigning watershed w to harvest schedule j
P_{xj} = net return from assigning watershed x to harvest schedule j
Z_{wji} = acres of harvest schedule j for watershed w that are mature timber in period i
Z_{xji} = acres of harvest schedule j for watershed x that are mature timber in period i
V_{wj} = (maximum volume which could be harvested in period 2 in watershed w under harvest schedule j) − (maximum volume which could be harvested in period 1 in watershed w under harvest schedule j)
T_i = minimum number of acres of mature timber that must be left uncut in period i

Two types of constraints appear in the problem. An even-flow constraint assures that the timber harvested in period 1 equals the timber harvested in period 2. Inventory acreage constraints ensure that the acres of mature timber left uncut in each period across the forest exceeds some amount. The harvest schedules compete to determine which can most efficiently meet area or forest-wide inventory requirements.

This approach has the advantage of permitting the consideration of spatially feasible harvest choices in mathematical programs that are solvable. It has the disadvantage that the spatial considerations are embedded in the decision variables and, therefore, their costs are difficult to measure.

Overall, the approach can ensure that habitat dispersion requirements are met across time and space. Each decision variable contains a scheduling package that represents a spatially feasible harvest schedule, e.g., a harvest schedule that meets habitat dispersion objectives. These feasible harvest schedules compete to determine which best meets the objective being maximized within the constraints on harvest flow, acreage inventory requirements, and related concerns.

Acknowledgements

T. Mitchell and J. Baglien contributed significantly to the development of theory supporting habitat dispersion objectives. For their help we are deeply grateful. We are also grateful for the special assistance of the following people in preparation and critical review of this paper: T. Bullock, B. Gilbert, E. Gryczan, R. L. Hoover, B. M. Kent, L. Schick, D. L. Schweitzer, T. Stuart, and D. Turman.

Literature Cited

Baglien, J. 1981. Integrating wildlife objectives into forest allocation and scheduling linear programs. Forest planning records. USDA For. Ser. Unpub. Rep. Wallowa-Whitman Nat. For., Baker, Ore.

Clawson, M. 1975. Forests for whom and for what? The Johns Hopkins Univ. Press. Baltimore, Md. 175 pp.

Johnson, K. N. 1981. Timber activity scheduling on the national forests: the second revolution. *In* Forestry predictive models—problems and applications. Wash. State Univ. Press, Pullman, Wash.

Mealey, S. P., and J. R. Horn. 1981. Integrating wildlife habitat objectives into the forest plan. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46: 488–500.

Mitchell, T. 1981. A discussion of timber yield tables and dispersion. Forest planning records. USDA For. Ser. Unpub. Rep. Wayne-Hoosier Nat. For., Bedford, Ind.

Thomas, J. W., H. Black Jr., R. Scherzinger, and R. Pedersen. 1979. Deer and elk. Pages 104–127 *in* J. W. Thomas, ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. U.S. Dep. Agric., Washington, D.C.

Thompson, E. F., B. Halterman, T. Lyon, and R. Miller. 1973. Integrating timber and wildlife management planning. Forestry Chron. Dec. 1973: 247–250.

USDA Forest Service. In prep. Integrating wildlife habitat objectives into forest plans. U.S. For. Serv. Land Manage. Plan. Staff–Fish and Wildl. Manage. Staff, Washington, D.C.

Status of the Habitat Evaluation Procedures

Mel Schamberger

Habitat Evaluation Procedures Group, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, Fort Collins, Colorado

William B. Krohn

Habitat Classification and Evaluation, Office of Biological Services, U.S. Fish and Wildlife Service, Washington, D.C.

Introduction

The 1970s was a decade of increased awareness of environmental problems, and emphasis was placed on the development of procedures for predicting impacts of proposed developmental activities on natural systems. Impact assessment has evolved from a focus on species numbers, human use, species richness, and related methods to include the investigation of habitat as a supplemental or alternative approach to environmental planning, mitigation, species management, and impact assessment (Schamberger 1979, U.S. Fish and Wildlife Service 1980a, 1980b). The impetus for habitat-based assessment techniques came primarily from two sources: (1) environmental legislation requiring noneconomic project evaluations; and (2) an awareness within the scientific community that traditional methods of inventory and analysis were inadequate for land and water planning purposes. Baseline studies of the early 1970s typically resorted to inventories of existing plant and animal species. Such inventories were time consuming, documented only existing conditions, and did not provide a framework appropriate for predicting and evaluating future conditions. In addition, Federal land management agencies generally focus on habitat, not species, management (e.g., Crawford and Lewis 1978). Thus, a documented need exists for a habitat approach to impact assessment. The U.S. Fish and Wildlife Service (FWS), in cooperation with the U.S. Soil Conservation Service (SCS), U.S. Army Corps of Engineers (COE), U.S. Bureau of Reclamation (BR), and State and private organizations developed a standardized, habitat-based evaluation technique to meet this need.

The development and implementation of a standardized habitat evaluation system serves two major purposes. First, a standardized system improves communication within and among organizations and professions. Biologists often are at a disadvantage in resource planning because, when compared to engineering and economics, established and reliable fish and wildlife evaluation methods are generally unavailable. The use of an evaluation method that focuses on habitat can lead to effective communication and, therefore, promote better fish and wildlife management. Secondly, a standardized method provides a framework around which species-habitat research can be focused. Other impact evaluation approaches for fish and wildlife resources also may be necessary in order to accommodate diverse needs of assessment and management. However, given present budget and personnel constraints throughout government, it is particularly important that the fish and wildlife profession focus, not disperse, their limited resources. A standard methodology helps provide this focus.

Historical Background

A task force of Federal, State, and private conservation group representatives prepared a report (White 1971) that gave early impetus for developing habitat-based evaluation procedures. This report contained a number of suggestions for improving the consideration of fish and wildlife resources in Federal projects, including the recommendation that the FWS begin development of a nonmonetary evaluation procedure for use in project planning. A number of available systems were evaluated, and a system published by Daniel and Lamaire (1974) was selected for further consideration and development. The *Ecological Planning and Evaluation Procedures* (Joint Federal-State-Private Conservation Organization Committee 1974) was developed and later revised and published as the *Habitat Evaluation Procedures: For Use by the Division of Ecological Services in Evaluating Water and Related Land Resource Development Projects* (U.S. Fish and Wildlife Service 1976). The Habitat Evaluation Procedures (HEP) were applied to numerous occasions, during which time conceptual and practical weaknesses were identified. Between 1977 and 1980, several approaches to improve the concept of habitat evaluations were identified and investigated (Schamberger and Farmer 1978).

HEP was revised in 1980 and published as three components within the FWS' Division of Ecological Services (ES) operational manual series: (1) an accounting procedure to handle habitat quality and quantity data (U.S. Fish and Wildlife Service 1980b); (2) a method to determine habitat quality by developing models to obtain a Habitat Suitability Index (U.S. Fish and Wildlife Service 1981); and (3) a method to convert habitat data into dollar values (U.S. Fish and Wildlife Service 1980c). The FWS is implementing HEP and will continue testing the concepts and practicality of HEP-80.

Some of the improvements incorporated in HEP-80 included the use of documented habitat models, an alteration of the basic accounting system so that species were followed throughout the evaluation, and the development of software for automated data processing.

HEP is receiving nationwide application in both the public and private sectors. Several conceptual papers have proposed the use of HEP for wetland evaluations (Schamberger et al. 1979, Short and Schamberger 1979a, 1979b, Schamberger and Kumpf 1980). A recent FWS survey indicated that HEP was the most widely used evaluation technique by ES, with 112 applications in 1981 (Hardy 1981).

HEP Accounting System

HEP is based on combining a measure of habitat quantity with an index of habitat quality to determine habitat values (U.S. Fish and Wildlife Service 1980b). The relationship:

$$\text{Habitat area} \times \text{Habitat quality (HSI)} = \text{Habitat units (HUs)},$$

provides the basic framework by which habitats are inventoried and analyzed for the species or guilds of interest. The habitat quality measure (HSI) can be determined by a number of methods, as long as the method is documented and includes quantification of the evaluation criteria. The HSI is defined as a value between 0.0 and 1.0, with 1.0 representing maximum habitat quality in a defined area, assumed to be positively correlated to carrying capacity (U.S. Fish and Wildlife Service 1981).

HEP provides data that can be used in baseline and impact assessments, planning, management, mitigation, or other actions that anticipate a change in either habitat quantity or quality, or both (Farmer 1979, Short and Schamberger 1979a). In baseline studies, different areas are compared at one point in time. For impact assessments, areas are compared at different points in time or under alternative management or development options to determine anticipated changes in available HUs.

Data generated from the HEP process provide information concerning: (1) the amount of habitat involved in the proposed action; (2) the quality of that area as habitat for species or species groups of concern; and (3) an index value derived from combining quality and quantity (HUs). Table 1 presents baseline data for four sites. Sites 1 and 3 contain habitat of the highest relative quality, and sites 2 and 4 have the lowest habitat quality. A decision might be made, on the basis of this information, to select sites 2 or 4 for economic development because they have the lowest habitat value for wildlife. The data can be used for different purposes depending on the study objectives (i.e., either to prevent the loss of valuable wildlife habitat or to select areas with the greatest management potential as wildlife habitat). It is important to note that HU data are generated for each species, life requisite, life stage, or guild used in the evaluation. It is extremely important that the objectives of the study be clearly stated and the evaluation species carefully selected.

In impact assessments, several potential management actions or perturbations may be anticipated for the same area, and the probable changes in both area and habitat quality must be predicted. Although it is difficult to predict future conditions, this is a requirement in all impact assessment studies and is not a HEP-specific problem. Data generated from these predictions can be used in decision making to determine which alternative best meets the stated objectives of a given project or management plan. In Table 2, Alternative C is a development action that would result in no suitable pine marten habitat. Alternative B is a development plan that includes some habitat management to compensate for adverse impacts; Alternative A is essentially a habitat management plan for the same area. In an actual project, the same types of data would be displayed for a number of species and/or alternative sites, providing an array of planning data.

The basic HEP accounting system is a straightforward combination of habitat quality and quantity data that has numerous applications. The accounting portion

Table 1. The use of HEP habitat unit data in baseline assessment (hypothetical data).

Study site	Area/acres	HSI	HU
1	1,000	1.0	1,000
2	1,000	0.2	200
3	10,000	0.9	9,000
4	10,000	0.4	4,000

Table 2. The use of HEP habitat unit data for impact assessment (hypothetical data for the pine marten).

Study site 4	Area/acres	HSI	HU
Baseline	10,000	0.4	4,000
Alternative A	10,000	0.8	8,000
Alternative B	1,000	0.2	200
Alternative C	1,000	0.0	0

of HEP is computerized, and the use of the software aids in the calculation of HU data, relative importance values, and trade off analyses.

Habitat Suitability Index Models

HEP-76 called for the subjective estimation of habitat suitability for selected species. These values were averaged and a single value for each cover type used for the rest of the assessment. In contrast, HEP-80 provides for the tracking of individual species, life stages, life requisites, or guilds throughout the evaluation and promotes the use of models for determining habitat quality. Results of studies at the University of Missouri indicated that the most repeatable methods for evaluating habitats are those that measure environmental variables rather than those that subjectively estimate habitat quality (Ellis et al. 1978, 1979). The models currently being developed by the FWS are called Habitat Suitability Index (HSI) models and focus on the measurement of physical and chemical habitat variables. HSI models include: information on habitat use; literature reviews; a model structure; and documentation of model assumptions, application, and related information. They usually do not include variables such as competition, disease, or environmental contaminants, although these variables can be included when appropriate.

The measurement of habitat quality is recognized as a difficult task and as having major importance to the reliability of HEP and other fish and wildlife assessment methods (Adams 1980, New England Research, Inc. 1980). The relative importance of biological versus physical factors in determining the carrying capacity of a habitat requires further study. Although the technical literature contains descriptive information on many species, few studies provide quantitative information on relationships between habitat variables (e.g., canopy cover, ground cover, size of trees, or distance to water) and animal numbers. It is difficult to derive a relationship that quantitatively predicts what will happen, for example, to gray squirrel populations when 50 percent of the mast trees are removed from a given forest. To partially overcome this problem, standards for modeling species-habitat relationships have been established (U.S. Fish and Wildlife Service 1981), and models are being developed using these standards. We are in the process of field testing several models with the COE and other agencies.

The use of quantitative habitat models that require the measurement of environmental variables places an additional burden on field biologists. Sampling design, especially in terms of the accuracy and precision of sampling procedures, must be carefully evaluated. An inventory techniques manual is available that provides guidance to field biologists in selection of measurement techniques for terrestrial habitat variables (Hays et al. 1981).

The marten (*Martes americana*) will be used to demonstrate habitat model applications to management. The species-habitat relationships for the marten were developed through literature surveys and reviews by experts. For the complete model, including references and documentation, see Allen (1982).

Hypothetical data were selected for the environmental variables used to calculate habitat suitability for the marten (Table 3). These hypothetical field measurements were plotted against the standards of comparison in Figure 1 to obtain the suitability index for each model variable. Index values were aggregated using the equation $(V_1 \times V_2 \times V_3 \times V_4)^{1/2}$ to obtain the estimates of habitat suitability (HSI) displayed in Table 3. An analysis of the suitability indices for the model variables can assist the manager in locating habitat factors that are limiting. Management or mitigative measures designed to maintain or improve habitat should focus on the most limiting habitat factors, assuming that all habitat variables are equally manageable.

Approximately 15 terrestrial, 15 inland aquatic, and 5 estuarine HSI models are scheduled for publication in 1982. These models are being developed by the Western Energy and Land Use Team and National Coastal Ecosystems Team of the FWS' Office of Biological Services. In addition to the mechanistic models, a variety of other species-habitat models can be used in HEP by following the guidelines for conversion in ESM 103 (U.S. Fish and Wildlife Service 1981).

Human Use and Economic Evaluations

Sometimes it is desirable to convert habitat data into data useful for economic analyses. This can be accomplished by the Human Use and Economic Evaluation (HUEE) procedures (U.S. Fish and Wildlife Service 1980c). HUEE can be used to convert fish and wildlife resource data to the dollar value of human use (both consumptive and nonconsumptive). Basically, this procedure utilizes biological supply as the limiting factor in the economic analysis. HUs are converted to estimates of animal populations, from which sustainable use is predicted. Changes in HUs will be reflected in the animal population that can be supported by the habitat, and changes in animal populations are directly related to changes in sustainable use. HUEE analyses can provide supplemental information for cost-benefit studies that address changes in the availability of wildlife for human use.

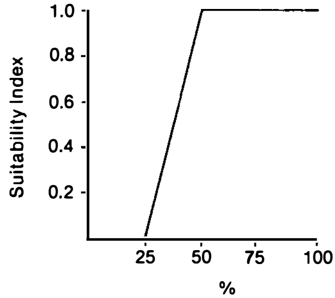
Implementation

Training

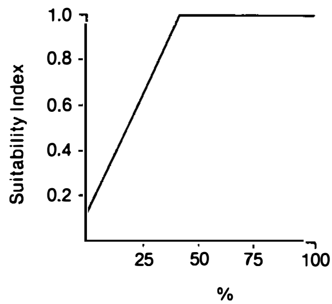
The success of any new technology depends on user understanding and acceptance. A nationwide training program was initiated to introduce users to the concepts of habitat evaluation techniques and to provide general information about the actual steps of a HEP evaluation. A one-week course has been offered at over 25 locations in the United States, and over 1,300 persons have received training in the use of HEP. Participants in the training courses have included representa-

Variable

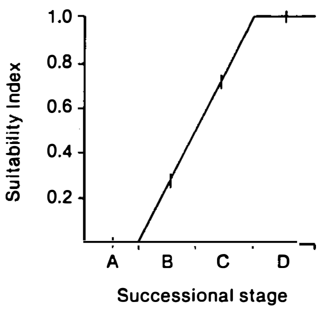
(V₁) % tree canopy closure



(V₂) % of overstory canopy closure comprised of fir or spruce



(V₃) Successional stage of stand
A) shrub-seedling
B) pole sapling
C) young
D) mature or old growth



(V₄) % of ground surface covered by downfall which is ≥ 7.6 cm (3 in.) in diameter

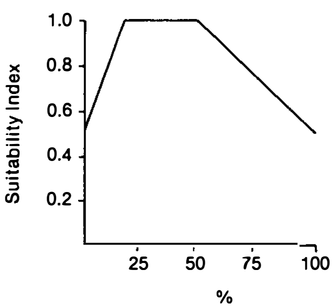


Figure 1. Suitability Index graphs for winter cover for the pine marten.

Table 3. Baseline and impact assessments using HEP-80 on hypothetical marten data.

	Variable	Field measurement	Suitability index value[a]	Habitat suitability index[b]	Area (acres)	Habitat units
Baseline	(V_1) Percentage tree canopy closure	85%	1.0	1.0	2,000	2,000
	(V_2) Percentage of overstory canopy comprised of fir or spruce	60%	1.0			
	(V_3) Successional stage of stand	old growth	1.0			
	(V_4) Percentage of ground surface covered by downfall	20%	1.0			
Alternative A	(V_1) Percentage tree canopy closure	30%	0.1	0.1	2,000	200
	(V_2) Percentage of overstory canopy comprised of fir or spruce	10%	0.3			
	(V_3) Successional stage of stand	pole/ sapling	0.3			
	(V_4) Percentage of ground surface covered by downfall	40%	1.0			

[a]From Suitability Index, Figure 1.
[b]Derived by use of Suitability Index Values and the model: HSI = $(V_1 + V_2 + V_3 + V_4)^{1/2}$.

tives from the COE, SCS, U.S. Bureau of Land Management, U.S. Forest Service, other Federal natural resource agencies, Federal and State departments of transportation, over 40 State fish and game agencies, private consultants, universities, and several foreign governments. Training also is available on the use of HEP software, site specific development and application of HSI models, and economic concepts as they relate to habitat.

Demonstration Projects

The FWS entered into a joint testing program with the COE and SCS to evaluate the institutional effectiveness and technical credibility of HEP-80. Four projects were selected by the COE and three by the SCS for initial evaluation. Although the final evaluation is not completed, the overall concensus to date is that HEP does supply useful and reasonable planning information. Strong points of HEP include: (1) HEP is a habitat based system; (2) the use of documented HSI models provides a record of the evaluation and a sound basis for recommendations; and (3) the use of documented models provides assistance in identifying limiting factors, thus providing a good diagnostic tool for management and impact assessment.

Certain weaknesses in HEP-80 also are being identified by the demonstration projects. The use of mechanistic models requires numerous measurements and mathematical calculations, and HSI models must be solved many times in a single study. Software is being developed to expedite computations, although early studies did not have access to computer software. The lack of adequate data in the literature for developing habitat models is a basic problem that will continue to plague habitat evaluation systems for years to come. However, the proper use of the literature and input from species experts, combined by standardized modelling techniques, have led to the development of models that users find reasonable and helpful.

Efficient Use of HEP

It is recognized that many environmental assessments do not require a detailed study, and portions of the HEP system can effectively be adapted and used for special purposes. Although detailed guidance cannot be provided in this paper, there are several adaptations that can simplify the application, thus reducing the time and costs of using HEP.

1. *Proper Setting of Study Objectives:* The appropriate definition of study objectives can greatly narrow data requirements. For example, if decision makers are concerned about only one or two featured species, there would be little need to evaluate the entire faunal community.
2. *Cover Type Selection:* Costs will decrease if only those cover types or habitats that are critical to important species or guilds (i.e., related to the managers' concerns and objectives) are evaluated. If some cover types are not significant, or comprise only a very small portion of the impacted area, they may not need to be considered in a small study.
3. *Species Selection:* If the impact will be on selected habitats, include only species or guilds that are important components of those cover types. Multicover type species are more difficult to model and evaluate than single cover type users.

If a choice exists between species, choose single cover type users in order to simplify data requirements and model calculations.

4. *Habitat Models:* Models can be selected or developed with a view toward using only a few variables. Habitat models also can be developed or modified for studies utilizing aerial photography in lieu of field data collection. Although there will be less resolution, valuable habitat information can be obtained from aerial photographs for use in early planning stages. Pettinger et al. (1979) concluded that some habitat variables could be accurately measured from infrared aerial photographs and that habitat quality could be estimated from those photographs.
5. *Target Years:* Impact assessments require the analysis of conditions at future years. These are referred to as target years in a HEP application and can be selected at any future point in time when study conditions are expected to change. In studies where a number of anticipated changes are identified, several target years may be used. One way to simplify the study is to determine the end point and compare the baseline conditions with those that are expected to occur once all changes have taken place (i.e., pre and post project conditions).
6. *Number of Alternatives:* The number of alternative futures with or futures without the project can be limited. In cases where only one component of the study will change, it may be unnecessary to completely reevaluate each project alternative. Simply separate the portion that is different from the others, and conduct the analysis on that part of the study.
7. *Sampling Reliability:* A common approach to impact studies is to obtain baseline data that are highly accurate with high confidence levels. However, when these data are projected for 100-year evaluations, the level of resolution in the 100-year projection is far below that of the baseline data. In such cases, the sampling design could require fewer field samples to reduce the time and costs for both data gathering and data analysis. The level of reliability used to determine baseline conditions should correspond to the level of resolution for the study as a whole.

Future of HEP

Problems identified in HEP applications will continue to be addressed as we work to improve habitat based evaluations. A shortage of good quality habitat models is recognized as a problem because habitat approaches are difficult to apply without reliable models. To meet this problem, habitat models are currently being published, and we intend to continue with these publications over the next several years. The primary short term thrust will be the testing and improvement of species habitat models; the COE and BR presently are assisting in this effort. We are investigating the possibility of using guilds to develop a community model (Short and Burnham 1982), and the use of multivariate statistical methods is a promising approach to a more quantitative definition of wildlife habitats (Capen 1981). The HEP accounting software is now available, and the development of software for building and applying HSI models is continuing, with assistance from the COE. Training will be continued, although at a reduced level of effort.

Summary

Fish and wildlife evaluation methods can take many approaches, and techniques based on animal numbers, human use, and habitat relationships are all successfully being used to influence land and water management decisions. A habitat-based method also is needed because habitat management is an important part of many State and Federal land management programs. Future conditions can be predicted by examining habitat variables. Legislative mandates and pressures from various groups provided the impetus for the FWS to develop HEP. During the past four years, HEP has been evaluated, refined, and published as part of the FWS Division of Ecological Services Manual series. A nationwide training program in the theory and use of HEP has trained over 1,300 people from more than 40 States. HEP currently is being used by ES, COE, SCS, State agencies, consultants, and others. The general lack of data quantifying the relationships between species and their habitats is a limitation to model development, but this problem is not unique to HEP. In order to help overcome this problem, methods and standards have been developed to produce useful species habitat models. Computer software is now available to expedite the use of HEP accounting procedures, and HSI software soon will be available. Once software and HSI models are readily available, we anticipate a further expansion in HEP use. Suggestions on improving HEP are appreciated.

References Cited

Adams, D. A. 1980. Wildlife habitat models as aids to impact evaluation. Environmental Professional 2: 253–262.

Allen, A. 1982. Habitat Suitability Index (HSI) model; Marten (*Martes americana*). FWS/OBS-82/10.11. USDI Fish and Wildlife Service, Washington, D.C.

Capen, D. E., ed. 1981. The use of multivariate statistics in studies of wildlife habitats. General Tech. Rept. RM-87. USDA Forest Service, Washington, D.C. 249 pp.

Crawford, J. E., and D. E. Lewis. 1978. U.S. Bureau of Land Management views: Wildlife and wilderness management on the public lands. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 362–367.

Daniel, C., and R. Lamaire. 1974. Evaluating effects of water resource developments on wildlife habitat. Wildl. Soc. Bull. 2(3): 114–118.

Ellis, J. A., J. M. Burroughs, M. J. Armbruster, D. L. Hallett, P. A. Korte, and T. S. Baskett. 1978. Results of testing four methods of habitat evaluation. Contract 14-16-0008-2014. Prepared by University of Missouri–Columbia for USDI Fish and Wildlife Service, Washington, D.C.

Ellis, J. A., J. N. Burroughs, M. J. Armbruster, D. L. Hallett, P. A. Korte, and T. S. Baskett. 1979. Appraising four field methods of terrestrial habitat evaluation. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 369–379.

Farmer, A. H. 1979. Development of mitigation alternatives: A process. Pages 327–330 *in* Proceedings: The mitigation symposium: A national workshop on mitigating losses of fish and wildlife habitats. General Technical Report RM-65. USDA Forest Service, Fort Collins, Colo.

Hardy, J. W. 1981. A survey of the habitat evaluation methods used by the U.S. Fish and Wildlife Service. USDI Fish and Wildlife Service, Office of Biological Services, Washington, D.C. Mimeo report. 10 pp.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. FWS/OBS-81/48. USDI Fish and Wildlife Service, Washington, D.C. 111 pp.

Joint Federal-State-Private Conservation Organization Committee. G. Hickman, chairman. 1974. Ecological planning and evaluation procedures. USDI Fish and Wildlife Service, Washington, D.C. 269 pp.

New England Research, Inc. 1980. Investigation of the relationship between land use and wildlife abundance. Contract Report, 80-62, V. U.S. Army Corps of Engineers, Ft. Belvoir, Va. 146 pp.

Pettinger, L. R., A. Farmer, and M. Schamberger. 1979. Quantitative wildlife habitat evaluation using high-altitude color infrared aerial photographs. Paper presented at the Pecora IV Symposium on Application of remote sensing data to wildlife management. 10–12 October 1978. Sioux Falls, S. Dakota. 11 pp.

Schamberger, M. 1979. Habitat evaluation. Water Spectrum 11(2): 26–34.

_____, and A. Farmer. 1978. The Habitat Evaluation Procedures: Their application in project planning and impact evaluation. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 274–283.

Schamberger, M. L., and H. E. Kumpf. 1980. Wetlands and wildlife values: A practical field approach to quantifying habitat values. Pages 37–46 *in* V. S. Kennedy, ed. Estuarine perspectives. Academic Press, N.Y.

Schamberger, M., C. Short, and A. Farmer. 1979. Evaluating wetlands as wildlife habitat. Pages 74–83 *in* P. E. Greeson, J. R. Clark, and J. E. Clark, eds. Wetlands functions and values: The state of our understanding. Amer. Water Resour. Assoc., Minneapolis, Minn.

Short, C., and M. Schamberger. 1979a. Evaluation of impacts on fish and wildlife habitat and development of mitigation measures. Pages 331–335 *in* Proceedings: The mitigation symposium: A national workshop on mitigating losses of fish and wildlife habitats. General Technical Report RM-65. USDA Forest Service, Fort Collins, Colo.

_____ . 1979b. Habitat analysis methodology as applied to plains riparian habitats. Pages 47–54 *in* Proceedings: 31st annual meeting, Forestry Committee, Great Plains Agricultural Council. 18–21 June 1979. Fort Collins, Colo.

Short, H. L., and K. P. Burnham. 1982. A technology for structuring, evaluating, and predicting impacts on wildlife communities. Special Scientific Report-Wildlife 244. USDI Fish and Wildlife Service, Washington, D.C. 34 pp.

U.S. Fish and Wildlife Service. 1976. Habitat Evaluation Procedures: For use by the Division of Ecological Services in evaluating water and related land resource development projects. Mimeo report. USDI Fish and Wildlife Service, Washington, D.C. 30 pp.

_____ . 1980a. Habitat as a basis for environmental assessments. 101 ESM. USDI Fish and Wildlife Service, Division of Ecological Services, Washington, D.C.

_____ . 1980b. Habitat Evaluation Procedures (HEP). ESM 102. USDI Fish and Wildlife Service, Division of Ecological Services, Washington, D.C.

_____ . 1980c. Human Use and Economic Evaluation (HUEE). 104 ESM. USDI Fish and Wildlife Service, Division of Ecological Services, Washington, D.C.

_____ . 1981. Standards for the development of Habitat Suitability Index models. 103 ESM. USDI Fish and Wildlife Service, Division of Ecological Services, Washington, D.C.

White, W. M., chairman. 1971. Action report: Conservation and enhancement of fish and wildlife in the national water resources program. U.S. Bureau of Sport Fisheries and Wildlife, Washington, D.C. 50 pp.

Evolution of the Colorado Division of Wildlife's Inventory System

Donald L. Schrupp
Colorado Division of Wildlife, Denver

Introduction

As a result of public pressures over the past decade, state and federal legislators have passed a number of laws in response to public concern for wildlife (Leopold 1978). Jahn (1978) emphasizes the opportunity that exists under today's legislation to address ecological considerations, rather than just economic considerations as was done in the past. He points out that it is extremely important for resource planners to employ a "four-step system—identification, delineation, maintenance, and management—" for "use in resource planning and evaluation to perpetuate critical areas and habitats essential to the populations of all fish and wildlife species." This paper outlines the evolutionary process in which the Colorado Division of Wildlife has been involved in addressing its habitat identification and delineation tasks in compliance with its charge under state and federal natural resource laws.

An Inventory Program in Support of the Strategic Plan

The Colorado Division of Wildlife's "Wildlife Inventory" originated in 1972 under a Planning Section program to prepare the *Strategy of Today, For Wildlife Tomorrow,* the Division's long-range management plan for Colorado wildlife (Colorado Division of Wildlife 1974). It was designed as a planning tool to facilitate data collection of wildlife population and distribution information for use in a supply and demand program to forecast future availability and use of wildlife resources. Supply side figures were calculated by mapping species distribution on AMS/USGS maps (1:250,000 scale) and associating population numbers with occupied ranges. The source for this information was Division of Wildlife conservation officers and regional biologists. To facilitate review of the map data in a statewide frame of reference, the maps were digitized under private contract to obtain tabular listings of habitat area and small-scale (1:500,000) computer-generated map overlays for each of 60 important species. The overlays for each species displayed habitat use in terms of three categories—overall range, winter range, and biological activity areas. The population numbers and habitat acreage figures were totaled from the tabular information for each species in order to determine the "supply" figure. The maps served to show where the "supplies" were located, allowing consideration to be focused on how resource management strategies may affect those supplies.

For aquatic resource evaluation, known fisheries-supporting streams and lakes were assigned code numbers and a survey form was completed and computerized for each. Information collected on the fisheries forms allowed the planners to determine resource availability, its general status, and, through a code number indexed to base maps, its location. In addition to its use in the preparation of the Division's long-range management plan, both the aquatic and terrestrial components of the Wildlife Inventory, with their map-based formats, proved useful as resource baselines for use in review of environmental impact statements and land-use plans. Applications were roughly balanced among: (1) inhouse planning uses for EIS review; (2) Federal government uses for Bureau of Land Management (BLM), U.S. Forest Service (USFS), and U.S. Fish and Wildlife Service (USFWS) management plans; and (3) uses by the private sector for ecological consulting applications. The 1972 wildlife inventory was updated for two-thirds of the terrestrial species in 1973 and used without further changes until 1974.

Inventory Baseline Applications to the Land-Use Program

In the fall of 1974, the state legislature passed the Colorado Land Use Bill, HB 1041, and the Division accelerated the Wildlife Inventory efforts to address new responsibilities. The Division's mandate under the bill was to furnish technical expertise to county governments in the identification of significant wildlife habitat. An ad hoc committee was formed at the Division to develop Guidelines for the Identification, Designation, and Administration of Wildlife Habitats and Shorelands (Hoover 1974). USDA Forest Service and USDI Bureau of Land Management resource managers participated in development of the Guidelines.

The Guidelines prescribed implementation of two concurrent program processes; one to identify terresterial wildlife resources, the other to identify the aquatic resources. The aquatic resource identification process used the aquatic component of the 1972 Wildlife Inventory database as a springboard for evaluating the importance of streams and lakes in each county. The identification process involved redistribution of 1972 survey sheets for each body of water in a county; review of these surveys with a county frame of reference (as opposed to a statewide perspective); update of information if necessary; and subsequent determination of a relative value to the county of each stream and lake. Stream and lake values for each fishery were calculated by summing points for variably weighted categories. These categories were: water quality, pool-riffle ratios, water temperatures and clarity, fish food supply, condition of fish, legal accessibility, aesthetic value, meander components, and potential for improvement. After determining individual stream and lake values, the fisheries were then placed into ten ranking levels by subtracting the lowest value from the highest value and dividing by ten to determine an index value for each fishery.

The terrestrial resource identification guidelines detailed a process whereby Division of Wildlife biologists would prepare maps and associated tabular information to describe wildlife habitats for a variety of species in each county. The 1972–1973 Wildlife Inventory baseline data was used in this process, but only after careful review and update of the earlier information. The update process involved transfer of the earlier baseline information to a larger scale map (1:126,720) in order to improve the resolution of the species distribution information during the update session. The basemap supplied ancillary information on cultural features, place names, topography, and political boundaries as well as a locational referencing grid. By using a more detailed map, the fieldmen's ability to relate field observations to the mapping of habitat use was greatly enhanced. These observations from Division of Wildlife field biologists were interpreted to create thematic maps to describe overall species range, seasonal use areas, and important breeding, feeding, and resting areas. The resulting map overlays were used to point out to county planners the variability to intraspecific habitat needs. Additionally, the process called for application of the multiple overlay map technique (McHarg 1966) to display and analyze the associative/accumulative aspect of species habitat selection and range overlap. After several counties worth of information were manually overlayed and analyzed, the benefits of using computerized map overlay technologies and the analytical capabilities of geographic information systems (GIS) became evident. Previous experience through a private contractor had suggested that an inhouse geographic information system, with data management and analysis by the user/biologist, would be preferable in situations requiring data input, archiving, retrieving, update, and analysis on a repetitive basis with an acceptable turnaround time. To develop computer programs having the aforementioned GIS capabilities, a cooperative agreement was made between the Colorado Division of Wildlife and Dr. Jack Gross of the Colorado Cooperative Wildlife Research Unit at Colorado State University. The resultant programs allowed for entry of map data in polygon form; computer storage of map-associated tabular information; archiving and retrieving data from magnetic tapes; display and analysis of the spatially related information; and subsequent output to hard copy devices, line-printers, and digital plotters. The original package of programs was completed in 1976. After the cooperative project, Dr. Gross began work for the U.S. Fish and Wildlife Service in development of their Systems Application Group Information System (SAGIS) and its resource evaluation programs. The geographic information systems developed by Dr. Gross and associates formed a common link between U.S. Fish and Wildlife Service Rapid Assessment Methodologies work (Western Energy and Land Use Team 1979) and the Division's Wildlife Inventory work. The Colorado Division of Wildlife has been able to benefit from a number of important geographic information system capabilities developed in conjunction with the Fish and Wildlife Service effort, most notably through use of the map analysis program, WINDOW (Bartholow 1981).

Geographic Information System—Capabilities, Content, and Applications

The geographic information system programs along with the Wildlife Inventory staff, the Wildlife Inventory database of seven years development, and the hardware to enter, archive, retrieve, and analyze wildlife population/distribution information comprise the Wildlife Resource Information System (WRIS). There are two people assigned directly to the Wildlife Inventory. They perform all the operations from data acquisition through delivery of finished map and tabular products to system users. This keeps the technical job requirements confined to the Wildlife Inventory staff in terms of data archiving, retrieval, and analysis. The Wildlife Inventory biologists supply support services to field biologists and conservation officers on a statewide basis in recording and disseminating wildlife resource information.

The hardware configuration for accessing Wildlife Resource Information System programs is identical to that utilized by the Division's four regional offices for doing their population dynamics modeling. The equipment used is a cathode ray tube, a refresh graphics computer terminal, an acoustic coupler for data transmission to remote computing sites, a flexible disc unit for local data capture, and a hard copy machine for making copies of information from the computer terminal's screen. The only additional piece of equipment necessary for map data entry is a device called a graphics tablet which allows one to create computer files of *x, y* coordinates from map unit boundaries. This is the distinguishing data format of geographic information systems. Two of four Division regional offices have this additional capacity for map data entry. The Wildlife Inventory staff operates two full data entry-analysis stations at their Denver headquarters. While most data entry currently is handled through the Denver staff, data review and analysis can be done in the regional offices. Furthermore, personnel in those regions with graphics tablets for map data entry are being trained in use of the computerized mapping programs as their job needs demand local data entry capabilities.

The geographic information system component of the WRIS handles most of the generic capabilities that geographic information systems perform on spatial data; geographic searches, variable scale displays, variable resolution data handling, areal calculation, simple statistical summaries, map compositing, simulation, and modeling (Tessar and Caron 1980). The data are thematically structured to display field-observed seasonal, functional, distributional variations in species use of habitats, with mapped areas grouped categorically; i.e., winter range, roost sites, active nests, inactive nests, production areas, leks, etc. The limitation to this approach is its dependency on either observable phenomena or interpretive projection of known occurrences to similar ecological locales. The key to this approach is professional judgement. The benefit is that this can generally be done without detailing the underlying determinants of habitat value for frequently studied and observed species. The alternative is modeling species distribution as the union of separately identified habitat components such as food, water, and cover. This method has gained practicality because GIS's have the capabilities to display and analyze the interrelationship of multiple components in an iterative mode. Models can be built, run, modified, and rerun within reasonable time frames. The limiting factors will continue to be: (1) the ability to identify significant factors in a species use of habitat; (2) the ability to define a way of measuring this factor on the ground to allow its display in the spatial domain (maps); and (3) the intensive time and labor it takes to create a database capable of graphically displaying the results of a habitat use model. Future inventory activities will undoubtedly be a hybrid of the two aforementioned habitat identification approaches. The Division has several projects under way to assess the benefits of using intensive resource mapping information within the Wildlife Resource Information System.

Ancillary Data Uses Within the Wildlife Resource Information System

Colorado LANDSAT Demonstration Project

The Division of Wildlife is currently working to evaluate land-use/land-cover information from LANDSAT and color-infrared aerial photography as a data level within the geographic information system for determining habitat availability and change. By combining locational information on habitat availability with species distributional information the Division can begin to evaluate the relative importance of habitat components within occupied ranges on a regional basis. Division work with LANDSAT is directed to develop inhouse capability to process satellite imagery and, further, to evaluate the utility of products derived from remote sensing.

The first step in this direction was agency participation in a technology transfer project sponsored by the National Aeronautics and Space Administration's (NASA) Western Regional Application Program through the NASA/Ames Research Center. Participants, in addition to those from NASA/Ames, came from the Pueblo County Planning Commission, the Colorado Division of Wildlife, the Colorado Department of Agriculture, the Colorado State Forest Service, and the Colorado Division of Planning–Department of Local Affairs (Campbell 1979). A 17-category land-use/land-cover classification of LANDSAT information was performed for Pueblo county (Hogan and Morse 1981). The LANDSAT-based classification was then compared to an air-photo-based land-use/land-cover map produced using the Colorado Land-Use Classification System (Burns 1976). A quantitative assessment has yet to be performed. Early review, however, suggests that better information content for natural resources planning was provided through the use of LANDSAT data.

Greater Prairie Chicken and Frontrange LANDSAT Projects

As an offshoot of the Pueblo county work, the Wildlife Inventory staff was enlisted as a facilitator in two other LANDSAT applications for mapping wildlife habitat components: the Greater Prairie Chicken Project (Miller and Schrupp 1981) and the Frontrange Range and Agricultural/Urban-Suburban Conversion Investigation Project. These projects are being carried out in cooperation with the Agronomy Department at Colorado State University. Analysis was performed on the LANDSAT data using the LANDSAT Mapping System (LMS) developed by Colorado State University's Earth Resources Department (Riggs and Maxwell 1977). The purpose of these studies is to evaluate LANDSAT as a tool for "mapping" habitat location and conversion and to develop the methodologies and technical expertise to perform computerized classifications inhouse. Additionally, the Division will investigate methods for making classification results compatible for use in its geographic information system. A number of similar efforts are being carried out in other federal and state agencies (Richason 1982).

Information System Data Use with Socioeconomic Information

Ultimately, systems for monitoring the use of our natural resources need to assess the interaction between the natural environment and the built environment. The Division of Wildlfie has furnished computerized map files of Wildlife Inventory information for use by the Executive Diector's Office of the Colorado Department of Natural Resources. They are using the files in GIS-based efforts to model the impact of energy development in northwest Colorado. In addition to resource impacts, socioeconomic impacts are being taken into consideration, and modeled, using a GIS (Colorado Department of Natural Resources 1981).

Database Management Systems Applications

Wildlife Resource Information System endeavors have indicated a number of instances where valuable resource information cannot be reduced to mapped units.

This is because there is seldom enough time, money, and labor available to map naturally diverse ecosystems in detail. In such cases, the importance of natural phenomena can be identified in terms of similar/dissimilar relationships, in a textual rather than graphical manner. Through the use of computer information systems, these associative relationships can be recorded and analyzed based on their presence or absence in relationship to specified conditions. For example, associations may be defined regarding which vegetation types are utilized by various species of wildlife, and then records may later be extracted to show which wildlife species may be found in a specific vegetation type.

EXIR-Based Data

The Division of Wildlife has utilized several textual database management systems in developing databases for a variety of applications. The first database, WILDATA, utilized the EXIR program (Watt 1976) from the University of Colorado to store, retrieve, update, and analyze textual data from the Colorado Latilong Distribution Studies for birds (Kingery and Graul 1978), mammals (Bissell 1978), and reptiles and amphibians (Langlois 1978). This database stores records of distribution and status for 634 species in Colorado based on one degree latitude by one degree longitude units. Habitat associations and relative seasonal abundances are also included (Bissell and Graul 1981).

The EXIR program was also used to store 180 items of information for each of 3,124 streams surveyed in Colorado. Descriptors for stream survey information relate to stream termini location, water chemistry, game and rough fish presence, and potential limiting factors on the stream's ability to support a fishery. A similar database is being planned for lake survey information.

FWS/MANAGE Based Data

Three developmental databases will utilize the program FWS/MANAGE (Shumate et al. 1981) to archive their records. The SCICOLL database will have three data sets relating to scientific collecting permit information; one for collector related information, one for fish collection records, and one for birds, mammals, reptiles, and amphibian collection records. The second FWS/MANAGE database, DOWCNHI, is being developed to show the Wildlife Resource Information System capabilities to store, archive, retrieve, and analyze Colorado Natural Heritage Inventory (CNHI) LCD Element records, based on Nature Conservancy data requirements. These LCD records denote the geographical location of unique elements of natural diversity. The geographic information system capability to archive and display CNHI topographic quadrangle related information has been developed and demonstrated.

The third FWS/MANAGE supported database is one being designed to accommodate information collected through a multiagency effort to develop the Colorado Wildlife Species Database (Porter et al. 1979). This program is a cooperative effort among the Colorado Division of Wildlife, the USDI Bureau of Land Management, Fish and Wildlife Service, Office of Surface Mining, and USDA Forest Service and Soil Conservation Service. The objective is to develop a comprehensive database for use in meeting fish and wildlife information needs for regulatory programs, land and water use planning and management, inventory and assessment, research, and education information transfer. As such, the program is the prototype application in a western state of the "Procedures for Describing Fish and Wildlife" developed by the Eastern Energy and Land Use Team, U.S. Fish and Wildlife Service (Du Brock et. al. 1981). The collection of information embodied in the "Procedures" is overseeen by a Steering Committee composed of representatives of the aforementioned agencies. Under the Steering Committee's direction, the "Procedures" were reviewed and modified to accommodate Colorado data needs related to existing agency programs (i.e., the Division's Latilong Studies and the USDA Forest Service's Wildlife Habitat Relationships Program [USDA Forest Service 1981]). Concurrently, species experts were identified and contacted regarding their interest in contracting to complete "Species Description Booklets" for one or more species. The booklets for use with the "Procedures for Describing Fish and Wildlife" are designed to facilitate computer entry of species background information, with the entries keyed to their corresponding references. Information categories relate to taxonomy, species status, distribution by natural and artificial units, habitat associations, food habits, environmental requirements, life history, management practices, and references. The objective of the "Procedures" is to provide a format and location for the assemblage of species information, to establish a baseline from which to update and improve, and to define datagaps en route to establishing a centralized source of information for use in wiser wildlife resource decision making.

Conclusion

Indeed, the Wildlife Inventory has "evolved" to its present form under the influences of its operating environment. It is a combination of people, tools, and methodologies assembled to address today's common resource related problems. At the same time, Wildlife Resource Information System programs have a built-in flexibility for data manipulation, making them adaptable for solving the unseen resource problems of tomorrow. After all, "environmental programs are not failures if the information provided by unexpected events is used to improve policies" (Hollings et. al. 1978).

The Wildlife Inventory has proven effective and timely in addressing wildlife data needs for (1) county land use planning; (2) long-range management planning at the Division, as well as at federal resource agencies; and (3) private sector responses to environmental regulations. Computerized mapping and textual information programs assist in delivering professional products for use early in the planning processes. This effectively shifts the Division's position from one of defense to one of offense. By doing this the Division has more opportunity to maximize consideration of, and benefits for, wildlife.

Literature Cited

Bartholow, J. 1981. SAGIS-WINDOW Documentation. U.S. Fish and Wildl. Serv., Western Energy and Land Use Team, Biol. Serv. Program, Fort. Collins, Colo. 40 pp.

Bissell, S. J., ed. 1978. Colorado mammal distribution latilong study. DOW-R-D-10-78. Colo. Div. of Wildl., Denver. iv + 20 pp.

———, and W. D. Graul. 1981. The latilong system of mapping wildlife distribution. Wildl. Soc. Bull. 9: 185–189.

Burns, R. 1976. The Colorado Land Use Classification System. Information Serv. Report No. 5. Colo. Dep. of Local Affairs, Denver. 25 pp.

Campbell, L. 1979. The Pueblo county, Colorado Landsat Demonstration Project. Div. of Planning, Colo. Dep. of Local Affairs, Denver. 12 pp.

Colorado Department of Natural Resources. 1981. The Colorado Resource Information System (CRIS); An overview of integrated mapping capabilities. Colo. Energy and Nat. Resour. Manage. Program, Executive Director's Office, Colo. Dep. of Nat. Resour., Denver. 43 pp.

Colorado Division of Wildlife. 1974. The strategy of today, for wildlife tomorrow. vol. I, A strategic plan for the comprehensive management of Colorado's wildlife resource. DOW-G-I-34. Colo. Div. of Wildl. Denver. 103 pp.

DuBrock, C. S., G. R. Gravatt, R. N. Rowse, D. N. Gladwin, C. T. Cushwa, and J. M. Brown. 1981. A procedure for describing fish and wildlife: coding instructions for Colorado. U.S. Fish and Wildl. Serv., Eastern Energy and Land Use Team, Biol. Serv. Program, Kearneysville, W.Va. 45 pp.

Hogan, C., and D. Morse. 1981. State of Colorado Landsat Demonstration Project, final report. Technicolor Graphic Services, Inc., NASA/Ames Research Center, Moffett Field, Ca. 61 pp.

Holling, C. S., ed. 1978. Adaptive environmental assessment and management. John Wiley and Sons, Chichester, England.

Hoover, R. L., ed. 1974. Guidelines for the identification, designation, administration of wildlife habitats and shorelands. Colo. Div. of Wildl. Denver. 105 pp.

Jahn, L. R. 1978. Habitat data needs for managing wildlife. Pages 5–12 *in* Classification, inventory, and analysis of fish and wildlife habitat, Proceedings of a National Symposium. FWS/OSB-78/76. U.S. Fish and Wildl. Serv., Biol. Serv. Program, Washington, D.C. 604 pp.

Kingery, H. E., and W. D. Graul, eds. 1978. Colorado bird distribution latilong study. Colo. Field Ornithol. and Colo. Div. of Wildl., Denver. vii + 58 pp.

Langlois, D., ed. 1978. Colorado reptile and amphibian distribution latilong study. DOW-R-D-11-78. Colo. Div. of Wildl., Denver. 17 pp.

Leopold, A. S. 1978. Wildlife in a prodigal society. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43: 5–10.

McHarg, I. L. 1966. Design with Nature. Amer. Mus. of Natur. Hist. Doubleday/Natural History Press, Garden City, N.Y. 197 pp.

Miller, G. C., and D. L. Schrupp. 1981. Characteristics of greater prairie chicken range in Colorado. *In* Proceedings of Prairie Grouse Technical Council Meeting. Nebr. Game and Parks Comm., Lincoln, Neb. In press.

Porter, R., D. Gladwin, and D. Schrupp. 1979. A cooperative study to implement and evaluate a statewide fish and wildlife species information system for Colorado. U.S. Fish and Wildl. Serv. Reg. 6 and Eastern Energy and Land Use Team, and Colo. Div. of Wildl., Denver. 13 pp.

Richason, B., Jr., ed. 1982. Remote sensing: An input to geographic information systems in the 1980's—Proceedings of the 7th Annual William T. Pecora Memorial Symposium. Amer. Soc. of Photogram., Falls Church, Va. 632 pp.

Riggs, R. L., and E. L. Maxwell. 1977. LMS User's Guide. Dep. of Earth Resour., Colorado State Univ., Fort Collins, Colo. 185 pp.

Shumate, K. J., R. P. Mehta, and J. C. Wilcott. 1981. FWS/MANAGE User's manual, Release 6.1.B. Western Energy and Land Use Team, U.S. Fish and Wildl. Serv., Biol. Serv. Program, Fort Collins, Colo. 33 pp + 3 appendices.

Tessar, P. A. and L. M. Caron. 1980. A legislator's guide to natural resource information systems. Nat. Conference of State Legislatures, Denver. 59 pp.

USDA Forest Service. 1981. Wildlife and fish habitat relationships. Range and Wildl. Manage., U.S. Dep. of Agric., Rocky Mtn. Reg., Denver. Vol. I, 886 pp.; Vol. II, 333 pp.

Watt, D. 1976. EXIR User's Manual. Inf. Sci./Genet. Resour. Program, Univ. of Colorado, Boulder. 315 pp.

Western Energy and Land Use Team. 1979. Proceedings of the Rapid Assessment Methodology: a demonstration conference—December 4–5, 1979. W/CRAM-79/W36. Western Energy and Land Use Team, U.S. Fish and Wildl. Serv., Biol. Serv. Program, Fort Collins, Colo. 91 pp.

The Forest Service Wildlife and Fish Habitat Relationships Program

Robert D. Nelson
Wildlife and Fisheries Staff, USDA Forest Service
Washington, D.C.

Hal Salwasser
Wildlife and Fisheries Staff, USDA Forest Service
Fort Collins, Colorado

Introduction

Congress has entrusted the USDA Forest Service (USFS) with managing habitats for the full variety of wildlife and fish resources on National Forests. This includes habitat protection for: (1) species sensitive to land management practices, (2) habitat improvement for population recovery of threatened and endangered species, (3) habitat enhancement for the production of game and commercial species such as deer and salmon, and (4) species of special interest to people. The mission is carried out nationally through the Forest and Rangelands Renewable Resources Planning Act (RPA) program and, locally, through Forest Land and Resource Management Plans under the National Forest Management Act (NFMA). Current and planned intensive use of forests and rangelands for timber, minerals, energy, water, livestock grazing, and recreation makes the wildlife and fish management job complex and difficult.

To fulfill the responsibilities for wildlife and fish habitat on lands managed for all resources, decision makers need specific and accurate information on the capabilities of land areas to produce wildlife and fish and the probable consequences of alternative management prescriptions for wildlife and fish and their habitats. Such information for more than a few species (e.g., deer, grouse, trout, and elk), let alone for all vertebrates on a forest, has not been readily nor efficiently available to biologists or decision makers. To fill this critical need, the Forest Service is organizing the pioneering work of Holbrook (1974) "Featured Species', Siderits and Radtke (1977) "Diversity", Patton (1978) "RUNWILD", Thomas (1979) "Wildlife Habitats in Managed Forests", Verner and Boss (1980) "California Wildlife and Their Habitats", U.S. Fish and Wildlife Service (USFWS 1981) "Habitat Suitability Indexes", and other similar efforts into the Wildlife and Fish Habitat Relationships (WFHR) Program. Nationally, the effort is the coordinated development of Regional, State, or Area WFHR programs that will integrate wildlife and fish population and habitat inventory with species-habitat relationships models, habitat evaluation procedures, and a research and monitoring program to develop, test, and refine species-habitat ecology knowledge and our procedures for evaluating habitat quality.

Goal

One hundred and ninety million acres (77-million ha) of national forest land and water are occupied by over 3,000 fish and wildlife species. These lands are administratively divided into 9 Regions and 2 Areas. The goal of each Regional Wildlife and Fish Habitat Relationships Program is to provide a systematic method for evaluating habitats for all fish and wildlife species so that they can be effectively considered in land and resource planning, projects that affect fish and wildlife habitat, and efforts to improve habitats for selected species. The management intent is to efficiently plan wildlife and fish habitat management to produce multiple-resource benefits. This paper presents the objectives, structure, administration, and progress of the Forest Service WFHR Program.

WFHR Objectives

Objectives for the WFHR Program derived directly from legal requirements and procedural needs at the project and National Forest levels. They are to:

1. Provide managers with the capability to predict wildlife and fish responses to habitat conditions and changes at both the community and selected species levels;
2. Make species-habitat relationshps information and analytical models available to managers in formats usable at all levels of resource decisions;
3. Implement application procedures that result in more efficient use of field and office time in inventory, analysis, planning, and monitoring;
4. Capitalize initially on existing local resource inventories, analytical models, research findings, and data management systems through better coordination within and outside the Forest Service;
5. Facilitate the evolution of integrated, multi-resource classifications, inventories, and analytical models; and
6. Provide a mechanism for identifying information needs and guiding research and development efforts to fill knowledge and technology gaps.

WFHR Program Organization

Resource Decision Needs

Resource management decisions rely upon data on land and resource conditions and capabilities, and upon analytical models that allow the prediction of future conditions, tradeoffs among resource outputs, and the ecological and economic costs and benefits of management alternatives. Land and resource data come from inventories and include information on such things as soils, vegetation types, size class of trees, stream class, water temperatures, snag density, standing volume of timber, etc. These data are increasingly being collected through integrated resource inventories so that all resource specialists will have a common resource data base.

Analytical models include timber yield tables, wildlife species-habitat relationships, cost/benefit models, population and habitat simulation models, optimization models for resource allocation and scheduling, and habitat evaluation procedures. Recently, both resource managers and scientists have been cooperating in the development of new inventories and analytical models.

The fundamental needs for information and analytical capabilities for wildlife and fish are:

1. Existing and potential habitat and population conditions and capabilities;

2. Models that relate species populations to different habitat conditions, especially those affected by anticipated management activities; and
3. Procedures that allow the integration of wildlife and fish with other important resources in analysis and planning of land production alternatives.

Components of a WFHR Program

Wildlife and fish habitat relationships is a relatively new term—it is not a new philosophy or approach to resource management. It is simply the organized application of the vast array of existing information and the development of new knowledge and procedures in a way that is useful in managing animals through management of their corresponding habitats. The philosophical basis of WFHR dates back to Joseph Grinnell and Aldo Leopold. Intertwined is the current state-of-the-art of ecosystem approaches to natural resource management and, in this case, an attempt to view wildlife and fish habitats from the animal community as well as the single species perspective. WFHR Regional programs incorporate four parts in doing this (Figure 1):

1. *Wildlife and fish habitat and population data: Inventory.* The resource data needed for management decisions and analytical models are gathered based on the objectives for a project or planning area. Population information is gathered cooperatively with State fish and wildlife agencies. These data are coordinated with, and we hope soon will be integrated into, multi-resource data acquisition and management systems. Each Region will develop its own wildlife and fish inventory system to include information on:

a. Species and habitat distribution, abundance, and conditions, and
b. Maps and a data base management system to provide ready access to the data.

Some national standardization will occur.

2. *Species-habitat relationships models: Wildlife and fish "yield tables."* The systematic organization of knowledge on the habitat relationships of all vertebrate species is essential for assessing the full array of wildlife and fish habitat capabilities and predicting species responses to management. This knowledge must be readily available to biologists in a usable format. It should include information on the habitat variables that resource management affects. Each Region's set of species-habitat relationships models will encompass:

a. A species taxonomic classification;
b. A habitat classification that allows use of other resource classifications and inventories;
c. Species ecology and life history information;
d. Species distribution maps;
e. Species-habitat relationships coefficients;
f. Special habitat quality criteria and management principles; and
g. A systematic way of managing this information to provide ready access by users.

Standards for these elements currently vary between Regions. Some National standardization will occur.

3. *Habitat evaluation procedures: Applications.* Evaluation procedures are the technologies and processes for applying data and analytical models to management decisions. Resource data and the species-habitat relationships models must be

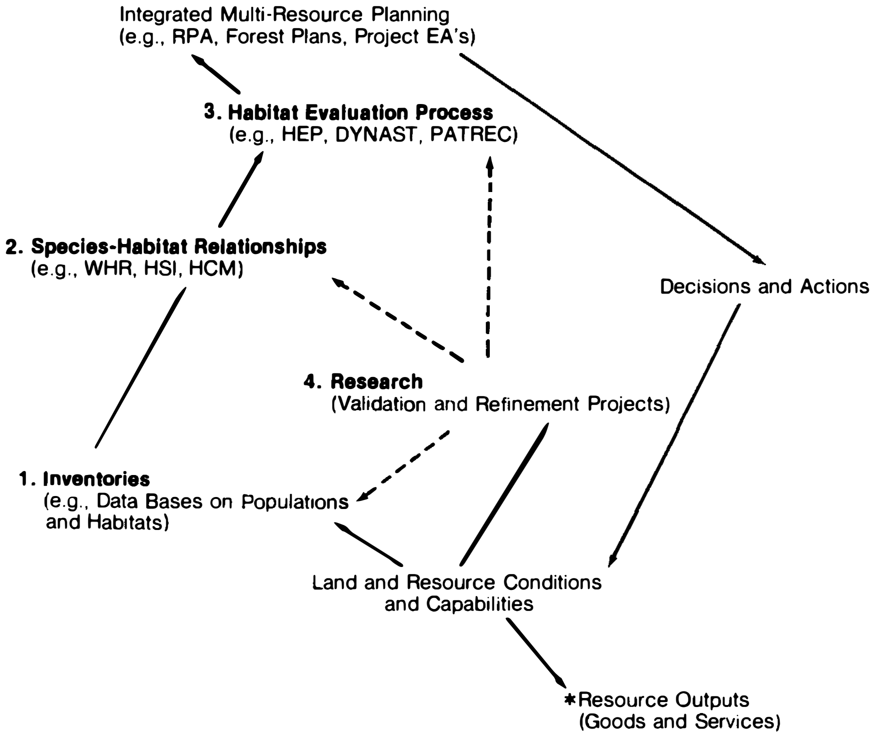


Figure 1. Relationships betweeen land resources, inventories, analytical models, habitat evaluation methods, research, and the multi-resource decision process. Each Regional, State, or Area Wildlife and Fish Habitat Relationship Program covers elements 1–4, and their linkages.

synthesized and interpreted in order to make valid assessments of wildlife and fish resources. Economic analyses must be included in the evaluations to show multi-resource costs and benefits. Each Region will develop and integrate these procedures into its planning processes, drawing upon appropriate methods:

a. Statistical models (e.g., regression, multivariate analysis),
b. Simulation models (e.g., DYNAST [Boyce 1980]),
c. Optimization models (e.g., FORPLAN),
d. Habitat evaluation models (e.g., HEP [USFWS 1980], PATREC [Russell et al. 1980], and
e. Economic analysis models.

4. *Research, Development and Monitoring: Validation and refinement.* Research projects will focus on the development, validation, and refinement of: (a) inventory technology and monitoring procedures, (b) species-habitat relationships models and basic ecology (stressing a systems approach to understanding how organisms function within wildland environments), (c) habitat evaluation procedures, and (d) information management procedures. Each Region, Station, and Area will develop

this effort in coordination with cooperating universities. Monitoring the responses of wildland ecosystems to management activities will be an important part of model validation.

The WFHR Approach to Habitat Classification

The Forest Service approach to wildlife and fish habitat classification labels habitats according to the dominant biological and/or physical attributes of sites (commonly the plant community and its developmental structure) and the specific environmental variables that are habitat resources for certain species.

The system employs a three level hierarchy:

1. Dominant attribute of site (e.g., dominant vegetation or aquatic system);
2. Structural or physical modifiers of the dominant attribute (used as a surrogate for successional stage);
3. Specific habitat elements present.

This design allows for habitat identification from other resource classifications and inventories, e.g., timber, range, and water, at the first two levels. It also provides for the recognition of habitat changes. For example, successional stages, would be identified by changes in dominant vegetation and the structural modifiers. An example of the system applied to a terrestrial habitat is:

1. Mixed Conifer (a series level vegetation descriptor)
2. Large tree ($>$ 24 inches [61 cm] dbh), dense canopy ($>$ 60 percent canopy closure)
3. Large, soft snags ($>$ 24 inches [61 cm] dbh, broken tops, bark off).

For aquatic habitats, an example might be:

1. Palustrine
2. Tall emergent plants ($>$ 22 inches [56 cm] height), moderate cover (40–60 percent vegetative cover)
3. Persistent surface water, muddy substrate

The dominant attribute and most structural or physical modifiers should be identifiable through remote sensing at scales less than 1:30,000. Identification of most specific habitat elements would require field work. Each Regional WFHR Program will specify the details of its habitat classification within the structure of this approach. Adherence to other resource classification standards and schemes at the Regional and State level is encouraged.

Relating Species to Habitats: Three Levels

The WFHR Program relates species to habitats at three levels of resolution to meet different management needs (Table 1): Level 1–Individual to habitat on a site for each life requisite at an instant in time; Level 2–Groups to habitats within an area for all life requisite needs over seasonal to annual periods; and Level 3–Populations within an area for potential habitat capacity over many years. Methods for relating species to habitats also differ between levels.

At Level 1, each wildlife and fish species is related to habitats according to life requisites. Dominant site attributes, as modified by structural or physical conditions, are rated for the probability that a species can find resources for reproduction, cover, and feeding in such a place: High (optimum or primary habitat), Medium (moderate or secondary habitat), and Low (poor or marginal habitat). It

Table 1. Utility of different levels of species-habitat relationships models in assessing wildlife or fish diversity and selected species habitat capability at project and land use plan levels

	Application			
Species-habitat relationships model resolution	Diversity analysis	Selected species populations	Project	Land use plan
Level 1: Individual to habitat on site, related to life requisites.	Good for potential community richness; intended use (alpha level)	Poor; inadequate detail in level 1 models	Good; intended use	Good; intended use
Level 2: Groups to habitats in an area, related to all life needs.	Poor if inadequate species coverage; Good, if management indicator species represent all others. (beta and gamma levels)	Good; intended use	Good; intended use	Poor, most plan areas are too large and complex for level 2 models. Use level 3 model.
Level 3: Populations to habitats in an area, related to range capability expressed in numbers of animals.	Poor if inadequate species coverage; Good if management indicator species represent all others (beta and gamma levels)	Good; intended use	Depends; most project areas are too small for whole populations; usually better to use level 2 models.	Good; intended use

is assumed that these ratings relate to the capability of the habitat to support relatively high, moderate, and low densities of the species. It does not imply that those densities will actually be achieved; other niche factors have much to do with actual animal numbers. Specific habitat elements are rated according to the degree to which the species relies upon the element for a life requisite: Essential (required for the species to be present), or Preferrable (the presence of the element is not required but it does enhance habitat value for the species). We believe that the habitat rating system would ideally be based on a probability of occurrence expression (it is more "testable"), but state-of-the-art knowledge only justifies qualitative ratings at this time.

The principal application of Level 1 species-habitat relationships models is the assessment of potential species richness and the relative values of different habitats for wildlife or fish communities. Level 1 models are, by design, a within-stand (alpha level) species and habitat diversity analytical tool. The Level 1 models also have application in "guilding" studies (see Short 1982) to determine the communities that might be present in habitats managed for indicator or featured species.

Species-habitat relationships models at Levels 2 and 3 are designed for analysis of selected species (management indicator or featured species) habitats. Level 2 models integrate the habitat variables that exist, or are predicted to exist, in an area (e.g., a watershed, stream reach, timber compartment, winter range), and rate their composite value for providing all life requisite needs for a group of individuals of the species (subpopulations). A variety of approaches are being developed, applied, and tested for Level 2 models, including Habitat Suitability Indexes (USFWS 1981), and Pattern Recognition (PATREC) (Russell et al. 1980).

Level 3 species-habitat relationships models address the problem of aggregating all habitats within one area (e.g., a National Forest or range of total population) in order to evaluate the existing and future capability (capacity) of the area to support a number of individuals. These models are necessary to determine minimum viable population numbers and their distribution, and the projected output of featured species populations. Because of the specific definitions for capability and suitability in Forest Service planning regulations (36 CFR 219), the Forest Service calls its Level 2 and 3 species-habitat relationships models Habitat Capability Models. Thomas et al. (1979), USFS (1980), and Hurley et al. (1982) give examples of preliminary Forest Service applications. Level 2 and 3 models can be used for between-habitat and overall diversity analysis (beta and gamma levels).

We recognize and encourage cooperative interagency work on all levels of species-habitat relationships modeling.

Special Habitat Quality Criteria

Some habitats are of such importance to a variety of wildlife or fish that it is appropriate to address them as a special habitat and establish condition (quality) standards for the entire animal community dependent on them. Examples are riparian areas, meadows, cliffs, and snags. Each Region is developing criteria for managing special habitats, e.g., Thomas (1979), and Hurley et al. (1981).

Application Procedures

The major purpose of the WFHR Program is to be more efficient in planning for wildlife and fish resources. This will happen through application of the species-habitat relationships models and special habitat quality criteria to management decisions at all levels, from projects to National Programs. Regions are developing application procedures and conducting training in them. Concepts and philosophies demonstrated by Holbrook (1974), Hall and Thomas (1979), Salwasser and Tappeiner (1981), and Mealey at al. (1982) are being implemented using WFHR products.

Research, Development and Monitoring: Validation and Refinement

Research has played a vital role in developing the WFHR Program. Research Project Leaders essentially started the program (Patton 1978, Thomas 1979, Verner and Boss 1980, DeGraaf et al. 1980, 1981, and DeGraaf and Rudis 1981). Research is continuing its developmental role, but is shifting to greater emphasis on model validation and refinement. The adoption of the WFHR Program by the Forest Service has resulted in an unprecedented close working relationship between research and management. The WFHR models constitute jointly-developed research and management hypotheses about wildlife and fish and their habitats. Managers use the hypotheses as "best current information," while research focuses on their refinement. Monitoring the responses of wildlife and fish and their habitats to forest management is vital to validation and improvement of our species-habitat relationships models. Systematic monitoring is to be achieved as part of NFMA Forest Plans.

Wildlife and Fish Habitat Relationships Program Implementation

In keeping with the Forest Service's tradition of decentralized decision making, the Wildlife and Fish Habitat Relationships Program will be accomplished by Regional (or Area) WFHR programs according to broadly structured National standards. The Regional WFHR Programs will be tailored to local (e.g., timber, range, fuels, and watershed management) resource programs to better meet the differing needs of cooperating agencies.

National Coordination

National coordination of the WFHR Program is accomplished through the National WFHR Steering Committee composed of: Deputy Director Fish and Wildlife Management—Program Leader, National Wildlife Ecologist—Wildlife Habitat Relationships Coordinator, National Fisheries Ecologist—Fish Habitat Relationships Coordinator, National Fish and Wildlife Program Planner—WFHR Administration, Forest Environment Research Director—Research Coordinator, Regional WFHR Coordinators, Wildlife and Fish Research Project Leaders, and others as deemed appropriate. The function of the Steering Committee is to develop program direction and insure that resources are available to meet program objectives. They will develop the standards essential for National RPA needs and maintain interagency coordination at the national level.

The committee met once in 1980 and once in 1981, and has established interagency communications. National goals are:

1982 Develop and implement National standards for Regional WFHR programs; and
Assist all Regions in implementing WFHR Program

1983 Complete and implement all parts of Regional WFHR Program; and
to Develop a systematic approach to application, validation, and refinement
1986 of WFHR Program elements

Regional Coordination

Each Region has a Steering Committee, which functions similar to the National Steering Committee. Regional steering committees include line officers and representatives of cooperating agencies. The work of developing and implementing Regional WFHR Programs is done by ad hoc technical task groups under the general direction of the Regional WFHR Coordinator. Management biologists, scientists, university personnel, and others as needed are involved in the technical work.

Progress and Summary

As of spring 1982, all Forest Service Regions have developed or are well along with the "first-generation" of Wildlife and Fish Habitat Relationships. Level 1 models are nearly completed and documented. These efforts vary in their construction, standards, and degree of cooperation, but all accomplish the same general goal: organization of pertinent knowledge in usable formats.

The National WFHR Steering Committee is developing direction for the "second generation" of products. This will increase National standardization, but still allow for Regional differences in use of computer software, cooperation with the various states, and other legitimate Regional differences. It will also emphasize the development, application, and testing of Level 2 and 3 Habitat Capability Models in forest management. Research will focus on validation of models and their refinement.

The aim of the WFHR Program will remain to provide a systematic and efficient way of evaluating habitats for all fish and wildlife species on the National Forests so they can be effectively considered in land and resource planning in projects that affect fish and wildlife and in projects designed to improve habitats for selected species.

Acknowledgements

We appreciate the review and comments on this manuscript provided by E. Schlatterer, W. Krohn, and C. Cushwa.

Literature Cited

Boyce, S. G. 1980. Management of forests for optimal benefits (DYNAST-OB). USDA For. Serv. Res. Pap. SE-204. Southeastern For. Exp. Sta., Asheville, N.C. 92 pp.

DeGraaf, R. M., G. M. Witman, J. W. Lanier, B. J. Hill, and J. M. Keniston. 1980. Forest habitat for birds of the northeast. USDA For. Serv. Northeastern For. Exp. Sta. and Eastern Region. 598 pp.

DeGraaf, R. M., and D. D. Rudis. 1981. Forest habitat for reptiles and amphibians of the northeast. USDA For. Serv. Northeastern For. Exp. Sta. and Eastern Region. R9-35-9-15-RRWL. 239 pp.

DeGraaf, R. M., G. M. Witman, and D. D. Rudis. 1981. Forest habitat for mammals of the northeast. USDA For. Serv. Northeastern For. Exp. Sta. and Eastern Region. R9-11-1-81-RRWL. 182 pp.

Hall, F. C. and J. W. Thomas. 1979. Silvicultural options. *In* J. W. Thomas, ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA For. Serv. Agric. Handbook No. 553. U.S. Dep. Agric., Washington, D.C. 512 pp.

Holbrook, H. L. 1974. A system for wildlife habitat management on southern National Forests. Wildl. Soc. Bull. 2(3): 119–123.

Hurley, J. F., S. R. Robertson, S. R. Brougher, and A. M. Palmer. 1981. Wildlife habitat capability models and habitat quality criteria for the western Sierra Nevada. USDA For. Serv. Stanislaus National Forest, Sonora, Calif. 56 pp.

Hurley, J. F., H. Salwasser, and K. Shimamoto. 1982. Wildlife habitat capability models and special habitat criteria. Cal-Neva. Trans. (Western Section, The Wildl. Soc.) In press.

Mealey, S. P., J. Lipscomb, and K. N. Johnson. 1982. Solving the dispersion problem in forest planning. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 47: 142–153.

Patton, D. R. 1978. RUNWILD: A storage and retrieval system for wildlife habitat information. USDA For. Serv. Gen. Tech. Rep. RM-51. Rocky Mtn. For. and Range Exp. Sta., Fort Collins, Colo. 8 pp.

Russell, K. R., G. L. Williams, B. A. Hughes, and D. S. Wadsworth. 1980. WILDMIS—a wildlife mitigation and management planning system—demonstrated on oil shale development. Colo. Coop. Wildl. Res. Unit, Colorado State Univ., Fort Collins, Colo. 152 pp.

Salwasser, H., and J. C. Tappeiner II. 1981. An ecosystem approach to integrated timber

and wildlife habitat management. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46: 473–487.
Short, H. L. 1982. Development and use of a habitat gradient model to evaluate wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 47: 57–72.
Siderits, K., and R. E. Radtke. 1977. Enhancing forest wildlife habitat through diversity. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 42: 425–433.
Thomas, J. W. ed. 1979. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA For. Serv. Agric. Handbook No. 553. U.S. Dep. Agric., Washington, D.C. 512 pp.
——, H. Black, Jr., R. J. Scherzinger, and R. J. Pedersen. 1979. Deer and Elk. *In* J. W. Thomas, ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. USDA For. Serv. Agric. Handbook No. 553. U.S. Dep. Agric., Washington, D.C. 512 pp.
USFS. 1980. Wildlife habitat management handbook. FSH 2609.23R: R-8. USDA For. Serv., Atlanta, GA.
USFWS. 1980. Habitat evaluation procedures. USDI Fish and Wildl. Serv. 102 ESM. Div. Ecol. Serv., Washington, D.C.
——. 1981. Standards for the development of habitat suitability index models. USDI Fish and Wildl. Serv. 103 ESM. Div. Ecol. Serv., Washington, D.C.
Verner, J., and A. S. Boss. 1980. California wildlife and their habitats: Western Sierra Nevada. USDA For. Serv. Gen. Tech. Rep. PSW-37. Pacific Southwest For. and Range Exp. Sta., Berkeley, Calif. 439 pp.

Closing Remarks

Hal Salwasser and William B. Krohn

At the 1979 North American, Pete Petoskey concluded a special session on habitat assessment by stressing the needs for coordinated development and progress toward common approaches to wildlife habitat assessments. The preceding papers are, in part, a progress report on the effort. Jack Thomas laid out the perspective on needs and approaches, emphasizing the requirements of recent environmental legislation, and identifying two of the predominant methodologies, Habitat Evaluation Procedures (HEP) and Wildlife and Fish Habitat Relationships (WFHR), as evolving tools to meet the needs for evaluating selected animal species and animal community habitats. There are many variations on the theme of species-habitat relationships. Perhaps the key point in Thomas's paper is the need to put our state-of-the-art knowledge into resource management decisions made under risk and uncertainty. To play the game of planning land and water resource management for future wildlife and fish populations, one must have some tools. The remainder of the session displayed some of those tools and their applications.

Farmer et al. offered a set of assumptions and limitations for species-habitat relationships models used in planning. It is an excellent starting point for the much needed development of a theoretical framework for the discipline. Short presented an approach for constructing and applying such models to assessments of species richness changes under anticipated management. The whole area of species groupings, called guilding by some, is a fertile field for new theoretical developments and practical applications. Inkley and Anderson have developed a mechanism for relating species to habitats at a very broad level. Perhaps their contribution indicates an avenue for hierarchical habitat classification.

Seitz et al., in comparing habitat evaluation approaches, showed there remain problems in standard procedures for validation and repeatability in applying models. One of the major difficulties is that models designed to estimate or correlate with animal densities cannot be efficiently tested because we cannot measure densities easily. Lancia et al. showed a way around that problem by basing the model on probability of occurrence and the test on frequency of occurrence. Calibration of species-habitat relationships models to real situations needs major attention.

Matulich et al., Sheppard et al., and Mealey et al. all showed applications of habitat models to planning problems. Most significant in all three is the attempt to integrate species-habitat relationships into complex, multi-resource planning efforts. This is obviously what needs to be accomplished to get wildlife and fish more effectively into the planning game. We have seen only the beginning of such complicated applications.

Many agencies are establishing programs to manage their knowledge and the procedures needed for efficient planning. Schamberger and Krohn reported on the increasing implementation of HEP, and especially the habitat suitability indexes, as a good tool in evaluating habitats for selected species. Shrupp presented the Colorado Wildlife Resource Information System, perhaps the most comprehensive State system for population and habitat inventory and planning tools. In the final paper, Nelson and Salwasser reported on the U.S. Forest Service's Wildlife and Fish Habitat Relationships program for efficiently linking habitat inventory to planning for wildlife and fish outputs. The WFHR system employs many of the methodologies and procedures presented in this session in an agency-wide application to project and National Forest planning.

In summary, this session identified the status of the technology, remaining problems, and possible solutions to problems. Habitat assessments must be driven by the specific objectives of a particular decision. Those objectives determine the necessary inventory and the needed reliability of assessing current and future wildlife and fish outputs. Most importantly, there must be a mechanism for integrating the assessments into the decision process. As Jack Thomas has stated elsewhere, "to those who say it is too soon to develop and apply these tools, there are only two choices: too soon, and too late." Beyond a recognition of the vital need to be "in the game," some critical tasks remain:

1. Develop and verify a sound theoretical foundation for habitat assessment technology.
2. Develop ecologically valid procedures for dealing with concepts like indicator species, guilding, and habitat capability/suitability.
3. Empirically validate models and calibrate model outputs to real world situations.
4. Develop and refine procedures for applying the technology in the complex situations in which wildlife and fish habitats are managed.
5. Continue the ongoing efforts in interagency cooperation and coordination in the evolving habitat assessment field.

Formal Education—Resource Career Development Relationships

Chairman:
THOMAS S. BASKETT
Leader
Missouri Cooperative Wildlife Research Unit
University of Missouri, Columbia
Cochairman:
JAMES A. TIMMERMAN
Executive Director
South Carolina Wildlife and Marine Resources Department
Columbia

New Directions in Career Preparation: The Campus Connection

David T. Hoopes
R. W. Beck and Associates, Seattle, Washington

Prologue

During the last 10 years or so, I have had cause to shift my career from the public to the private sector where I have worked both independently and for an established firm involved in the development of hydroelectric power. Along the way I have had the opportunity and pleasure of teaching three or four courses in ecology and environmental science at the undergraduate level.

Having run the gamut of research, resource management, teaching, and resource development, I believe I have gained some insight as to new directions education and professionalism need to take if resource managers and administrators are to effectively cope with the challenges of the 1980s and beyond.

Changing Times; Changing Emphasis

Certain trends or shifts in wildlife and fishery management emphasis have developed during the last 10 to 20 years in response to an expanding group of interrelated management problems. Chief among these are:

1. The growing number of conflicts in resource use, in which one or more resource or social value becomes diminished as a consequence of some form of development.
2. The loss or alteration of fish and wildlife habitat resulting from conflicts in resource use and the concomitant reduction in carrying capacity for desired species.
3. A broadening public awareness and interest in non-economic resource values such as threatened and endangered species.

My own experience leads me to believe we need a more holistic approach to education in general with an attendant regard for improving decision-making skills and developing a more creative basis for problem solving.

In our society, the college or university campus has traditionally served as the connection between aspiring young professionals and the careers they wish to pursue. Recently, however, I have begun to question whether we might be narrowing future career development by not providing undergraduates with an education better suited to a twentieth, or even twenty-first, century resource manager.

Future career opportunities for recent graduates with baccalaureate degrees in fish or wildlife management may no longer be as plentiful in the more traditional areas of public sector employment. Inflation, coupled with a general redirection of resource priorities by the current Federal Administration, has put the economic bite on many State and Federal resource agencies, resulting in reduced operating funds and lowered personnel ceilings.

College graduates must be prepared to explore a wider range of possible career opportunities in both the public and private sectors if they are to find positions in their chosen profession during the years ahead. Taking advantage of such opportunities will require a more diversified educational background that not only includes a thorough grounding in recognized areas of fundamental science, but that also incorporates areas of study and skills relevant to resource management and administration as approached from both the public and private sectors. Wildlife and fishery managers, dealing as they do with both quantitative and qualitative concepts, have become more and more involved with the management of people, and in particular the conflicting desires and needs of often quite disparate groups of individuals. Future training must include courses in "people management" if wildlife and fishery managers are to be effective.

Subject Areas Requiring Emphasis

The need for further research in fields not traditionally thought of as falling within the purview of fish and wildlife managers, such as economics, sociology, and psychology has been noted by Sanderson et al. (1979). Sanderson and his colleagues identify a critical area in pointing out that the transfer of research information to resource managers has not been effective. We must recognize that research results are practically valueless if the information acquired is not interpreted and transmitted to decision makers and administrators during the development and implementation of critical management plans and regulations. Professional training in communication skills is necessary to ensure that the quick decisions demanded by many management and land-use situations are based on the most recent research data available.

Moyle et al. (1979) have noted that biologists are often responsible for developing management plans, the objectives of which are essentially economic. Just as legislators sometimes fail to perceive the biological consequences of legislation and judges the impacts of their legal decisions, so do biologists frequently not have a good grasp of the economic consequences of their actions. Furthermore, when forced to evaluate resources that do not lend themselves to valuation within a market-oriented economic system, wildlife and fishery managers have fallen woefully short of making a case for external benefits and collective goods. Basically, environmental economics is the study of the unintended consequences associated with some choice of action. It is high time we, as resource managers and the teachers of resource managers, realize the importance of including the study of economics in any natural resource curriculum. In response to this need, a growing number of institutions are including such courses as prerequisites in their degree programs and this trend should be encouraged.

More and more, resource managers are confronted with the interpretation and application of a growing body of regulatory and environmental law. Greater numbers of fish and wildlife biologists in the private sector are being asked by corporations and businesses to assist them in complying with environmental regulations and permit or licensing requirements. Many of these regulations and requirements pertain to fish and wildlife resources.

Resolution of problems involving environmental impacts on fish and wildlife as the consequence of development frequently involves a considerable amount of coordination and negotiation among regulatory agencies and special interest groups, often far beyond that merely required to reach a "biological" solution. A sensitivity to the objectives and allegiances of other parties and individuals involved in the resolution of any problem will contribute markedly to successfully concluding negotiations.

Too often we unwittingly polarize relatively simple issues by forgetting that other interests may be as legitimate as our own. Resource managers would do well to occasionally adopt a resource user's outlook and vice versa. Such abilities can be enhanced at the undergraduate level by requiring more courses in law, ethics, political science and in the fields of sociology and psychology.

Teaching Attitudes Also Need Changing

Changing times require a critical examination of our undergraduate teaching methodology as well. While the important role universities play as centers of research, particularly at the graduate level, is well recognized (Weller et al. 1979), not much attention has been given as to whether undergraduate training still adequately prepares entry level fishery and wildlife managers for the variety of challenges they must now confront and deal with on a daily basis.

On-the-job responsibilities may range from reviewing the adequacy of an environmental impact statement to negotiating instream flows with other agencies and a public utility district. While basic research provides vital support to a habitat evaluation or instream flow negotiation, the ability to successfully apply that research does not emerge from a lab tray.

Thus, the question becomes one of preparing students to fill both roles. Just as we now realize that a more holistic approach to resource management is required to successfully counter the collective impact of an ever-growing number of environmental perturbations, so must we recognize the need to diversify our educational and informational backgrounds to meet these new challenges.

Our educational system rests, for the most part, on the concept that the technical aspects of the subject are of prime importance. Students progress through sequences of education devised by people of particular expertise. As they progress, they are expected to acquire this expertise. Those that do, graduate; the remainder are marked as failures.

To be relevant to real-life situations, course content and approaches must be issue oriented. We need to invoke the process of learning rather than the transmission of tradition. For example, the theory of plate tectonics may be summed up in a single sentence, as John McPhee has so beautifully done by saying, "The summit of Mt. Everest is marine limestone" (McPhee 1981). If we have our students understand the process, the facts can be acquired as needed. This approach also lessens the likelihood of our passing along invalid information from generation to generation.

Options in Career Preparation

Obviously, no student wishing to graduate with a bachelor's degree in four years can hope to master all the skills I have suggested as useful to those seeking a career as fish or wildlife managers. The concept of offering either a management or research undergraduate option in the fish and wildlife curriculum has been adopted by at least one university (University of Alaska) as one approach to solving the dilemma of career orientation.

This choice at the undergraduate level offers several advantages. By concentrating on foundation courses, students become well grounded in basic principles of population ecology, animal behavior, and population dynamics as well as fundamental courses in other sciences, mathematics and data processing, and interpretive skills. Those students desiring research-oriented studies, perhaps leading to further work at the graduate level, would be afforded the opportunity to explore more advanced courses in such subjects as genetics, physiology, and chemistry. Management-oriented students would follow basic courses with a wider range of studies in fields more related to resource management.

The typical technique courses would be abbreviated to a study of principles involved in their selection and use. Techniques change and the particular aptitudes or procedures required at any one time are usually readily attainable prior to or during the period they are needed. The utility of learning field methodologies leading to the relatively rapid assessment of habitat values (HEP and IFG methodologies) may, however, constitute an important exception to this generality.

With technique courses reduced to a minimum, more time would become available to broaden each student's educational foundation. Courses in land use planning, resource administration, environmental law, and related subjects will provide future managers with the skills required to integrate fish and wildlife management into an overall system directed toward fostering environmental and cultural values while encouraging those developments that serve the best interests of our Nation's citizens.

Additional measures are currently being taken to ensure students receive an educational background tailored to meet both individual academic requirements and professional goals. The judicious use of restricted electives can help achieve exposure to academic areas not falling within the confines of a required curriculum. Another means of assisting students to evaluate and select courses best suited to their needs lies in the area of student advisement. Enlightened advisors can use the curriculum to help each student realize her or his own aspirations by building on that student's uniqueness as an individual. A combination of required and elective courses can provide the materials needed to shape the best possible program for meeting each student's particular needs. A sensitive advisement program coupled with a selection of pertinent electives can prepare students for the new directions in career emphasis already noted above.

The Question of Professional Advocacy

Our adaptation to present and future fish and wildlife management needs must also be implemented at the professional level. Both practitioners and professors of fish and wildlife management have long maintained that professionalism generally precludes adopting a position of advocacy. The public expression of personal opinions, no matter how well substantiated, regarding actions adverse to fish and wildlife resources is often discouraged by departmental policy at both the Federal and State levels. The excuse most frequently given is that such expression is "unprofessional" and that, somehow, professionalism must be equated with a detached, impersonal viewpoint that can never enjoy expression outside "official" channels. The private sector is not without its aura of censure as well. In this instance, it is most often the corporate image or client relationship that may be considered threatened.

The time has come for wildlife and fishery managers to dispel this archaic concept and to take active roles as responsible advocates for those concepts and values we hold as vital to the future well-being of both the natural resources under our stewardship and the publics we serve.

The knowledge that species and ecosystems are suffering perturbations resulting in depletion, degradation, or destruction is well known to those of us closely associated with resource management. We also understand in broad terms the importance of maintaining ecosystems and their component parts and the steps necessary to achieve such objectives. We have not, however, effectively communicated this knowledge and a sense of its importance to enough decision makers to achieve the courses of action we deem desirable.

The goal, then, is to impart our knowledge and understanding to those who make or influence decisions having bearing on natural resource management. This vital need has been clearly articulated previously by others and nicely summarized by Munro (1979).

By advocacy, I do not mean irresponsible and uninformed opposition to projects or programs perceived as threats without thorough study of their possible consequences and alternatives. Advocates must learn the most effective methods of disseminating information and encouraging understanding among those agencies, political groups, and private factions that will influence the final course of action or proposal outcome.

Chances of success will be enhanced greatly if fish and wildlife managers and administrators possess skills in political analysis, resource policy development, the regulatory and legislative process, and environmental law. Knowledge from these fields can be applied when constructing a cohesive and effective case to support management decisions and goals. The possibility of advocacy as a profession seems to be completely overlooked, yet the field of environmental law as well as numerous national and regional advocacy groups offer possible employment opportunities. Above all, we need to learn to think like resource managers, which also requires learning to think like resource users.

I personally believe it is incumbent upon every professional fish and wildlife manager to become a responsible advocate of those values and actions generally recognized by the profession as necessary to maintain a high standard of environmental quality. Rest assured that civil engineers, foresters, ranchers, mining engineers, and real estate developers have no hesitation when it comes to advocating their particular projects or objectives! We can be equally as effective if we begin now by training future fish and wildlife managers in advocacy-oriented skills. It would appear that to actively advocate those values and courses of action that will ensure this and future generations a quality environment in which to live not only represents a logical extension of our professional responsibility, but constitutes an undeniable moral obligation as well.

Epilogue

The realization by growing numbers of people that natural resources are not without bounds, coupled with an increasing profusion of conflicts over often incompatible resource uses, presents career professionals in resource management and administration with the ultimate challenge. Can we stem the tide of thoughtless resource misuse and environmental degradation? Can we reverse this trend and begin to truly mitigate adverse impacts or even enhance our natural environment through more careful project planning and development? Or will we only become the educated scribes that observe and record, in minute detail, the misuse and destruction of countless acres of wildland habitat, the extinction of thousands of plant and animal species and, perhaps, even the eventual demise of our own species as well?

The challenge is very real and must be approached on many fronts to be met successfully. No more important arena exists, however, than our institutions of higher education where future professional resource managers prepare for employment by first acquiring their educational foundations.

All too often in the past we have promoted our best biologists to positions of managerial and administrative responsibility as the reward for their biological contributions and to insure a decent compensation for their work. Some have made good administrators and decision makers, many have not, while the remainder have done nothing more than to maintain the status quo.

We can no longer continue to fill top resource management positions in such a haphazard fashion. Preparing to become effective fishery and wildlife managers now necessitates a background diversified enough to at least provide a minimum understanding of other, often competing, professions and resource uses. We must give more thought to the training and background of those responsible for decisions affecting both the development and the management of our Nation's vast array of natural resources.

The process of formal education must not simply prepare graduating students to fill entry level positions, it must also equip them with some knowledge of a much broader range of skills than heretofore imagined that will continue to provide support throughout their careers. Education must maintain a critical balance between the practical aspects of present need and opportunity and the more abstract development of the wisdom that will govern how and when we apply the knowledge we have acquired.

Acknowledgements

I am indebted to Drs. T. S. Baskett, E. K. Fritzell and J. D. Hall for their critical review of this manuscript prior to going to print. Their constructive comments have led to changes in the original manuscript that I hope reduce chances for misinterpretation. The conclusions, of course, remain solely my own.

References Cited

McPhee, J. 1981. Basin and range. Farrar, Straus & Giroux, New York, N.Y. 216 pp.

Moyle, P. B., R. E. Andrews, R. M. Jenkins, R. L. Noble, S. B. Saila, and W. O. Wick. 1979. Research needs in fisheries. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 176–187.

Munro, D. A. 1979. A strategy for the conservation of wild living resources. Trans. N. Amer. Wild. and Natur. Resour. Conf. 44: 19–25.

Sanderson, G. C., E. D. Ables, R. D. Sparrowe, J. R. Grieb, L. D. Harris, and A. N. Moen. 1979. Research needs in wildlife. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 166–175.

Weller, M. W., N. R. Kevern, T. J. Peterle, D. R. Progulske, J. G. Teer, and R. A. Tubb. 1979. Role of universities in fish and wildlife research. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44: 209–216.

Teaching Vertebrate Pest Control: A Challenge to Wildlife Professionals

Robert M. Timm
Department of Forestry, Fisheries and Wildlife
University of Nebraska, Lincoln

Vertebrate pest control deals with wild animals that create health hazards, damage resources, or become a general nuisance. Some people prefer the terms "wildlife damage control" or "animal damage control" because they focus on controlling damage rather than controlling animals. This is an important principle. Vertebrate animals that cause damage often have many positive values. In dealing with these situations our objective should always be to reduce or prevent damage; this does not necessarily require the killing of animals. I use the term "vertebrate pest control" because I believe it is less ambiguous than "damage control." When I call an animal a "pest," I do so realizing this is a subjective term, and another person may have a different opinion.

A Neglected Area

The ecology and control of vertebrate pests remains one of the most neglected fields within the academic discipline of wildlife biology, despite a growing public interest in recent years. The number of teachers and researchers who have expertise or interest in vertebrate control is relatively small. A recent survey of more than 450 university and college wildlife faculty members in the United States and Canada found only 41 with an emphasis in this area versus 114 who indicated expertise in endangered species (Blaskiewicz and Kenny 1978). This is not to say there is too much emphasis in endangered species; rather, vertebrate pest control is far under-represented in wildlife curricula, given the need and significance of the problem to agriculture, wildlife management, public health, urban areas, and natural resources conservation.

Students in wildlife biology, agriculture, and related areas are expressing greater interest in vertebrate pest problems and are seeking training in this field (Howard 1974). This is particularly the case in land-grant universities. Some schools offer a major or an emphasis in "pest management" but completely neglect vertebrate animals. There are relatively few undergraduate courses in vertebrate pest control, although more are taught today than 15 years ago. Although various universities have one or more vertebrate pest control courses, few offer undergraduate or graduate training with emphasis in this area. Those that do include the University of California at Davis, Bowling Green State University in Ohio, and Colorado State University.

Vertebrate pest control has been neglected for a number of reasons, including:

1. The view that control of vertebrate pests and pest damage does not require any particular training. Actually, vertebrate control is applied ecology and frequently deals with fundamental, yet challenging, aspects of population regulation and animal behavior (Howard 1962). At times, vertebrate control activities necessarily involve reducing pest populations to more manageable levels. But

both the public and many wildlife professionals have done a disservice to this field by equating it with the indiscriminate killing of wildlife.

2. The low job demand for persons trained in this area. In the past, government (city, county, state, and federal) has dominated operational work in much of this field. Government tends to hire beginning-level biologists who receive on-the-job training to become vertebrate pest specialists. Because of government domination in field rodent and predator control, for example, private enterprise has never gained a large foothold. Private pest control companies conduct rodent control, and to a lesser degree, bird control in and around structures. A major part of their business, however, is insect control, so they often hire entomologists and train them to do vertebrate control. The same situation is true for the public health field, where most sanitarians employed are trained in vector control, thus favoring the entomology student.
3. Lack of recognition by administrators and others who make curriculum decisions of the need to teach vertebrate pest control. Wildlife faculty generally have shown little interest in vertebrate control. Zoologists have often felt that involvement with such applied research problems was detrimental to their careers (Howard 1962). By default, entomologists and others not trained in wildlife biology often have been forced to deal with vertebrate pest control problems in addition to their own areas of specialization (Stone and Hood 1979).
4. Reluctance by college advisors to encourage students to enter vertebrate pest control (Eadie et al. 1961). Possibly this is because advisors themselves have not felt competent or comfortable with the subject matter. Wildlife faculty generally are accustomed to management for production of game and desirable nongame animals, rather than control of vertebrate pests or pest damage (Swanson 1970). Students may feel this subject area carries a stigma because it sometimes involves working with species that are not well-liked (e.g., Norway rats), or because the field itself has been held in poor esteem by "environmentalists" and others. This is unfortunate; every wildlife manager, sanitarian, entomologist, and agricultural pest control specialist should have at least one good course in vertebrate pest control.
5. Difficulty in obtaining research funds, which often complement teaching efforts and faculty development, for vertebrate pest studies. At the federal level, vertebrate pest responsibilities lie in the U.S. Fish and Wildlife Service of the Department of the Interior (USDI) rather than in the Department of Agriculture, which supports a good deal of research in colleges of agriculture. Although the Fish and Wildlife Service has done excellent animal damage control research, funds have not been adequate to allow research except within a few high-priority areas. In general, wildlife damage control research within governmental agencies is "grossly inadequate, and for most practical purposes, nonexistent" (Miller 1982). Grants from USDI to support vertebrate pest research within universities and colleges have not been abundant. Even in instances where funds could be obtained, vertebrate pest research often has not been prestigious or even popular with faculty colleagues or administrators.

Perhaps as a result of this lack of emphasis, no adequate college textbook in vertebrate pest control is available. Instructors teaching such courses have had to prepare their own materials and to rely on proceedings of vertebrate pest symposia. In general, written information in this field is widely scattered among various journals and other publications. Since control recommendations for particular species vary according to locality and situation, and because methods change as new techniques are developed, a text containing specific methodologies quickly would become outdated. However, a good textbook dealing with general principles of vertebrate control and giving specific damage situations as examples would be a significant contribution.

At the 1962 conference, Walter E. Howard described the need for improving the status of vertebrate pest control (Howard 1962). Some progress has been made since then. In the United States, four regularly-scheduled conferences now provide opportunities for professionals in vertebrate control to interact and share information. The Vertebrate Pest Conference in California, the Great Plains Wildlife Damage Control Workshop in the Midwest, the Bird Control Seminar in Ohio, and the Pine and Meadow Vole Symposium on the East Coast have started since 1960. All four conferences publish proceedings that are valuable sources of information on various aspects of vertebrate control. In addition, since 1976 the American Society for Testing and Materials has sponsored symposia on Vertebrate Pest Control and Management Materials, held in conjunction with the Vertebrate Pest Conference. Papers from these symposia are published as a series of special technical publications (ASTM 1977, 1979, 1981). The amount of published information in vertebrate control represents a significant improvement over that available 20 years ago. This information provides the foundation for a strong and growing educational program.

An organization for professionals working in vertebrate pest control, the National Animal Damage Control Association, was founded in 1979. Its goals include development of public awareness and understanding of the purposes, principles, and parameters of animal damage control, and the development of education and information programs designed to develop knowledge and stimulate public and private decision-making regarding animal damage control.

What Should Be Taught?

Vertebrate pest problems are diverse. Seldom are two situations alike. Furthermore, pest control methods and techniques are subject to change. Thus, a course that emphasizes rigid rules or set solutions to particular problems will not be broadly useful. To be most valuable, a course should teach general principles and approaches and use specific problem situations as examples of how to apply these principles. I suggest that a course might include:

Animal Populations. Factors that regulate populations; density-dependent and density-independent controls; cyclic and irruptive populations; adaptations that favor success in man-modified or disturbed habitats.

Economics of Damage. Evaluation and quanitification of damage; an overview of damage assessment work in the U.S.; cost of damage versus cost of control; the utility of economic threshold models and simulation modeling.

Wildlife and Human Values. Human perceptions of pest damage and nuisance pests; positive and negative values of "pests"; political and sociological aspects of vertebrate pest control; human relations skills necessary for successful pest control projects.

Public Health. Wildlife as reservoirs and vectors of disease; epidemiology of diseases that affect humans and wildlife; disease control methods.

Identification of Problems. Recognition of pest sign and typical damage; using evidence from the damage site to identify the species responsible.

Control Methodology. Categories of control methods: exclusion, repellents, population reduction, etc.; selection of the proper method(s) for a particular species and situation; increasing control selectivity through timing, control technique, and user expertise.

Biological and Related Controls. The limited potential of diseases and predators as control agents; habitat manipulation and its relative lack of species-selectivity; behavioral modification techniques; cultural and agricultural practices.

Laws and Regulations. Federal, state, and local statutes affecting wildlife; government regulatory agencies and authorities; pesticide use restrictions.

Toxicology. Commonly-used toxicants and repellents, their modes of action, common formulations and potential hazards; variation in intra- and inter-species response to a given compound; dose-response curves; LD_{50} values; primary and secondary poisoning; chemosterilants.

History of Vertebrate Control. Historical needs for vertebrate control; the evolution of vertebrate control programs; present needs and responsibilities for vertebrate control.

Of necessity, course content must be adjusted for the level of understanding students have at the outset. Required prerequisite or concurrent courses in subjects related to the above areas (e.g. general biology, entomology, mammalogy, ornithology, population biology, or animal behavior) can enhance the course's effectiveness. A laboratory session can allow students to see damage first hand and to visit with persons experienced in various aspects of vertebrate control. It can also provide students the opportunity to conduct laboratory trials (e.g. feeding preference studies), to get hands-on experience with control tools and methods, or to use computers to simulate pest populations under various control regimes.

Classes may be able to observe or participate in actual control operations being conducted locally by governmental organizations or private pest control operators. Students interested in vertebrate pest control as a career may wish to serve an internship with a pest control operator. Whatever curricula or activities may be included, students should be made aware that there are no perfect solutions; any biological, political, or economic solution to a given vertebrate pest problem will have trade-offs that will be undesirable to some people (Howard 1980).

Who Should Teach It?

Since vertebrate pest control is actually applied ecology (Howard 1966), it should be taught by a vertebrate ecologist interested in, and experienced with, the subject. Vertebrate control requires primarily an ecological, not chemical, approach (Eadie et al. 1961). Such an approach should not exclude the human dimensions—political, sociological, psychological, and economic—of vertebrate pest problems. Ideally, the instructor should have had practical field experience with animal damage problems and solutions and should be able to understand these problems from the point of view of the person who is sustaining the damage to his crop, livestock, home, or other resource. Since vertebrate pest problems involve a wide range of wildlife species, wildlife biologists should have the best background for teaching this subject. Although within wildlife biology vertebrate control is still regarded as the poor stepchild, it must, in my opinion, receive more emphasis.

Where an entire course in vertebrate pest control cannot be justified, it is possible to recognize this area within existing classes. Students may have interest in writing a term paper on such topics as predator control, use of steel traps, urban wildlife problems, or commensal rodents. Some of the more controversial topics may be good subjects for a student debate. Classes in wildlife management techniques can include techniques used in damage control. Independent study options provide additional opportunities for both students and faculty to increase their understanding of particular topics. Graduate students can find a wealth of areas related to vertebrate pests that would make suitable thesis topics.

Toward the Future

As human population increases, increased demands are placed on the world's resources. Vertebrate pest problems can be expected to increase in intensity and diversity as human needs for agriculture and housing become more acute.

Another trend, concurrent with increasing urbanization, is a reduced understanding of wildlife and the principles of wildlife management. For example, 75 percent of the public in a recent survey did not know coyotes are not an endangered species (Kellert 1981). This lack of understanding can weaken wildlife management when public policy decisions are involved. The public is not likely to understand or support vertebrate pest control programs if they do not recognize that vertebrate damage affects them. The 97.3 percent of the U.S. citizens who do not live on farms have no apparent reason to be concerned about coyote predation on sheep and calves, rat and mouse damage to insulated farm buildings, or starling consumption of livestock feed. They have no recognized monetary investment in that crop, no labor, no pride, no interest—their ox is not being gored. Many adults and children in the U.S. do not know or care where food and fiber come from as long as they are attractively packaged and affordable (Miller 1982).

Few people realize the economic costs of vertebrate damage. Documentation of losses to agriculture and other resources is grossly inadequate. What documentation exists is not widely used. There is little doubt that these losses are substantial. For example, a conservative estimate of vertebrate pest damage to agriculture in California is $100-million annually. The use of control measures prevents an estimated additional annual loss of about $500-million (Howard 1979).

To have progressive, safe, effective, and well-supported programs in vertebrate pest control (and in wildlife management, in general) we need better education in this area. A current bumper sticker reads "Education Expensive? Try Ignorance." If we do not increase our understanding of vertebrate pest problems through all available means, we will find ourselves repeating past mistakes, such as using bounty systems for predator control. We, as professionals, must take advantage of this opportunity by training students and educating the public. We must keep open minds, realizing that the term "pest" is a subjective definition; there are no "good" or "bad" animals, but each person's judgment of a species' value depends upon his relationship with it (Howard 1974).

Persons trained in vertebrate pest control, as well as in the more traditional aspects of wildlife biology, will have a broad, realistic understanding of applied ecology. They also will be in demand for jobs requiring this expertise. Continued improvement in the status of vertebrate pest control will benefit the entire field of wildlife and natural resources management.

Acknowledgements

I thank R. E. Marsh, W. E. Howard, W. B. Jackson, G. R. Dudderar, R. J. Johnson, and R. M. Case for their many helpful comments in reviewing an earlier draft of this paper. I thank J. L. Andelt for typing several drafts of this manuscript. Any errors present in the final paper are my own.

Literature Cited

American Society for Testing and Materials. 1977. Test methods for vertebrate pest control and management materials. STP 625. W. B. Jackson and R. E. Marsh, eds. ASTM, Philadelphia, Pa. 258 pp.

______ . 1979. Test methods for vertebrate pest control and management materials. STP 680. J. R. Beck, ed. ASTM, Philadelphia, Pa. 323 pp.

______ . 1981. Test methods for vertebrate pest control and management materials. STP 752. E. W. Schafer, Jr. and C. R. Walker, eds. ASTM, Philadelphia, Pa. 197 pp.

Blaskiewicz, R. and E. A. Kenny, eds. 1978. North American guide to graduate school faculty in wildlife biology. University chapter, The Wildlife Society. SUNY College of Environmental Science and Forestry, Syracuse, N.Y. 227 pp.

Eadie, W. R., J. O. Lee, W. G. Leitch, W. B. Robinson, D. A. Spencer, and W. E. Howard. 1961. Report of committee on economic losses caused by vertebrates. J. Wildl. Manage. 25: 319–322.

Howard, W. E. 1962. Means of improving the status of vertebrate pest control. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 27: 139–150.

______ . 1966. Principles of vertebrate animal control. Pages 627–629 *in* Congres de la Protection des Cultures Tropicales, Chambre de Commerce et d'Industrie, Marseille, March 23–27, 1965. 998 pp.

______ . 1974. The biology of predator control. Addison-Wesley Module in Biology, Addison-Wesley Publishing Co., Reading, Mass. 48 pp.

______ . 1979. Political and sociological aspects of wildlife damage control. Pages 147–165 *in* Proceedings, Fourth Great Plains Wildlife Damage Control Workshop, Manhattan, Kan., December 4–6, 1979. Great Plains Agricultural Council and Kansas State University, Manhattan, Ks. 267 pp.

______ . 1980. Teaching the complex biological problems of wild vertebrate populations. Pages 205–212 *in* T. S. Bakshi and Z. Naveh, eds. Environmental education. Plenum Publishing Corp., New York. 285 pp.

Kellert, S. R. 1981. Knowledge, affection, and basic attitudes toward animals in American society. Stock no. 024-010-00-625-1. U.S. Gov. Print. Off., Washington, D.C. 162 pp.

Miller, J. E. 1982. Wildlife damage control and the cooperative extension services. Pages 5–13 *in* R. M. Timm and R. J. Johnson, eds. Proceedings, Fifth Great Plains Wildlife Damage Control Workshop, Lincoln, Neb., October 13–15, 1981. Great Plains Agricultural Council and Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln.

Stone, C. P., and G. A. Hood. 1979. Extent, costs, and trends in control of plant pests: vertebrates. Pages 218–232 *in* W. B. Ennis, Jr., ed. Introduction to crop protection. American Society of Agronomy and Crop Science Society of America, Madison, Wisc.

Swanson, G. A. 1970. Wildlife damage and control. Pages 208–225 *in* S. S. Atwood, chmn., Land use and wildlife resources. National Academy of Sciences, Washington, D.C. 262 pp.

Training Biologists in Institutional Topics: Federal Needs and Viable Approaches

Stephen A. Miller
U.S. Fish and Wildlife Service, Fort Collins, Colorado

Dennis L. Schweitzer
USDA Forest Service, Fort Collins, Colorado

Introduction

Consider the following question:

"A proposed development activity that promises substantial economic benefits will have significant adverse impacts on fish and wildlife resources in the area. What percentage of all your agency wildlife and fisheries professionals could develop and present a fully professional defense for the faunal interests in the area to an audience largely oriented towards commodity development?"

Before you become too uneasy with your answer to that question, let me pose another:

"Your wildlife and fish budget request to carry out a proposed program, regulatory activity, project or operation has been challenged. What percentage of all your agency wildlife and fisheries professionals could adequately defend the budget request to non-biologists?"

If your answers to both questions are personally discomforting, I will add to your dismay by saying that you are part of the majority. In a recent survey, these same questions were posed to a number of federal agency administrators of wildlife and fish programs who collectively represent nearly 3,500 wildlife and fisheries professionals. These administrators indicated that less than half of their staffs could effectively perform either task.

A consensus within the profession has been established (Cookingham et al. 1980) that the level of skills of biologists in essential non-biological areas should be upgraded. Functional specialists are not well-equipped to deal with broader aspects of their responsibilities. Here, we further explore the adequacy of the formal education of professional resource managers to understand and apply concepts of ecological, economic, and sociological analysis.

While federal wildlife and fishery management programs will continue to be determined by many factors, analytical methods adopted from non-biological disciplines are gaining increasing emphasis for use in rationalizing the advantages of resource management alternatives and in competition for scarce budget allocations and personnel ceilings. Wildlife and fisheries biologists and managers must have some minimum level of understanding of the institutional context in which the fate of their resources is determined and of the importance and use of the tools associated with that process. This paper contrasts the level of knowledge regarding various institutional themes held by federal wildlife and fisheries professionals with the level thought to be required by their respective agencies. The paper also presents a summary of priority training needs and a discussion of alternative delivery systems for implementing such training programs.

Methods of Conducting This Study

In late 1981, the views of federal agency administrators on their agency needs of wildlife and fisheries professionals in the ancillary skills of various institutional themes were surveyed with a written questionnaire. For the purposes of this study, wildlife and fisheries professionals were defined as those employees whose duties are to perform, under general administrative supervision and with wide latitude for the exercise of independent judgment, work in administering, directing, or exercising control over programs, regulatory activities, projects, or operations that are concerned with fish and wildlife conservation and management.

The questionnaire was mailed to key administrators within the headquarters offices of the USDA Forest Service, Soil Conservation Service, the USDI Fish and Wildlife Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, and the National Marine Fisheries Service. Collectively, the replies from these agencies were based on an assessment of 3,489 wildlife and fisheries professionals. Our conclusions are based on the collective response from these agencies. The questionnaire format and summarized survey results are shown as Table 1.

The questionnaire asked each agency to (1) identify the importance or priority of knowledge of selected institutional topics (see Table 1) to wildlife and fisheries professional *positions* in their agency, (2) identify the current level of knowledge of the topics held by *current occupants* of these positions; and (3) identify their priorities for training wildlife and fisheries professionals in these topical areas. Because the scope of this survey focused on a general state-of-affairs, the personal judgments of the agency respondents were adequate.

The first portion of the survey asked each agency to indicate the priority that they would assign to knowledge of selected institutional topics for wildlife and fisheries professional positions in their respective organizations. Given the total number of professional positions within each agency, the respondents were asked to enter the percentage of positions that fell under each priority class for each topic. A high priority designation meant that knowledge of the topic was essential to do an adequate job in the position. Assignment of a medium priority ranking inferred that knowledge of the topic is not essential for an adequate performance in the position, but was essential for the best possible performance in the position. A low priority designation meant that knowledge of the topic was not required for performing in the position. A summary of the answers to this question is presented in Part A of the questionnaire.

The second portion asked each agency to identify the current level of knowledge of the institutional topics that were held by current occupants of their wildlife and fisheries professional positions. The respondents were asked to focus just on the positions identified in Part A as having a high or medium priority for knowledge of each topic. Agency respondents were requested to enter the percentages of current professional staff that could be categorized under four levels of knowledge:

1. exceeds level for current position;
2. fully adequate for current position;
3. generally adequate, but individual is frequently perplexed; and
4. below level required for current position.

Table 1 (Part A). Identification of the importance of knowledge of selected topics to wildlife and fisheries biologist *positions*.

Percentage figures indicate the priority that respondents assigned to a knowledge of the listed topics for wildlife and fisheries professional positions in their agency. The percentages indicate the total number of positions that fall under each priority class.

	Priority class		
	High priority–essential knowledge required to do an adequate job	Medium priority–not essential for an adequate performance, but essential for best possible performance	Low priority–knowledge not required for performance
SAMPLE—role of government in the economy	10%	50%	40%
1. the role and responsibility of the civil servant in government and society	42%	39%	19%
2. how decisions about general agency policies are made	48%	37%	15%
3. how decisions about annual agency budgets are made	43%	36%	21%
4. the operating relationship between my agency and other federal agencies	46%	33%	21%
5. the operating relationship between my agency and state wildlife and fish agencies	58%	24%	18%
6. the operating relationship between my branch of my agency and other branches	80%	17%	3%
7. the relative importance of various interest groups that influence my agency	63%	26%	11%

Table 1 (Part A). (cont'd.)

	Priority class		
	High priority–essential knowledge required to do an adequate job	Medium priority–not essential for an adequate performance, but essential for best possible performance	Low priority–knowledge not required for performance
8. the factors that affect the opinions of those influential groups	49%	41%	10%
9. the impacts of my agency's activities on wildlife and fish resources	67%	19%	14%
10. the impacts of my agency's activities on the economic circumstances and quality of life of people	49%	35%	16%
11. the requirement for and application of economic and social analysis techniques to wildlife and fisheries problems within my agency	27%	37%	36%

A summary of the answers to the second question is presented in Part B of the questionnaire.

The third portion of the survey served as a cross-check on the training priorities that evolved from the summaries shown in Parts A and B of the questionnaire. We asked the agency respondents to indicate their priorities for training wildlife and fisheries professionals in the listed institutional topics.

Results of the Study

Federal agencies appear to be satisfied with their professional employees' level of knowledge regarding the role and responsibility of the civil servant in government and society. Only 17 percent of the current professional staff were assessed as requiring additional training in this topic and the agencies assigned it one of their lowest priority ratings on the training needs agenda.

Although additional training on the development of agency policies has apparently been relegated to a "back-burner" status, the respondents indicated a high

Table 1 (Part B). Identification of current level of knowledge of selected topics held by *current occupants* of biologist positions.

Percentage figures indicate the total number of professional employees that hold the delineated levels of knowledge.

	Current levels of knowledge			
	Exceeds level for current position	Fully adequate for current position	Generally adequate but individual frequently perplexed	Below level required for current position
SAMPLE—role of government in the economy	5%	50%	30%	15%
1. the role and responsibility of the civil servant in government and society	10%	35%	38%	17%
2. how decisions about general agency policies are made	4%	19%	47%	30%
3. how decisions about annual agency budgets are made	3%	14%	38%	45%
4. the operating relationship between my agency and other federal agencies	8%	36%	30%	26%
5. the operating relationship between my agency and state wildlife and fish agencies	9%	27%	27%	37%
6. the operating relationship between my branch of my agency and other branches	7%	31%	39%	23%
7. the relative importance of various interest groups that influence my agency	13%	33%	36%	18%

Table 1 (Part B). (cont'd.)

	Current levels of knowledge			
	Exceeds level for current position	Fully adequate for current position	Generally adequate but individual frequently perplexed	Below level required for current position
8. the factors that affect the opinions of those influential groups	49%	41%	10%	
9. the impacts of my agency's activities on wildlife and fish resources	67%	19%	14%	
10. the impacts of my agency's activities on the economic circumstances and quality of life of people	49%	35%	16%	
11. the requirement for and application of economic and social analysis techniques to wildlife and fisheries problems within my agency	27%	37%	36%	

priority need for training in agency budget formulation processes. Knowledge of this topic was indicated as appropriate for approximately 79 percent of the professional positions represented in this assessment. However, nearly one-half of the current occupants of these positions were considered as having a skill level below that required for their job. The agency respondents collectively assigned this topic as one of the highest priority training needs.

Knowledge of the operating relationships between and within agency organizational structures, and between federal agencies and state wildlife and fish agencies appears to be important. Levels of knowledge held by current professionals were assessed as needing to be upgraded, but in the context of a mid-level priority for actual training programs to be implemented.

The category of topics exhibiting the poorest correlation between apparent training needs and assigned training priorities is that pertaining to interest groups that influence federal agency policies and operations. Both topics in this category are cited as important elements of knowledge for performing in professional wildlife and fisheries positions. The level of knowledge within these topical themes held by current professional staff is assessed as relatively low, indicating an apparent training priority. The training priority assigned by the agency respondents, however, is not commensurate with this presumption. The low priority assignment might simply reflect the current situation. An era of active lobbying by these groups occurring during the survey period might have increased the assigned priority for these topics.

Knowledge of the impacts of federal agency activities on wildlife and fish resources was rated considerably higher in importance than a comparable knowledge of the impacts of human resources. Although the current levels of knowledge for both topics are normally distributed across the four skill level categories—indicating a relatively low training priority—the survey respondents assigned one of their highest priority rankings for all topics to the knowledge of agency impacts on faunal resources. Knowledge of agency impacts on the economy and quality of life was assigned a more moderate priority in line with its apparent stature as indicated in the questionnaire summaries.

The preceding priorities probably conform to most of our expectations. Wildlife and fish resources have traditionally been involved in land use decisions involving competing uses of resources primarily as legal or social constraints. The historically poor showing of faunal resources when pitted against competing resources for land use is largely attributable to our insistence that they be viewed as a functional independent rather than from an integrated perspective with other commodity resources. As a profession, we have focused on minimizing adverse impacts on faunal resources in competing resource use decisions because we have not been able to play by the same "rules-of-the-game" as practiced for commodity resource areas. This defensive approach has guaranteed an underdog status for wildlife and fish resources, and we resource managers have reacted, as expected with most underdogs, in a highly defensive and inward-looking fashion, to the exclusion of other ecological, economic and social concerns of the ecosystem.

The present decade demands that wildlife and fisheries professionals change their approach. Wildlife and fisheries managers will have to deal with projections of future demands and supplies of resources and causes and effects of change in their planning processes. Such planning concepts are necessary to reduce future resource deficiencies and conflicts resulting from misallocation of land, labor and capital (USDA Forest Service 1981). We believe the survey respondents recognized this, if somewhat hesitantly, in their response to the last topical entry on the questionnaire.

Almost 40 percent of the 3,500 professional positions represented in the survey were judged by the respondents as not requiring knowledge of the requirement for and application of economic and social analysis techniques to wildlife and fisheries problems. Of the 64 percent of positions for which this topic was considered relevant, the respondents stated that about half of the current biologists were deficient in the skill required for the job. The apparent and assigned training priority is high for this topic, probably higher than indicated in the summaries because of the relevance of the topic to an obviously larger number of professional staff than the survey results indicate.

Alternative Delivery Systems

A wide array of approaches to developing and presenting instruction in the priority institutional topics is possible. They include university training, in-service training, and individual development.

Federal employees have frequently been enrolled at the graduate level in standard university curricula, usually under provisions of the Government Employee Training Act, to increase their technical capabilities. When several employees enroll together, universities frequently offer supplementary guidance and seminars to meet the particular needs of such students. There have also been instances where one or several universities have developed specialized graduate-level curricula to meet the particular needs of a sponsoring federal agency. However, most federal employees receive university training through much more narrowly focused short courses that last several days to a week.

Most federal in-service training is also brief and focused on narrow technical or managerial topics. Highly structured short courses frequently rely on a mix of agency personnel and consultants for instructors. The more common workshops tend to be strongly oriented towards resolving current problems and usually rely on group interactions and practicums rather than on information-giving.

Individual development relies almost solely on individual initiative. Numerous correspondence courses are available; the Soil Conservation Service offers a correspondence course in economics to its employees and the USDA Graduate School offers a full catalogue of courses to anyone who is interested. The Society of American Foresters has developed an elaborate technique to structure activities of individual members. Definitions of Society-required types of involvement, detailed record-keeping, and public recognition of accomplishments are key ingredients.

Given an objective to provide a general understanding of the selected institutional topics to federal wildlife and fisheries professionals, and considering probable limitations on expenditures, the standard and specialized university curriculum approaches can be discarded in the context of this report (recognizing that they may be relevant in particular circumstances). However, in the long-run, guest lecturing by agency personnel, participation on professional committees concerned with education, and other techniques to influence traditional university curricula are relevant and important activities.

Developing a course of instruction to be administered by mail seems a promising, low-cost approach. Because correspondence courses involve little student-teacher and no student-student interaction, however, they appear to be most suitable for supplementing or reinforcing on-site instruction. The broader, self-designed development approach is probably best suited for professionals to keep up-to-date in the area where they already have firm training.

The remaining methods are short courses and workshops. Since wildlife and fisheries professionals cannot reasonably be assumed to be well-grounded in the selected themes, it will be necessary to discuss concepts in some depth through structured lectures. Therefore, the most promising delivery system is a short course that includes both lectures and practicums, perhaps supplemented with at-home readings and applications.

Conclusions and Recommendations

In summary, we conclude that the survey results identify high priority needs in the following topics that directly relate to the hypothetical situations introduced at the beginning of this paper: (1) *the requirement for and application of economic and social analysis techniques to wildlife and fisheries problems,* and (2) *how decisions about annual agency budgets are made.*

There are several options for developing a course of instruction on these topics that are amendable to the training delivery system outlined earlier: through an ad hoc group of agency employees; through a contract with a consultant or university; or through some sort of professional wildlife group or consortium of agencies, perhaps utilizing a joint contract.

The first two options have the advantage of ensuring full agency control of the course, including the exploration of agency-specific requirements and problems. The third option would probably be less costly and promises the usual benefits of cooperative efforts.

The survey discussed earlier suggests that agency instructors are needed to define "how it really works," and professional educators are needed to provide the basics of more general skills or knowledge. Too many dollars have been wasted in having unprepared consultants talk about budgets and organization and agency employees talk about theory. Although large numbers of wildlife and fishery biologists in widely scattered locations require training, costs must be kept under tight control. We think it can be done if advantage is taken of technology.

We suggest developing, in modules, a comprehensive course in the desired topics for repeated presentation. This can be done through federal contracting with a university to produce videotaped instruction and supplementary printed materials. Selected modules could then be presented anywhere in the country; they could be supplemented with geographically-specific and/or agency-specific instruction; and appropriate printed materials would permit integration of taped instruction, practicums and self-study.

Such an approach would be a cost-effective means of developing and presenting instruction to large numbers of biologists. And it would be a feasible vehicle for cooperation among federal agencies, universities and professional organizations.

To this point, the wildlife profession has agreed that training in non-biological areas is deficient. This paper suggests that those deficiencies are of concern to federal agencies employing 3,500 wildlife and fisheries professionals. We believe that wildlife and fishery resources are being adversely affected as a result.

Who will do anything about it?

References Cited

Cookingham, R. A., P. T. Bromley and K. H. Beattie. 1980. Academic education needed by resource managers. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 45: 45–49.

USDA Forest Service. 1981. Problem analysis: Ecological analysis techniques for national assessments of wildlife and fish. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Expectations For Entry-Level Biologists: What Are State and Provincial Agencies Looking For?

Richard O. Anderson
Cooperative Fishery Research Unit
University of Missouri, Columbia

Introduction

Resource agencies and the fish and wildlife professions must necessarily consider and cope with challenges and changes that appear to be following an exponential rate of increase. Agencies must be able to do more with less, to protect the quality and diversity of renewable resources and the benefits they provide. The Professional Improvement Committee of the International Association of Fish and Wildlife Agencies has been charged with assessing and identifying professional educational needs and opportunities. Previously, this committee has assessed the need and opportunity for change as perceived by agency and academic administrators (Cookingham et al. 1980).

Two surveys of state and provincial resource agencies were conducted in 1981 by the Professional Improvement Committee. Objectives were to collect information on two points: (1) fishery and wildlife job titles and position descriptions that specify at least a 4-year college education; and (2) educational data about entry-level graduates who had been placed in full-time professional positions for the three fiscal years preceding July 1, 1981.

The job descriptions and expected skills and abilities for biologist positions in most agencies sampled were demanding. However, educational specifications were variable and often vague. In an effort to improve professional capabilities, the Professional Improvement Committee made several recommendations, which are reported here.

Methods and Results

The first questionnaire was sent to all state and provincial chiefs of fishery or wildlife programs. It requested job specifications for fishery and wildlife professionals with a college education at entry-level positions. Usable replies were received from 45 states and 3 provinces.

For positions such as technicians and aides, hatchery supervisors, area managers, and conservation agents (officers, wardens) academic requirements varied greatly among the agencies sampled. Specifications ranged from high school graduation, to some college experience, to an Associate degree, or a Bachelor's degree. No analysis of specifications for these positions is included here because of inconsistencies among the agencies as to what constituted professional positions.

Biologist Job Descriptions, Titles

For biologist positions, the job descriptions of most agencies were demanding. The knowledge, skills, and abilities commonly included the following qualities: knowledge of biological, ecological, and conservation principles and practices;

knowledge of fauna and flora and their habitat requirements; knowledge of laws, regulations, and functions of state and federal agencies and private organizations involved in conservation and management; skills in the operation and maintenance of motorized equipment, scientific instruments, and gear for various sampling techniques and methodologies in both field and laboratory; ability to plan and conduct surveys of habitat and organisms to define problems and recognize opportunities; ability to develop and implement effective and efficient management plans and operations; ability to apply scientific methods and approaches in the planning and conduct of research projects and resource investigations; ability to apply statistical procedures, to analyze and evaluate data, and apply sound judgment in arriving at conclusions and recommendations; ability to write clear and concise reports, technical publications, and informative popular articles; ability to effectively communicate orally with subordinates, peers, supervisors, other scientists, and the public; ability to plan, assign, supervise, and evaluate the work of subordinates and maintain effective working relations; and ability and motivation to perform as a professional for the benefit of the public served, the resources, and the agency.

In position titles, the term *Biologist* was consistently used as the primary noun by almost all agencies. The exceptions were *Resource Manager* (Illinois), *Agent* (Nevada), *Scientist* (New Mexico), *Natural Resources Specialist* (South Dakota, Wisconsin) and *Ecologist* (Saskatchewan). Common adjectives used were *fishery* or *fisheries* in contrast to *fish,* and *wildlife* in contrast to *game*. Other adjectives included *aquatic* (Hawaii, Massachusetts, Minnesota) and *conservation* (Illinois, New York). Alabama, Florida, New Hampshire, and Texas used only the title, *Biologist,* without adjectives.

Position descriptions and job duties and responsibilities were usually written separately and distinguished between fishery and wildlife biologist positions. However, duties and descriptions were combined as one position in 19 agencies (Alabama, Arizona, Arkansas, Colorado, Delaware, Florida, Georgia, Illinois, Louisiana, Nebraska, Nevada, New Hampshire, New Mexico, South Carolina, South Dakota, Tennessee, Ontario, Quebec, and Saskatchewan). Single job titles were often used to designate both professional areas, e.g., Game and Fish Biologist, Wildlife Biologist, Fish and Wildlife Biologist, Biologist, Wildlife and Fisheries Biologist, and Wildlife Scientist. The Committee believes that such titles and job descriptions are unrealistic.

To designate promotional or advanced entry levels, most agencies used roman numerals (I, II, III). Terms or adjectives such as *trainee, assistant, associate, senior,* or *specialist* were used by others (Florida, Georgia, Kentucky, Massachusetts, Minnesota, New Jersey, and New York). Two agencies used letters (California, Colorado).

Management and research responsibilities were usually combined into one position and job title. Some agencies included a research designation in job titles (Arkansas, Colorado, Idaho, Oklahoma, and Wyoming).

Academic Specifications

Educational qualifications for entry-level biologist positions in most agencies specified a Bachelor's degree. Some agencies specified a Master's degree or graduate courses for biologist entry levels, but also allowed promotion with a Bachelor's degree and full-time experience. Most states designated advanced entry-level placement with Master's degrees or graduate programs. Only three agencies (Delaware, Florida, and West Virginia) included a Ph.D. degree as an option for advanced entry or specialist positions.

The academic major was specified for biologist positions as fisheries or wildlife or related resource subjects by many agencies sampled (Alabama, Colorado, Connecticut, Delaware, Indiana, Kansas, Kentucky, Massachusetts, Montana, Nevada, New Jersey, New Mexico, Oklahoma, Oregon, South Dakota, Texas, Utah and West Virginia). Often agencies included biology or zoology as optional majors (Alaska, Arizona, California, Hawaii, Idaho, Illinois, Louisiana, Maine, Michigan, Missouri, Nebraska, New Hampshire, North Carolina, South Carolina, Tennessee, Vermont, Washington and Wyoming). A few agencies specified only a major in biology or zoology or any biological science (Arkansas, Florida, Georgia, Iowa, Ontario, Quebec, Saskatchewan).

Some agencies specified subject matter, courses, and course hours. Where specified, 30 semester hours in biological sciences was a consistent guideline (Table 1). The number of semester hours in specified fishery or aquatic courses for fishery biologists ranged from 9 to 24; the number of semester hours in specialized wildlife, zoology or natural resource courses for wildlife biologists ranged from 9 to 18.

Only one state sampled (Kentucky) specified that the college courses should satisfy the academic requirements for certification as a Fishery Scientist by the American Fisheries Society. Georgia has proposed such a specification to their Merit System. These academic guidelines include 30 semester hours of biological sciences, including four aquatic courses; 15 hours in physical science; 6 hours in mathematics and statistics; and 6 hours in communications.

Only one state (Oklahoma) specified college courses that satisfied the academic requirements for certification as an Associate Wildlife Biologist by The Wildlife Society. These academic guidelines include 30 semester hours in biological sciences (including 6 hours in wildlife courses, 6 hours in taxonomy courses, 9 hours in zoology, and 9 hours in botany); 15 hours in mathematics and physical sciences, including algebra and statistics; and 15 hours in humanities, including 4 hours in English composition and a course in resource economics. In 1983 the requirements will be modified to include 36 hours in biological sciences (24 hours of basic biological courses, 6 hours of wildlife management, and 6 hours of ecology); 9 hours in physical sciences; 9 hours in mathematics and statistics; 9 hours in social sciences and humanities; 12 hours in communications; and 6 hours in resource policy, administration, or law.

New Entry-Level Biologists

A second survey was sent to all state and provincial agency personnel officers and asked for information about employees placed in full-time professional positions in the last three fiscal years. Usable replies were received from 26 states and 2 provinces.

In the last three years these agencies have employed 272 biologists: 92 in 1979, 128 in 1980, and 52 in 1981 (Table 2). The marked reduction in 1981 may reflect recent fiscal constraints. Positions tallied as biologists were those with appropriate

Table 1. Courses or subjects specified or recommended for entry-level biologist positions. Numbers in parenthesis represent semester hours.

State and title	Course and subject specifications
California	
Water Quality Biologist	General or Inorganic Chemistry (1 year), Qualitative or Organic Chemistry
Georgia	
Associate Wildlife Biologist	Wildlife, Fisheries, or Marine Biology (10)
Wildlife Biologist	As above
Proposed	
Fisheries Biologist I Fisheries Biologist II	Biological Science (30, with four aquatic courses), Physical Science (15), Mathematics-Statistics (6), Communications (6)
Hawaii	
Aquatic Biologist II	Aquatic Biology (24)
Wildlife Biologist II	Wildlife Biology (18), Botany (6)
Iowa	
Fisheries Biologist I	Fisheries Biology (9)
Wildlife Biologist I	Wildlife Biology (9)
Kentucky	
Fishery Biologist	As specified for certification as Fishery Scientist, American Fisheries Society
Senior Fishery Biologist	As above
New Jersey	
Senior Fisheries Biologist	Fisheries (12)
New York	
Conservation Biologist Trainee	Biological Science (30, with 18 hours Fisheries, Wildlife, Natural Resources, Marine Biology)
Conservation Biologist	Graduate hours (30, with 15 hours in Fisheries, Wildlife, Natural Resources, Marine Biology)
Ohio	
Wildlife Biologist I (Aquatic Biologist)	Aquatic Biology, Aquatic Entomology, Invertebrate Zoology, Ecology, Plankton
Fish Unit Leader	Limnology, Organic Chemistry, Public Relations, Fish Management
Wildlife Area Supervisor	Wildlife Management/Biology, Agriculture, Supervision, Budgeting
Wildlife Biologist I (Game and Nongame)	Agronomy, Mammalogy, Ornithology, Vertebrate Anatomy, Botany, Plant Taxonomy, Ecology, Animal Behavior, Organic Chemistry, Invertebrate Zoology, Speech, Wildlife Management
Oklahoma	
Game Biologist I	Biological Science (30) with Wildlife (6), Taxonomy (6), Zoology (9), Botany (9), Mathematics and Physical Science (15 with Algebra, Statistics), Humanities (15 with English, 4)

Table 1. (cont'd.)

State and titles	Course and subject specifications
Oregon	
Fish and Wildlife	
Biologist I (Fisheries)	Fisheries (16)
Tennessee	
Wildlife Manager I	Ornithology, Icthyology, Limnology, Dendrology, Ecology, Fish Management
Washington	
Fish Biologist I	Fisheries (9)
Wisconsin	
Natural Resources Specialist I	
(Fish Manager)	Limnology, Aquatic Ecology, Fishery Biology, Population Ecology, Fishery Management, Statistics, Mathematics, Botany, Plant Ecology

job titles. Positions such as conservation officers, hatchery workers, and technicians that were reported filled were not included in the tally. Personnel officers with 12 agencies justifiably included these positions as entry level professional positions. Almost all of the successful applicants had college degrees.

Most (55 percent) of the biologist positions were filled by candidates with a 4-year college degree; 42 percent had graduate degrees (including 7 Ph.D. degrees). The rest had no degrees or Associate degrees. Fisheries or wildlife or natural resources were indicated as majors for 63 percent of the biologists; biology or zoology for 27 percent; for 10 percent the major was something else or was not indicated.

Information was included on institutions where degrees were earned by the biologists employed. Terminal degrees were awarded from 81 schools (Table 3); 22 schools provided only undergraduate education and the students continued on to a graduate program. About 75 percent of the positions in the 28 agencies were filled by graduates with terminal degrees from 31 schools. Five or more graduates were reported from 20 institutions. Only one graduate was reported from 35 schools. The balance of the schools reported having placed two or three graduates.

Discussion

What are agencies looking for in the qualifications of their entry-level biologists or managers? For some, one might answer, "not very much." Only specifying a degree in biology or zoology, with no curriculum guidelines, produces many applicants for positions, but probably relatively few with an adequate background to assume management responsibilities. Position descriptions often include research responsibilities and a Bachelor's degree as the minimum educational qualification. A candidate with a Bachelor's degree and two or three years of experience is probably not as well prepared for this function as a person with a graduate edu-

Table 2. States and provinces providing data and information about biologists employed.

State or Province	Positions filled (FY) 1979	1980	1981	Terminal degree None	A.A.	B.S.	M.S.	Ph.D.
Delaware	0	3	0	0	0	1	1	1
Florida	11	23	3	0	0	9	27	1
Georgia	4	6	1	0	0	2	8	1
Illinois	5	12	4	0	0	14	7	0
Indiana	3	2	1	0	0	2	4	0
Kentucky	1	3	1	0	0	4	1	0
Louisiana	13	9	8	0	0	21	9	0
Maine	0	0	0	0	0	0	0	0
Maryland	1	2	0	0	0	3	0	0
Massachusetts	1	0	0	0	0	0	1	0
Michigan	4	3	4	0	0	3	7	1
Minnesota	5	15	9	4	1	20	4	0
Mississippi	0	2	1	0	0	0	3	0
Missouri	1	13	2	0	0	9	6	1
Nebraska	7	4	0	0	0	9	1	1
Nevada	4	5	1	0	0	10	0	0
New Hampshire	1	5	0	0	0	5	1	0
North Carolina	3	0	0	0	0	0	3	0
North Dakota	2	1	0	0	0	0	3	0
Oklahoma	6	2	1	0	0	4	5	0
Tennessee	0	0	0	0	0	0	0	0
Texas	1	0	0	0	0	0	1	0
Utah	1	1	6	0	0	5	3	0
Washington	1	5	1	0	0	7	0	0
Wisconsin	9	2	2	0	0	3	10	0
Wyoming	5	5	2	0	0	7	4	1
Ontario	2	5	1	0	0	7	1	0
Saskatchewan	1	0	4	0	0	5	0	0
Totals	92	128	52	4	1	150	110	7

cation who has experienced the discipline associated with the preparation of a thesis or dissertation.

Analysis of job specifications and minimum educational qualifications does not necessarily define the credentials of biologists placed by state or provincial agencies. However, as judged from the limited data available, most biologist positions were filled by candidates with a 4-year college degree. Apparently, individuals can be educated to function well in professional positions with a Bachelor's degree. However, the best candidates are probably educated in schools with curricula that can satisfy the guidelines for a professional education.

There has been a major evolution toward professionalism in fisheries and wildlife, as evidenced by certification programs in The Wildlife Society and the American Fisheries Society, as well as by the development at many institutions of curricula that satisfy certification guidelines. I believe that most of the biologists placed by the agencies that provided data had academic backgrounds at such

Table 3. Schools awarding terminal degrees for biologists placed by agencies cooperating in survey; U, G and the number in parentheses indicate number of undergraduates and graduates reported.

Auburn University (U,G–10)	Southwest Texas State University (U–1)
Central Missouri State University (U,G–3)	Tennessee Technical University (U,G–8)
Colorado State University (U,G–7)	Texas A & M University (U–1)
Cornell University (U–1)	University of California (U–1)
Crookson Junior College (U–1)	University of Central Florida (G–2)
Eastern Illinois University (U,G–6)	University of Delaware (G–2)
Eastern Kentucky University (U,G–3)	University of Florida (U,G–5)
Florida State University (U–1)	University of Georgia (G–5)
Frostburg State College (U–1)	University of Guelph (U,G–5)
Georgia College (G–1)	University of Hawaii (U–1)
Humbolt State University (U–4)	University of Illinois (G–1)
Idaho State University (U–1)	University of Maryland (U,G–4)
Indiana University (G–1)	University of Massachusetts (U–1)
Iowa State University (U,G–5)	University of Michigan (G–1)
Louisiana State University (U,G–14)	University of Minnesota (U,G–14)
Louisiana Technical University (U,G–4)	University of Missouri (U,G–7)
McNeese State University (U–4)	University of Montana (U–2)
Michigan State University (U,G–10)	University of Nebraska (U,G–9)
Michigan Technical University (G–2)	University of Nevada-Las Vegas (U–4)
Mississippi State University (G–1)	University of Nevada-Reno (U–4)
New England College (U–1)	University of New Hampshire (U,G–3)
Nichols State University (U–3)	University of North Carolina (G–1)
North Carolina State University (U,G–8)	University of North Dakota (G–2)
North Dakota State University (G–1)	University of Oklahoma (U–2)
Northeast Oklahoma State University (U–1)	University of Saskatchewan (U–4)
Northern Illinois University (G–1)	University of Southwest Louisiana (U–1)
Ohio State University (U,G–4)	University of South Florida (G–2)
Oklahoma State University (U,G–5)	University of Southern Mississippi (G–2)
Oregon State University (U,G–4)	University of Toronto (U–3)
Purdue University (U–1)	University of Vermont (G–2)
St. Anselm's College (U–1)	University of Washington (U–4)
St. Cloud State University (U–2)	University of Wisconsin-Madison (U,G–5)
St. John's University (U–1)	University of Wisconsin-Stevens Point (U,G–9)
Salisbury State University (U–1)	University of Wyoming (U,G–7)
South Dakota State University (U,G–2)	Utah State University (U,G–4)
Southeast Oklahoma State University (U–1)	Virginia Polytechnic Institute and State University (U,G–6)
Southeastern Louisiana State University (U,G–2)	University of West Virginia (U–1)
Southeastern Massachusetts University (U–1)	Weber State University (U–1)
Southern Illinois University (U,G–9)	Western Illinois University (U–1)
Southwest Missouri State University (U–1)	Western Michigan University (G–1)
	Winona State College (U–1)

institutions. Does the fact that all positions were not filled by candidates possessing certification qualifications indicate a shortage of qualified people, or a weakness in the qualifications expected? I suspect that both factors may be involved.

There are marked contrasts in the development of the renewable resource professions of forestry, and fisheries and wildlife. Developing adequate educational programs was one of the founding objectives of the Society of American Foresters. Today, 44 academic programs are accredited by that Society.

In range management, another renewable resource profession, the U.S. Department of Agriculture has specified course work requirements for range conservation as 42 semester hours in a combination of plant, animal, and soil sciences and natural resources management that include at least 18 semester hours in range management; 15 semester hours in directly related plant, animal, and soil sciences (with at least one course in each); and at least 9 semester hours in natural resources management. Relatively few colleges of agriculture provide such a curriculum.

How many schools have fishery and wildlife programs in the United States and Canada? Cookingham et al. (1980) sent questionnaires to 151 schools with fishery or wildlife courses. Lackey (1979) observed that many university programs have only one or two professors educated in fishery science. He asked the challenging question, "Where do we draw the line between a 'fisheries program' and an institution with one or two fishery professors?" These questions have not been answered.

Often several schools within a state offer programs and are in competition for students and state fiscal resources. Many institutions have reached the point where difficult decisions are being made about terminating academic programs. It would seem logical, but admittedly idealistic, to assume that multiple programs within a state might be amalgamated with a transfer of people and dollars to create stronger and better academic programs. Since the future employees that will be the lifeblood of resource agencies are at stake, these agencies would logically be interested and involved in such important decisions.

There is no exact agreement on how best to structure academic programs and curricula to provide the background necessary for employment in fishery or wildlife positions. The scope of positions and variations among agencies will promote diversity. Professional curricula should produce students with knowledge not only of fish or wildlife but also socioeconomic perspectives (Lackey 1979, Hester 1979). Graduates need not only scientific knowledge but also abilities to plan, identify problems, make decisions, think, reason, and communicate (Donaldson 1979). Education is needed that promotes not only science and research but also effective management. Professional education must impart not only knowledge and abilities but also a philosophy of professionalism and the motivation and dedication needed for success (Chapman 1979, Olmsted 1979). Employee success is often due to 10 percent inspiration and 90 percent perspiration.

Recommendations

The recommendations listed here were drafted and approved by the Professional Improvement Committee and accepted with commendation by the Executive Committee of the International Association of Fish and Wildlife Agencies in 1981.

Resource agencies should recognize a Bachelor's degree as the minimum academic requirement for a professional position. A background including fishery and wildlife courses is desirable for many positions such as conservation agents, field service positions, technicians, and area managers. Biologist positions as management or research specialists should require professional education in fisheries or wildlife. In order to improve professional capabilities, all state, provincial, and federal agencies involved in conservation and management of fishery and wildlife resources should follow certain guidelines:

1. Evaluate, define, and upgrade as appropriate, the educational requirements for fishery and wildlife entry-level professional positions.
2. Whenever activities and responsibilities are appropriate, establish position titles and descriptions that recognize the important distinctions between the fishery and wildlife professions.
3. When management plans or decisions are a major responsibility of a position, specify fisheries or wildlife as the preferred major in academic programs.
4. When research planning or interpretation is a primary responsibility of a position, include completion of a graduate degree with a thesis or dissertation among the educational qualifications. Include a Ph.D. degree as an employment option for research or other specialists.
5. Specify for all entry-level biologist positions, academic curricula that satisfy the educational requirements for certification as a Fishery Scientist or Associate Wildlife Biologist as specified by the American Fisheries Society or The Wildlife Society.
6. To promote more consistency among agencies, this committee recommends the following as a guideline for entry-level biologist positions:

   Fishery Biologist I (e.g., District Manager Trainee, Hatchery Manager Trainee, Area Manager Trainee, Hatchery Biologist Trainee, Research Assistant). Academic qualifications should specify, where possible, completion of an undergraduate college program with a curriculum that satisfies the requirement for certification as a Fishery Scientist by the American Fisheries Society.

   Fishery Biologist II (e.g., Management Specialist, Researcher, Hatchery Biologist, District Biologist, Planner, Water Quality Biologist). Completion of a graduate college program with a curriculum that satisfies the requirement for certification as a Fishery Scientist by the American Fisheries Society.

   Fishery Biologist III (e.g., Research Specialist, Biometrician, Planning Specialist, Water Quality Specialist, Supervisory Biologist). Completion of a graduate college program including a dissertation with a curriculum that satisfies the requirements for certification as a Fishery Scientist by the American Fisheries Society.

   Wildlife Biologist I, II, and III for entry levels should carry appropriate designations of responsibility and academic qualifications that satisfy certification as an Associate Wildlife Biologist by the Wildlife Society.

Acknowledgements

I thank Dr. Howard Tanner, Director, Michigan Department of Natural Resources, and Chairman of the Professional Improvement Committee, for making it possible to conduct these surveys, and the other members of the committee for their advice and counsel (Richard Denney, Eugene Hester, Richard Hopper, Robert Hutton, Frank Lockard, Don Minnich, Ronald Robinson, Gustav Swanson, William Towell, and Billy White). My thanks go to the agency administrators and personnel officers who provided the information and data for this report. Erik Fritzell, School of Forestry, Fisheries, and Wildlife at the University of Missouri provided helpful comments and support in developing and tabulating the surveys, and Thomas Baskett offered helpful encouragement and advice. My appreciation and gratitude are extended to Sanford Schemnitz for his excellent presentation of the report of the Professional Improvement Committee to the Executive Committee of the International Association of Fish and Wildlife Agencies, and for his delivery of this paper.

Literature Cited

Chapman, D. G. 1979. Fisheries education as viewed from inside. Fisheries 4(2): 18–21.

Cookingham, R. A., P. T. Bromley and K. H. Beattie. 1980. Academic education needed by resource managers. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 45: 45–49.

Donaldson, J. R. 1979. Fisheries education from the state perspective. Fisheries 4(2): 24–26.

Hester, F. E. 1979. Fisheries education from the federal perspective. Fisheries 4(2): 22–24.

Lackey, R. T. 1979. Fisheries education in the 1980's: The issues. Fisheries 4(2): 16–17.

Olmsted, L. L. 1979. Fisheries education from the private sector perspective. Fisheries 4(2): 26–28.

Influence of Cooperative Wildlife and Fishery Units On Graduate Education and Professional Employment

Rollin D. Sparrowe
Office of Cooperative Research Units
U.S. Fish and Wildlife Service
Washington, DC

Introduction

In June 1982, several private conservation organizations will join the Iowa State University, and the Iowa Conservation Commission, in a 50-year celebration of the Cooperative Research Unit concept. The first Cooperative Wildlife Research Unit began there in 1932 in response to a recognized need for trained biologists and scientific information in the field of wildlife conservation. The unique partnership between federal, state, university, and private entities that resulted, evolved into the current nationwide program. There are currently 21 wildlife units, 26 fishery units, and 3 combined fish and wildlife units at 31 universities in 29 states (Figure 1). The Fishery Research Units were added in 1960, and the program is still supported as a truly cooperative venture between the Fish and Wildlife Service, universities, state fish and wildlife agencies, and the Wildlife Management Institute. The Wildlife Management Institute is a cooperator in 21 Wildlife and 3 Fish and Wildlife Research Units.

There are serious doubts about the future of the nationwide program because of budget constraints within the federal government. These doubts have surfaced old and new questions about Cooperative Units and are causing re-evaluation of the need for the program as it exists as well as consideration of possibilities for a better program if it remains. The objective of this paper is to document accomplishments of the Cooperative Wildlife and Fishery Research Units with specific reference to their role in graduate education leading to employment in fish and wildlife professions. In order to fulfill this objective, I will describe how units work and what they do, and present data that may be used to evaluate their contributions in research, graduate training, employment in the fish and wildlife field, and other professional activities.

Operation and Support of Cooperative Units

The Fish and Wildlife Service has stationed biologists to serve as Leader and Assistant Leader at each Cooperative Research Unit to carry out the basic program. Those staff must meet graduate faculty requirements at the cooperating university, and essentially work within the framework of the university to carry out research with graduate students. The university provides the administrative structure, libraries, laboratories, faculty, and scientific atmosphere for training and research. Research information is disseminated through scientific publications, management reports, teaching and workshops, and provision of technical assistance to cooperating agencies. Each state fish and wildlife agency assists with base

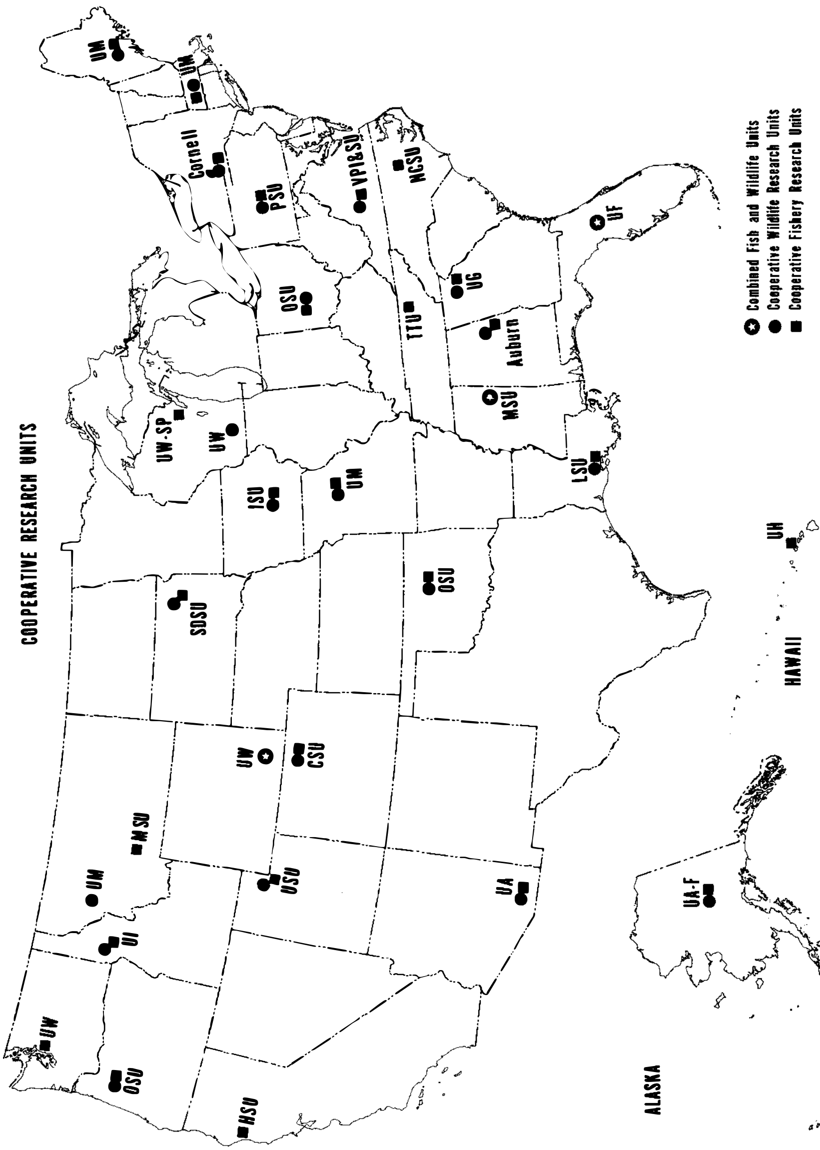


Figure 1. Location of existing Cooperative Research Units.

funding for student support and research. These and other base operating funds from the university, and the Wildlife Management Institute, allow the unit staff to develop research programs and build scientific expertise that attracts outside funding to finance most of the research (Table 1). In essence, support of each individual unit by federal, state, and private funds and the university structure provides a capability to conduct research and training, which the cooperating entities utilize to carry an increasing amount of their research load. At least nine states depend upon their units for their entire research program, and in many others the unit-university contact is the dominant research mechanism for the state agency.

The activities of the unit are guided by a Coordinating Committee, composed of representatives of each of the primary cooperators. Each unit develops, and periodically updates, a Program Direction Statement that indicates the focus for research and other activities that the cooperating agencies have agreed to support. The Unit Leader is charged with keeping up to date on the research needs of each of the cooperating organizations, and pursues funding for projects that help meet these needs. Funding for projects currently depends largely upon the information needs of state and federal agencies and private organizations or businesses, and comes to units in recognition of the expertise of unit staff and allied university scientists. Unit Leaders no longer function only as individual scientists training students, but are increasingly in a role of facilitating research through their peers at the university. Thus, a broader program of research is developed, drawing upon wider personnel diversity and allowing pursuit of a more directed program aimed at meeting agency needs.

A common misconception about Cooperative Research Units has been that they are independent research stations that conduct studies with federal funds on academic topics of their choice. In fact, Cooperative Units do not receive federal funds in their annual budget to conduct research. The federal base funds they do

Table 1. Support (in millions) for 50 Cooperative Research Units. Salaries utilize 95 percent of the Fish and Wildlife Service funds, and the remaining 5 percent plus state and university contributions provide an operating base to seek research funds. The Wildlife Management Institute provides $1,000 annually to each Wildlife and Combined Unit, and assists in obtaining research funds. In FY82 more than 90 agencies and organizations have funded more than $6 million in research through Cooperative Units.

	FY79	FY80	FY81	FY82
FWS base (salaries and operations)	$4.388	4.482	4.629	4.444
State agency base	$0.860	0.941	0.975	1.000
University (space, secretary, overhead waivers)	$1.000	1.300	1.500	1.600
Contracts	$3.517	4.795	5.799	6.000
Total	$9.765	11.518	12.903	13.044

receive are utilized for salaries and minimal operating costs. Almost all of the additional funds come to the units on a contract or similar basis, tied specifically to some contractual statement of work expected in return. A Fish and Wildlife Service field office, for example, can get extensive technical assistance from Unit Leaders, students, or even allied university staff, but actual field work, surveys, or hard research on new topics must be paid for. Such costs are essentially student stipends and laboratory or field expenses. If a management office lacks funds to support such a study, units can work with them to try to fund the work from other sources.

Provision of adequate operating funds has been a perpetual problem. While salary increases have been provided, the Fish and Wildlife Service has been unable to proportionately increase the level of operational funds needed for travel, equipment, and operations. Units do not have enough federal funds to comply with federal requirements for training, or to conduct strictly federal business. Likewise, university provision of secretarial help, storage, laboratories, and office space has not been consistent at all locations. The average contribution from state agencies is $20,000 annually, but this figure gives an inflated view of general state agency support. Many states still contribute a lesser amount; some at the same levels they started with decades ago. The Wildlife, and combined Fish and Wildlife Units, are generally supported by state funds at levels 50 percent higher than Fishery Units.

The Fish and Wildlife Service, and some state agency cooperators, have increased the level of their support through contracts for specific projects. These contributions are included in the contracts total in Table 1. Universities have increased their level of support through waiving indirect costs on contracts. These examples of increased support, plus the dramatic rise in outside contractual research (up 70% in 4 years), has broadened and strengthened many individual unit programs. However, the lack of better base support from immediate cooperators forces unit staff to spend much time seeking outside funding. Their personal involvement in research is reduced. Their ability to respond to specific needs of each cooperating agency is limited by demands of managing larger programs. In operating units in the future, a better balance must be sought between those conflicting forces. What has resulted is a mode of operation that is successful by some measures, but lacking in others.

Current Major Activities at Units

Research

The 50 Cooperative Research Units are currently conducting more than 730 research projects, ranging from short-term studies with a single student to multidisciplinary projects. In addition to base support, those projects are supported in FY82 by more than $6 million of basically contract research funds from more than 90 state and federal agencies, conservation organizations, and private companies. For example, the Oregon Wildlife Unit has pursued studies of spotted owls for almost a decade, which have led to major old growth forest management decisions in the Pacific Northwest. The U.S. Forest Service, and other agencies and organizations, have supported this work and received direct benefits from the results. A paper at this conference explores that research and related management decisions. Also in the Northwest, cooperative fishery units in Washington, Oregon, Idaho, and California are conducting 35 projects on salmon and steelhead problems in the Columbia and Klamath rivers and their tributaries. These research projects are significant efforts that benefit the states involved, several federal agencies, and power development corporations.

In the Midwest, the Wisconsin and Missouri Wildlife Units have worked with groups of states and the Canadian government to conduct Canada goose research, both in Canada and the United States. This work has pooled the financial and logistical support of the various governmental agencies, with help from the Wildlife Management Institute, and focused it on a common management problem. The results have direct application in management plans for discrete goose population units. In the Northeast, Massachusetts Fishery Unit research on Atlantic salmon, coupled with almost two decades of providing student labor and management assistance, has played a major role in the restoration of Atlantic salmon runs. These issues are among the very top priorities of the Fish and Wildlife Service and other federal and state agencies, and in each case the Cooperative Units are carrying a major part of the effort.

Similar efforts may be described for many areas of the country where research is coordinated through several units, and therefore several state agencies and universities, to bring expertise to bear on common problems faced by state and federal agencies. A major advantage to these agencies is access to a focal point for work, which can pool funding resources and which does not require an extensive investment in facilities and permanent staff. The Fish and Wildlife Service has recognized this value and is involving units or groups of units with its research laboratories in joint research thrusts. The Idaho Wildlife Unit continues to conduct a major part of the whooping crane restoration project with the Patuxent Wildlife Research Center. The new Wyoming Fish and Wildlife Research Unit is working with the Denver Wildlife Research Center on wildlife habitat research and on black-footed ferrets. Fishery units in Idaho, Washington, and Oregon are coordinating their research on salmonids with the Seattle National Fisheries Research Laboratory.

Much research, funded by various sources, satisfied needs of a particular cooperating agency without that agency having to carry a major portion of the funding. For example, the Cooperative Units have recently been involved in more than 50 research efforts that have direct bearing on endangered species programs. Only a handful are financed directly by the Endangered Species Program of the Fish and Wildlife Service, but endangered species benefit from the results of many other projects. Many important contributions are in studies that may not deal with an endangered species, but that have direct benefit and application through developing techniques or breaking new ground with allied species.

The Alabama Wildlife Unit has been supported by the states of Georgia and Alabama, the National Wildlife Federation, Auburn University, and the Fish and Wildlife Service to initiate research and management efforts with the eastern indigo snake. With joint support, a Recovery Plan has been drafted, techniques for propagation have been developed, initial actions toward recovery have been initiated with snakes produced at the unit, and research is being conducted to evaluate the survival of released animals. In this case, an entire "package" of research and management activity has developed through the unit that would not have occurred without the cooperative framework. The eastern indigo snake should be the most important beneficiary.

Special efforts to involve Cooperative Wildlife and Fishery Units in research on proposed water and associated land development projects began ten years ago with studies of stream channelization impacts. Pioneering studies were conducted at nine units in various ecosystems from North Carolina to Hawaii on both terrestrial and aquatic impacts. The Missouri Wildlife Unit began water resource work in 1970, and in 1974 began assisting with development and testing of new habitat evaluation techniques (HEP) for water development projects. This work produced prototype handbooks for use in field assessments on project sites. The Missouri effort has covered 12 years, involving many students and staff from about 20 state and federal agencies. As a result, more than half the Fishery and Wildlife Units have become involved in direct work in developing new methods and providing original field data for development of habitat evaluation methods. Massachusetts and Louisiana Wildlife Units took on large assessments of coastal bird colonies on the Atlantic and Gulf Coasts, and the data are incorporated in atlases of coastal resources. The Louisiana Units started studies of the Atchafalaya Basin fish and wildlife resources in 1971, and have continued to produce baseline information and new predictive tools for management of Basin resources.

The more than 100 research projects that annually deal with water and land developments through units are financed by a wide array of agencies, companies, and other organizations. The Corps of Engineers, Bureau of Reclamation, Environmental Protection Agency, many state fish and game and other resource management agencies, and private companies have benefitted directly from the research results. This strong involvement continues on the Columbia, Missouri, Mississippi, and other river drainages, and is expanding into studies on low-head hydro in New York and Massachusetts and acid precipitation in many affected areas of the Nation. The examples listed here are only a few out of the total.

There continues to be a wide array of significant, individual studies addressing specific problems, and long-range studies gradually unravelling complicated aspects of the biology of a single species. More than 25 years of research through a progression of graduate students at the Missouri Wildlife Unit has had significant impact on the management of mourning doves, and results of innovative research by the Missouri Fishery Unit on the use of variable length limits in the harvest of largemouth bass are used widely in many states. These and many other examples show direct management application of unit research results, fostered by the state-federal-private partnership through units.

Dissemination of Information

Publication of research results in refereed journals and other scientific outlets is acknowledged as a major tool for providing research results to users. For these reasons, it is an important part of graduate education to set the stage for future professional activity. The Cooperative Wildlife Research Units, including the staff and/or students, are responsible for 11 percent of the manuscripts published in the *Journal of Wildlife Management* from 1973 through 1980 (L.C. Hendry and R.F. Labisky, unpublished data). Table 2 summarizes publications by Cooperative Fishery and Wildlife Unit staff and students during a five-year period. These data

Table 2. Publications by Cooperative Research Unit staff and students from 1977–1981. Does not include 12 publications by combined Fish and Wildlife Units in 1981.

	1977	1978	1979	1980	1981
Journals, books, symposia					
Fishery Units	66	63	80	98	103
Wildlife Units	46	29	84	78	141
Subtotals	112	92	164	176	244
Technical reports, articles					
Fishery Units	61	78	34	65	91
Wildlife Units	38	44	64	26	33
Subtotals	99	122	98	91	124
Total	211	214	262	267	368

show a 74-percent increase in five years, with a 38-percent increase between 1980 and 1981. The latter change reflects both an increase in research funding and the advent of written performance standards that reaffirmed the importance of publication of research results. The Cooperative Units contributed 40 percent of the literature published by the Fish and Wildlife Service, as reported in its *Annual Report of Research* in 1979, and 24 percent in 1980.

Cooperative Units annually conduct and participate in about 40 workshops, short courses, and other organized activities to disseminate technical information. These range from regular annual involvement in training sessions for their state agency cooperator, to research management workshops that cover a wider range of audiences. Many of these are done on demand, with cooperative funding from the user. In addition, cooperative unit staff currently participate in or teach 80 courses annually to 1,500 students at the cooperating universities. These teaching assignments are most often in courses of special expertise taught by the individual unit staff, and also include team teaching with university faculty. The intent of unit personnel teaching is to strengthen existing graduate coursework, not to replace basic course offerings.

Cooperative research unit staff are utilized as technical experts by the primary cooperating agencies and advisory groups. The Fish and Wildlife Service depends upon cooperative units for assistance with development of habitat evaluation methods and background data, setting regulations, long-range planning, and permanent advisory groups on river basins, fish or wildlife populations, or assessments of management activities. Major involvements have included technical assistance to waterfowl flyway technical sections, assessing impacts of northern developments such as the Alaskan pipeline, technical advice on interpretation of the Boldt Decision regarding salmon rights in the Pacific Northwest, management of the Atchafalaya Basin, and fishery management in the National Park system. In many of these, and in other ways, the units directly aid the states as well. There are great educational benefits in a student being asked to participate in a management decision by the agency interested in his or her work. The depth of this involvement is great, and is increasing steadily.

Graduate Training

The federal staff at the 50 units serve as major professors to about 500 graduate students supported by research of the type described above. Several hundred additional students are involved in projects in which cooperative unit staff or equipment or other facilities play a significant role. The original purpose of the Cooperative Units was graduate training, and that still continues as the major focus through which units conduct research. While it offers some additional complexity to the student, involvement in the growing number of multidisciplinary or multiagency projects gives them a baptism of fire in preparation for professional employment.

The close agency contacts offer important additions to the atmosphere of graduate training at a university and even spill over into the undergraduate programs. Among students at unit schools there is a strong level of awareness of various agency activities and missions, both state and federal. This added dimension, plus the potential to work directly on cooperative projects with agency biologists, leads a number of well established universities to periodically inquire about a unit for their location. The Fish and Wildlife Service has not advocated additional units for the last decade. While some requests have been targeted at program building, the motivation in many cases is to add something that seems to be otherwise lacking, particularly the interagency cooperation, even in large well-supported university settings.

A significant effort in training minorities and women in the fish and wildlife field has grown since 1970, increasing enrollment from few in 1970 to about 150 (25%) in 1982. More than 30 of these are minorities. This has occurred partly through a growth of interest in our field and partly through specific extra efforts to assist such students with their education. The past results in employment are not spectacular: of about 100 women and minorities trained through units in the 1970s, only about 20 percent were hired by the cooperating state and federal agencies. This partly reflects the attitudes of individuals doing the hiring, but also reflects individual decisions made by the graduates themselves. The reasons for this relatively low success rate are complex and include students placing personal constraints on location, type of acceptable job, and timing of their availability. Current hiring freezes and agency cutbacks are limiting the number of job actions and have interrupted strong progress in employing women and minorities which had begun about 1980.

Employment of Unit Graduates

Two major factors that seem to enhance employability of unit graduates are (1) training through research on contemporary fish and wildlife issues that provide experiences in socio-economic aspects of resource management decisions, and (2) the array of contacts and personal exposure unit students get with agencies during their graduate programs. In states with units, in a significant number of states without units, and in federal natural resource agencies, unit graduates are in considerable demand for jobs. Approximately 25 percent of the students graduating from cooperative units are hired by state agencies each year and from 20–25 percent are hired by federal agencies (Table 3). I do not have data on the number of hiring opportunities this represents. While employing agencies, including state fish and

Table 3. Employment status of Cooperative Unit students from 1977–1981. Data include 5–8 percent students who left prior to receipt of degree.

Professional Categories	1977	1978	1979	1980	1981
Fish and wildlife biology					
Fish and Wildlife Service	21	26	17	11	13
Other federal agencies	11	22	21	13	15
State agencies	40	56	39	31	38
Foreign government	2	2	5	2	1
Private industry	16	10	14	10	18
University	20	21	28	25	18
Subtotals	110(71%)	137(75%)	124(73%)	92(72%)	103(77%)
Other biology	1	4	6	3	4
Peace Corps	3	1	0	1	0
Continued education	25	21	19	15	8
Miscellaneous	8	9	11	4	5
Subtotals	147(24%)	172(19%)	60(21%)	115(18%)	120(13%)
Unemployed	7(5%)	11(6%)	11(6%)	13(10%)	14(10%)
Totals	154(100%)	183(100%)	171(100%)	128(100%)	134(100%)

wildlife agencies, report long lists of applicants for their job openings, a majority of those applicants are often only marginally qualified. Dr. Richard Anderson's paper, presented earlier at this conference, explores some of those problems in depth.

Cooperative unit graduates are a major component of individual state and federal agency staffs as field biologists in both research and management and in administration. In the Fish and Wildlife Service, graduates of unit schools have served in all capacities, from technician to Director. Other federal, state, and foreign natural resource agencies employ graduates of unit schools in a variety of positions. An excellent example of the impact of the unit program and unit-trained personnel on an agency is found in Werner Nagel's book, *Conservation Contrasts,* published in 1970 by the Missouri Department of Conservation, which traces the history of that Department. Similar impacts are traceable throughout the country.

Currently about 125 biologists annually complete graduate degree programs through units, and more than 70 percent of these graduates are employed directly within the first year in fish and wildlife management. More than 90 percent of all graduates are employed or continuing their education, mainly in fish and wildlife or related biology, in the year after graduation (Table 3).

Many of the research projects currently funded through cooperative units are of such complexity and duration that they are extended beyond a graduate student's tenure. It is increasingly common that additional years of post-graduate work experience are gained in some technical capacity either participating in, or actually supervising, significant research endeavors. These kinds of experiences enhance employability and provide a more seasoned researcher or manager when the individual reaches the permanent job market.

Role of Units in Graduate Education in Fish and Wildlife Management

When the Cooperative Units began, there were few universities training fish and wildlife biologists. Addition of Cooperative Units provided a stable core of activity that included a limited number of staff, a funding base, and a focal point for interaction with resource management agencies. There are many more university programs today, which leads some to question whether the Cooperative Units are still necessary.

Proliferation of fish and wildlife curriculums, and especially graduate programs, is a problem to our profession. It no doubt contributes to the perception that there are too many schools graduating fish and wildlife biologists. Both the American Fisheries Society and the Wildlife Society have set standards for certification that a biologist has received appropriate training and experience. Many newly added wildlife programs at universities cannot provide the breadth of training adequate to meet these professional standards. Regional groups of professional societies have worked with these certification standards to try to limit further proliferation of programs. All of the universities that currently have cooperative unit programs turn out students who generally meet these standards and have no problems in meeting the expectations of the future employer. They also have some advantages in the breadth of their training, as described earlier in discussing employment potential.

The quality of graduate students recruited through units and cooperating universities is high. Large undergraduate enrollments have increased competition to enter graduate schools, and this is especially so at units because of their visibility. I believe that reductions in numbers trained and increases in quality of training are goals that a unit program in the future must pursue. Units and cooperating universities are recognizing the need to reduce the number of students. For example, reductions in additions to the job market by unit graduates were as follows:

	1977	1978	1979	1980	1981
Numbers Reported	154	183	171	128	134
Degrees Received	145	176	157	122	126

These data show that after a peak in 1978, numbers added to the job market decreased 26 percent and number of degrees granted among those same students decreased 28 percent by 1981. This is in spite of a 70-percent increase in contract funds during the same period. The increased research load has not been accomplished by increasing the flow of students to the job market, but through increasing the role of post-graduate, technician, and allied faculty involvement.

Universities are under financial stress at least as severe as any state or federal government entity. Major state universities, in addition to private schools, are entering periods of decline in funding and staffing that are already stressing fish and wildlife education. Allied university staff are increasingly involved directly in research studies funded through units. Direct funding covers student stipends and field expenses and faculty salaries, and indirect benefits from research often play a major role in supporting the cooperating university program. More than half of the strong graduate programs in fish and wildlife management in America include units as an important core capability. Without that capability, a significant number of these programs might fall below that critical number of professional staff that can offer a full curriculum to meet professional certification standards. If the Cooperative Research Units are discontinued, I believe that the fish and wildlife professions would have difficulty maintaining the cooperative ties that characterize this partnership.

Potentials for the Future

When the Unit Program began, the basis of the concept was an experienced biologist training a student in a one-on-one situation, supported by a cooperative framework. That basis is still present, but the shift in emphasis necessitated by growth in university fish and wildlife training, and increasing budget limitations, has broadened the concept of Cooperative Units. The Unit Leader in the future will be expected to assist in building a research and training program with recognized excellence in a definable area of fish and wildlife biology. Enough flexibility will be retained to cope with individual projects needed by the cooperators, but an identifiable thrust of the program will focus a large part of the energies of the unit staff and students, and resources of the cooperators, toward common objectives.

This conceptual approach has been followed in building the newest units that combine fish and wildlife research efforts. A hypothetical example would include a unit devoted to the study of wetlands, conducting approximately 75 percent of its research effort in wetland studies that fit a coordinated plan based on needs of the cooperating agencies in managing the fish and wildlife resources. Such an effort could include periodic involvements of hydrologists or economists to expand the application of the traditional biological data, with objectives leading to management applications. Within this framework, the Cooperative Units would likely evolve more than ever into a focal point for broader cooperative programs, rather than a one or two person individual research effort. One continuing advantage of units of the type described is that cooperating agencies can gain access to extensive expertise within the university, and even several universities, to focus on today's complex management needs.

This new conceptual framework is a different sort of challenge for the individual charged with running the unit, and offers somewhat different opportunities for the student. It is tailored to meet the needs of the times, providing relevance for an established training program through making it more flexible and directly productive in the conduct of its research. The true flowering of the concept of the Cooperative Units leads to coordinated, cooperatively supported efforts to solve common problems. There will certainly always be a need for individual research efforts as the core of a unit's expertise, but that will now have to fit into a larger, more focused program if the units are to continue to meet the needs of the nation.

If the Units persist in the future, I believe it is likely that existing programs will change significantly, perhaps reducing the number of stations and revising the mode of operation even further. If the program is retained but budgets cut further, it would be possible to devise a smaller but more strategically located program with a lesser number of units that would still meet the needs for which the program was established. Approximately two dozen units located on a basis of ecological regions of the nation, geography, agency interests, other existing capabilities, and needs related to resource developments, can be envisioned. The model "new unit" described earlier would fit in this context. One can envision units emphasizing large geographical aggregations of similar resources, such as coastal marshes, arid lands, agricultural impacts on wildlife, wetlands, Rocky Mountain energy developments, Arctic development, and so on.

The influence and potential of Cooperative Units was expressed very well by a university cooperator, commenting on the need to get Wildlife Unit Leaders to the North American Conference. He said, paraphrasing, "We need our unit leaders here to tell us what they are doing in research, and to exchange ideas. They have been visible leaders in our field for many years and have had a strong influence on our field. We need them as a bridge to what agencies are doing in wildlife conservation."

Not every unit scientist has become a national leader, but overall the impact of the program has been great. One has only to look into the ranks of professional societies and journal editors, as well as the agency staffs and literature of our field as described earlier, to find a solid contribution and leadership role. The importance of those units as part of the core of our profession is supported by their record.

Acknowledgements

I acknowledge compilations of data on research, publications, students, and other aspects of Cooperative Research Units by the Unit Leaders and Assistant Leaders, and staff in the Office of Cooperative Research Units.

Expanding Career Horizons Through a Formal Career Development Seminar

R. Douglas Slack, Richard L. Noble, Nova J. Silvy, and Raymond C. Telfair, II

Department of Wildlife and Fisheries Sciences, Texas A&M University, College Station

Introduction

Rapidly changing, and in some areas rapidly declining, employment opportunities have made the job search for undergraduates challenging at best. Academic institutions concerned with science education have only lately come to realize the importance of career planning and development in the academic setting. Concerns for career education and placement have been expressed by professional societies in various forms: creation of the American Fisheries Society Committee on Employment Opportunities; 1978 American Fisheries Society Annual Meeting Symposium on Fisheries Education (Chapman 1979, Donaldson 1979, Hester 1979, Lackey 1979, Olmsted 1979); placement surveys of The Wildlife Society (Evenden 1970, 1972, Spinks 1974, Zagata 1977, Hodgdon 1980a, 1980b); and general comments on relevance of education to employment (Brown and McCormick 1981).

Much of our growing awareness as professionals of the importance of career education has been triggered by a perception of the growing anxieties undergraduate students express as they approach the job search. Through discussions with students, individually and with our undergraduate student organizations, we arrived at the realization that our students at Texas A&M University (1) had not developed even a preliminary set of career goals and plans, (2) were not aware of the kinds and breadth of career fields their education equipped them to enter, and (3) were not familiar with even the basic rudiments of skills associated with conducting a job or graduate school search. The lack of preparation by our students and encouragement by our faculty and administration led us to develop a seminar course in Career Planning and Development. We wish to briefly relate the features of this course, present an analysis of the success of the course in terms of placement, relate changes in attitudes of students who have taken the course, and finally, present the results of a survey of schools with wildlife and fisheries curricula demonstrating the extent of career education efforts in undergraduate programs.

The Career Development and Planning Seminar

The Department of Wildlife and Fisheries Sciences at Texas A&M University has seven career-oriented curricula (Fisheries Ecology, Wildlife Ecology, Natural History, Aquaculture, Museum Science, Teaching, and Natural Resources Conservation) available to undergraduates. However, it has been our experience that students lack adequate knowledge of wildlife and fisheries employment opportunities to make a selection of academic and professional fields. We have found that students (1) have not developed career objectives, (2) do not have an appreciation for the breadth of opportunities in the wildlife and fisheries resources fields, and (3) are not adequately versed in the skills necessary for implementing a successful job or graduate school search. In response to these needs we developed a 1-credit seminar in 1978 entitled "Career Development and Planning."

Because a high proportion of our students enter as junior transfers, we offer our career seminar at the junior level—perhaps a little late for some to still be planning their careers, and a little too early for students to begin searching for employment. We have offered the Seminar (1 hour per week) each long semester since fall semester 1978. Our career seminar uses a team-teaching approach: one wildlife professor and one fisheries professor. This approach leads to more complete presentations and frequently leads to discussions arising from the different points of view of the fisheries and wildlife professors. Outside speakers are used sparingly to minimize emphasis on specific agencies, thus insuring discussions on a broader spectrum of job opportunities. Agency and private sector speakers are often more appropriately used in discussions on specific resource management questions in senior level courses.

Our course is divided into two segments: Career Planning and Job Search. Emphasis in the first part is placed on evaluating one's self and the profession. A professional career counselor works with us in reviewing Holland's (1974) occupational types and in administering a self-directed vocational search. We impress on the student that fishery and wildlife biologists have a stereotype profile, but that opportunities exist in our field for people with a range of interests and abilities. Each student is required to develop a career statement that outlines the duties and qualifications (both academic and personal) of his chosen career field. We proceed with an intensive coverage of professionalism, followed by a review of academic degree options available. Emphasis is placed on selection of elective courses, and each student is required to prepare a degree plan, including electives, that becomes his/her official requirement for graduation.

In the second part of the course, we discuss application procedures and cover the areas of possible employment, including graduate school. Major emphasis is placed on preparation of an effective resumé. We've impressed on the students that, in their absence, the resumé is their best representation. At the same time, we stress the importance of having credentials of significance (e.g., professional affiliations and work experience of any kind in their field) to include in the resumé. Each student is required to complete a personal qualifications statement (SF 171) for federal employment. During the first several semesters, we had a Civil Service Commission employee grade the applications and discuss with the class the in's-and-out's of federal application and employment.

As we have subsequently taught the course, we've begun to place more emphasis on non-traditional employment areas, particularly employment in the private sector. Although we have evidence that private employment attracts a substantial proportion of our graduates, we have felt somewhat limited in discussions because we have little feel for the employment potential of private industry. Studies are needed, such as those of Olmstead (1979), that project private employment in greater detail.

The course is quite demanding for 1 credit. Major assignments are due at approximately 2-week intervals. We impress on students the fact that the results of the job search are binary—they either get the job or they are rejected. We grade accordingly, returning assignments to the students until they get them right. Likewise, students are penalized automatically for failure to meet deadlines.

Course evaluations indicate that the students are pleased with the information they gain from the course. In spite of the heavy homework load, students recommend the course highly—frequently suggesting that it be required for all students. At the end of the course, each student assembles his entire semester's work into a Personal Portfolio that, after being graded, is returned to the student for future use. Favorable comments from students who have graduated indicate that they continue to use their portfolio to more effectively tackle the job market.

Evaluation of Seminar Course

Formal course evaluations were completed by students at the end of each semester. First-semester juniors typically reacted most favorably to the career-planning portion of the course: seniors were more interested in those parts directly related to the job search. Students occasionally suggested adding a discussion on the employment of women in natural resources.

Recommendations from students who have completed the course also serve as some testimony to its effectiveness. In recent semesters, seminar students have been polled at the beginning of the semester to determine how they learned of the course. Recommendations from other students and from advisors account for virtually all enrollments. Many of the students and our undergraduate student club have recommended that the course be required rather than elective.

We hypothesized that the effectiveness of the course could be objectively determined by comparing the subsequent employment of seminar students with that of students who did not complete the course. Of 274 graduates from December 1978 to August 1981, 112 (41%) had completed the course. Fate of all 274 students was pursued. Review of department employment files and surveys of advisors and some of our graduate students who had been in those graduating classes produced data on 173 persons. Data on 92 of the remaining 101 were obtained by telephone interviews of parents and relatives at permanent addresses. A graduate was first considered to be employed in natural resources if he held any full-time job in natural resources at the bachelor's level since graduation. All remaining graduates were assigned to "Further Education," other employment, or unknown status categories.

Employment statistics indicated very little difference between seminar students and non-seminar students (Table 1). Percentage of students pursuing further education and entering natural resource employment were only slightly higher for seminar students. The major difference noted was that a much larger percentage of non-seminar students (25.3%) entered "other employment," generally private enterprise, than seminar students (18.8%).

Although these statistics might lead to the conclusion that the seminar course does not enhance employment, some biases likely exist. Our evaluation is based on the assumption that a representative cross section of students enrolls in the course, whereas the course likely attracts disproportionately those students who are anxious or insecure about employment. For example, competition for jobs in conservation education has been least severe, and the course attracts few students from those curriculum options (Museum Science and Teaching). Nevertheless, 37 percent of the non-seminar students who entered natural resource employment were employed in conservation education. A similar bias is likely for students who are planning to enter graduate school.

Table 1. Fate of graduates of the Department of Wildlife and Fisheries Sciences, 1978–1981. Parenthesized numbers are percentage of total graduates.

	Career seminar students	Other students	Total students
Total graduates	112	162	274
Further university education	28 (25.0)	36 (22.2)	64 (23.4)
Natural resource employment	44 (39.2)	59 (36.4)	103 (37.6)
Other science and agriculture	9 (8.0)	11 (6.8)	20 (7.3)
Military	4 (3.6)	6 (3.7)	10 (3.6)
Housewife	3 (2.7)	3 (1.9)	6 (2.2)
Other employment	21 (18.8)	41 (25.3)	62 (22.6)
Unknown status	3 (2.7)	6 (3.7)	9 (3.3)

Evaluation of the course in this manner is also limited by the transfer of information that occurs outside the classroom. For the past two years, over 50 percent of the graduates have taken the course. Information is communicated to some extent from seminar students to others. Resource materials on the course bulletin board are available for all students to use. Finally, the overall awareness of students and faculty created or enhanced by the course may have led to a perceived increase in emphasis on career development and planning that likely affects all students in some manner.

Further evaluation of the career-seminar course was accomplished through a pre- and post-course survey of students' perceptions of their plans to continue in the natural resources field after graduation. We hypothesized that students who had taken the career-seminar course would have an expanded view of employment opportunities and the need for graduate education and should have answered these questions more affirmatively than would students who had not taken the course. These surveys were accomplished through a questionnaire given to students at the beginning of their first course in the department, usually taken during their sophomore year, and repeated at the beginning of the last course taken in the department, usually taken during their senior year. Because the career-seminar course was designed for students in their junior year, the questionnaire was usually administered prior to and again after the students took the career-seminar course.

Trends from the questionnaires were similar for students taking the career-seminar course and those not taking the course (Table 2). Students taking the seminar course did not differ in their desire to continue in the field; but did differ in their early perception of the value of a graduate education. Students who would later take the seminar course were significantly ($P < 0.05$) less likely to consider graduate school than were students who would not later take the seminar course. This result reinforced our speculation that the course did not attract a random group of students. Students who early in their career valued the graduate degree may have considered a "job-hunting course" not to be of value and, therefore, did not take the seminar course. By the time both groups had taken their last department course, attitudes toward pursuing graduate school were similar (Table 2). This was also reflected in the greater percentage of seminar students who

Table 2. Comparative responses of students taking career-seminar course to those not taking course, based on questionnaires given before and after seminar course was taken or would have been taken. Numbers in parentheses are percentages.

Response	Do you plan to work in field after graduation?				Do you plan to continue your education?			
	Seminar students		Non-seminar students		Seminar students		Non-seminar students	
	Before[a]	After	Before[b]	After	Before	After	Before	After
Yes	45(90)	30(81)	172(92)	129(83)	18(36)	13(35)	90(48)	70(46)
Maybe	2(4)	2(5)	8(4)	14(9)	14(28)	6(16)	64(34)	32(24)
No	3(6)	5(14)	7(4)	13(8)	18(36)	18(49)	32(17)	50(33)

[a]Questions given to students taking first course in the department and prior to taking seminar and questions given to students taking last course in the department and after seminar course was taken.

[b]Questions given students taking first course in the department (usually during sophomore year) and prior to when seminar course would have been taken (usually during junior year) and question given to students taking last course in the department and after (usually senior year) seminar course would have been taken.

actually continued their education (Table 1). The seminar course apparently increased students' awareness of the value of graduate education.

Career Education in the United States

To evaluate the extent and success of career education efforts in undergraduate programs throughout the U.S., we sent a questionnaire to 90 schools known to have wildlife and/or fisheries curricula. The National Wildlife Federation's *Conservation Directory* and membership in the Educator's Section of the American Fisheries Society were used to identify appropriate schools. No attempt was made to identify every wildlife and fisheries program. Whenever possible, questionnaires were addressed to colleagues in hopes of increasing return rate. Questionnaires were accompanied by a brief introductory letter that explained the objective of the instrument and insured anonymity of individual responses.

The survey instrument included 13 questions that requested information on size of undergraduate program, nature of departmental career education efforts, extent of career education program evaluation, type of placement services utilized, placement success, and cooperative education programs. Eighty questionnaires (88.8%) were returned, including those from four schools with no currently identifiable undergraduate curricula in wildlife and/or fisheries sciences. However, not all questions were answered by all respondents, leading to variable number of responses used in subsequent analyses.

The vast majority of schools (93%) used a combination of two or more career education mechanisms. In order of importance (% responding), these were as follows: faculty advising (97%); university placement offices (76%); university or student professional society programs (59%); formal credit course or seminar (47%); regular outside speakers (46%); non-credit course or seminar (12%); miscellaneous techniques (20%). Several schools suggested in comments that their career education was accomplished in credit courses with broader objectives (e.g., portions of an introductory conservation course). Most schools indicated concentrated career education efforts during the junior and senior years, although many maintained a career emphasis throughout a student's four years. Of the responding schools, 95 percent felt their programs either had reached current levels during the last five years or represented decided increase in efforts. Only 5 percent of the respondents reported a decrease in efforts. These data seem to reflect the growing concern among wildlife and fisheries educators regarding the career planning process.

Employment and graduate school placement estimates were highly variable. Annual employment in natural resources related positions averaged 38.4 percent ($N=69$) with a range of 5–90 percent. The percentage of students that go on to graduate school averaged 23.9 percent ($N=71$) with a range of 3–70 percent.

In spite of the fact that almost 45 percent (30 of 67) of the schools had some form of recognized career education efforts for more than 10 years, 74 percent of the responding schools had not evaluated their efforts. Although we did not ask for mechanisms of evaluation, several respondents indicated that monitoring of placement was used. Several others offered that their progress had been only evaluated "informally." Given the continued likelihood of reductions in certain public agency opportunities, the generally reduced numbers of students entering the renewable natural resources professions, the existence of evidence that career advising has been rated by most graduates as average to poor to nonexistent (Brown and McCormick 1981), and the rapidly changing opportunities for graduates in the private sector, on-going evaluation of career education efforts seems to be a high priority.

A rather recent innovation among most wildlife and fisheries departments has been the development of cooperative education programs. Cooperative education, used for years by many engineering colleges, provides excellent opportunities in career education as well as potential placement opportunities. Forty-four (60%) of the responding schools had some sort of cooperative education efforts for undergraduates. The overwhelming majority (86%) of these schools have from 0–10 co-op students, but three schools reported greater than 30 students enrolled in cooperative education programs. Interestingly enough, those schools with a cooperative education program reported 42.8 percent employment in natural resources related fields as compared to 31.2 percent employment from schools without a co-op program. The percentages of students placed in graduate programs was similar regardless of presence or absence of co-op education programs (with co-op program, 23.5%, without co-op program, 24%). Differences in employment associated with co-op programs could not be attributed to higher employment among co-op students alone, but rather may reflect an increased emphasis on career development and placement in co-op schools.

Employment of Graduates

Our survey of employment of our graduates provided data that reinforce the career development seminar's emphasis on exploring the wide variety of employment available. It also has implications for development of curriculum, student career counseling, and intelligent choice of elective courses.

Employment of graduates in the renewable natural resources field, as we perceive it from our department's perspective, was categorized by type of employer (Table 3). Natural resource employment in the private sector by far exceeded that in any other category and was nearly equal to that in state and federal agencies combined. Private employment is elaborated in Table 4. The large employment in aquaculture can be directly attributable to our specialized undergraduate curriculum option. Somewhat surprisingly, employment by environmental consulting firms was negligible, in contrast to the opportunities in that area less than a decade ago.

It would be a mistake to limit discussion on breadth of employment to those students who directly enter natural resource positions. Most graduates who pursued further education entered graduate school in natural resource fields and were employed on a part-time basis in research and/or teaching. These students, together with those graduates who entered natural resource positions, comprise 61 percent of all graduates. In addition, 20 graduates entered employment in science and agriculture, principally agricultural research, ranching, and computer programming, for which they were prepared by a portion of their undergraduate coursework. Certainly those entering the military as commissioned officers and many of the graduates entering the private sector qualified on the basis of their holding a college degree.

Table 3. Numbers and percentage of graduates of the Department of Wildlife and Fisheries Sciences employed in natural resource positions by various employers, 1978–1981.

Employer	No. employed	Percentage of natural resource employment	Percentage of all graduates
Federal agencies	14	13.6	5.1
State agencies	17	16.5	6.2
Universities	9	8.7	3.3
Municipalities	16	15.5	5.8
Secondary schools	12	11.7	4.4
Private industry	29	28.2	10.6
Foreign[a]	6	5.8	2.2
Total	103	100.0	37.6

[a]Includes 5 international students who returned to their countries and were assumed to be employed in their field.

Table 4. Employment of graduates of the Department of Wildlife and Fisheries Sciences in private sector natural resource positions, 1978–1982.

Employment areas	No.
Fish farms	11
Ranch wildlife management	3
Public utilities	3
Forestry	3
Marine fisheries	2
Youth camps	2
Art	2
Consulting firms	1
Game farms	1
Environmental groups	1
Total	28

Implications

Our surveys of placement of graduates reinforce our perception that the field of natural resources served by wildlife and fisheries science graduates is a diverse one. Certainly, as educators, we would be remiss to be training our students for a narrow field of specialization or any particular employer. As advisors and career counselors, we must take the responsibility to know the breadth of the field and apprise students of the comparative advantages and disadvantages of specialization versus generalization. The career development course can effectively formalize this counseling effort, while simultaneously increasing the student's skills in conducting the job search.

Our experiences in the career development course, coupled with the data on diversity of employment, have further implications for curriculum. Specialized curricula often force students to make at least tentative career decisions early in their college program, frequently prior to their realization of the breadth of wildlife and fisheries. In our program, we are initiating a freshman orientation since students usually must make a decision between terrestrial, aquatic, or educational curricula after one year, then further define their choice after the sophomore year to one of the seven curricula.

It is obvious from our national survey that most fisheries and wildlife programs consider career counseling to be an integral part of their teaching program. Employment statistics—ours and those of the other institutions—indicate that wildlife and fisheries employment is a reality for students graduating with a bachelor's degree. Undergraduate counseling would be particularly enhanced by information on career opportunities and proportions for the various employment sectors (e.g., state, federal, municipal, private). Professional societies, who in the future will depend on today's students, should take the lead in developing meaningful projections for employment.

Acknowledgements

We thank V. Droessler for help in course development and analyses of survey results. We express appreciation to L. Folse, C. Hopkins, and W. Swank for help in administration of perception surveys to our undergraduate students. A special thanks to all persons who gave their time to complete surveys on the extent of career education programs at their universities.

References Cited

Brown, K. L., and J. F. McCormick. 1981. Education and employment of ecologists in the United States. Bull. Ecol. Soc. Amer. 62: 193–196.

Chapman, D. G. 1979. Fisheries education as viewed from the inside. Fisheries 4: 18–21.

Donaldson, J. R. 1979. Fisheries education from the state perspective. Fisheries 4: 24–26.

Evenden, F. G. 1970. Survey shows placement of 1969 wildlife graduates. Wildl. Soc. News 127: 17.

______ . 1972. The 1971 graduate placement survey. Wildl. Soc. News 138: 3.

Hester, F. E. 1979. Fisheries education from the federal perspective. Fisheries 4: 22–24.

Hodgdon, H. E. 1980a. Enrollment of women and ethnic minorities in wildlife curricula: 1977. Wildl. Soc. Bull. 8: 158–163.

______ . 1980b. Employment of 1978 wildlife graduates. Wildl. Soc. Bull. 8: 352–355.

Holland, J. L. 1974. The self directed search—a guide to educational and vocational planning. Consulting Psychologists Press, Palo Alto, Calif. 14pp.

Lackey, R. T. 1979. Fisheries education in the 1980's: The issue. Fisheries 4: 16–17.

Olmsted, L. L. 1979. Fisheries education from the private sector perspective. Fisheries 4: 26–28.

Spinks, J. L., Jr. 1974. 1973 graduate placement survey. Wildl. Soc. Bull. 2: 97–99.

Zagata, M. D. 1977. 1976 graduate placement survey. Wildl. Soc. Bull. 5: 208–210.

An Integrative Approach to Resource Management Education

Ronald T. Rollet and Richard Block
University of Michigan, Ann Arbor, Michigan

Consider the following design solutions to this integrated resource management problem: Design an economical, socially acceptable, transportation vehicle for an arid environment, capable of traversing long distances without roads or readily available fuel sources.

This is one solution (Figure 1) designed by a single designer acting alone. Let's call it a horse designed by an individual. You can see that designer has modified the basic design—probably in response to complaints from the client, an Arabian trader/merchant.

Now let's look at another solution (Figure 2). This was designed by a multidisciplinary team of resource professionals working together. Let's call it a camel designed by a committee.

If you were the client, which solution would you buy?

Whoever said that a camel is a horse designed by a committee didn't understand either the camel or the group problem-solving process. When you think about it, the camel is a masterpiece of design, well adapted to its environment, efficient and economical, patient and durable. And the committee that reputedly designed it combined the talents of: a terrestrial ecologist, a wildlife biologist, an engineer with an understanding of appropriate technology, a social scientist with a mid-eastern cultural perspective, an international resource economist, a communications specialist with research in the diffusion of innovations in developing nations, and a planner/designer capable of giving all this knowledge an appropriate physical expression. The point is (as you know from your daily work experience): It can't be done alone.

1. Real world problems don't fit neatly into separate areas of expertise. Environmental/resource issues are by their very nature complex and interwoven, often extensive in scale.
2. Professional practice, otherwise known as the real world, requires a broadly skilled group of people who can work together to arrive at effective solutions.

At the School of Natural Resources, University of Michigan, we have been exploring a teaching/learning/research approach to help us meet the challenges of such problems. We call it the Integrative Studies Center.

I like to think of it as the conceptual equivalent to a camel designed by a School of Natural Resources, and we hope the Integrative Studies Center is as well suited to its peculiar academic environment as the camel is to its habitat. The purpose of the Integrative Studies Center is to provide a context and support to students, teachers, outside professionals, the public, and resource agencies to study intensively, critical and representative problems in the field of environmental resources from a multi-disciplinary point of view.

The Integrative Studies Center did not come about overnight. The roots of the center concept can be traced to the year 1882 when the University of Michigan offered "The Science of Forestry," the first full-semester forestry course offered

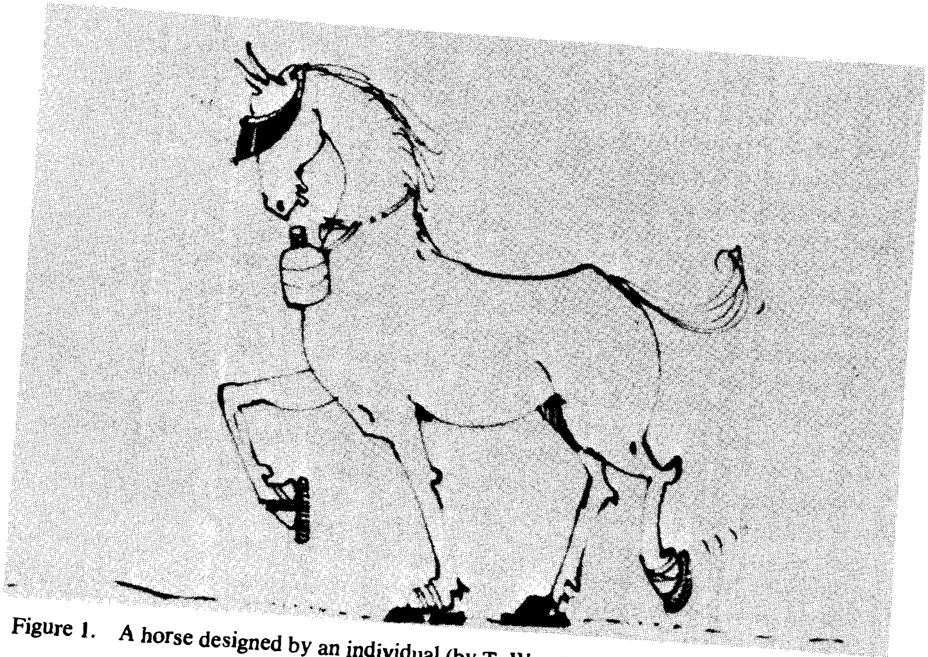


Figure 1. A horse designed by an individual (by T. Wang).

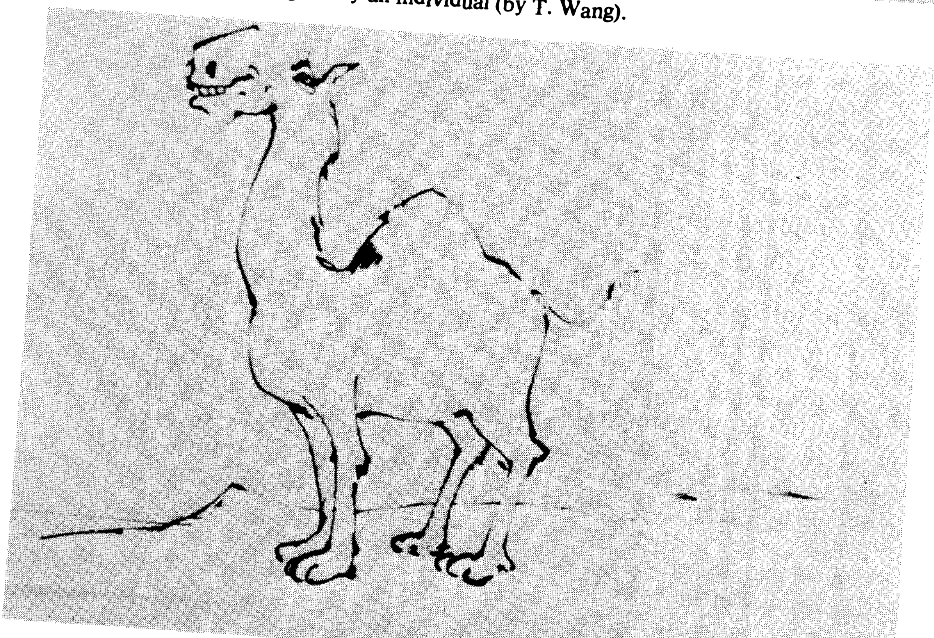


Figure 2. A camel designed by a committee (by T. Wang).

in the U.S. Uniquely enough, this pioneer course originated in the Department of Political Science. Even though it was a century ago, the course recognized the connection between forestry and the social and biological sciences. This early interdisciplinary concept is still at the heart of the Integrative Studies Center philosophy. The School of Natural Resources evolved from the School of Forestry and Conservation, the first school of its kind, founded in 1927. The School received its present title, School of Natural Resources, in 1950 under Dean Samuel Trask Dana. School faculty recognized the importance of integrating the traditional academic areas within the School, so, in 1970, department divisions were dissolved and program areas were established.

In 1976 the faculty began looking at the case study method as a means of increasing the interaction between disciplines in integrative approaches to natural resources studies. Given the emphasis on field-based research and education, it seemed natural that case studies would provide a positive experience in learning how to approach complex natural resource problems.

The initial effort was to be a voluntary activity within the School, allowing faculty to decide the level of their own involvement. The case studies would be focused in a "Problem Centered Learning Network." In 1977 the School sponsored an in-house workshop to further explore the potential for incorporating integrative studies at a more basic level. Over three-quarters of the faculty participated and the momentum encouraged a year-long planning process that resulted in the formation of the Integrative Studies Center, which became a major focus of integrative experiments within the School of Natural Resources.

In May 1979 the National Science Foundation funded, under the CAUSE Program—Comprehensive Assistance to Undergraduate Science Education—with a matching budget from the University of Michigan, the Integrative Studies Center, making it possible to develop a formal integrative program in the School of Natural Resources and establish a series of new undergraduate courses.

The grant supported the development of three courses: Freshman Discovery, an introductory resource management course for first semester undergraduate students; Integrative Field Studies, a field course for the School's summer program; and the Integrative Studies Studio, a capstone course for seniors in their last semester of college. A common focus of all three courses is problem-solving and communications skills. Each course provides students with the opportunity to identify and define resource problems, develop alternative solutions to these problems, and communicate their conclusions to the course faculty and resource professionals. In all three courses, group and individual exercises conclude with thorough written reports, oral presentations, and sometimes a combination of the two.

Freshman Discovery introduces students to resource management problems in the context of two case sites in Michigan. Each of the (two) 30-student class sections concentrates the semester's studies on one of the sites, the Sleeping Bear Dunes National Lakeshore or the Pigeon River Country State Forest. The semester begins with a staff supervised, but student organized, field trip to their respective case study areas. The students meet with resource professionals at both sites as well as with local business people and area residents. At the Sleeping Bear Dunes, students interact intensively with respresentatives of the National Park Service. The students at the Pigeon River meet with foresters and wildlife biologists from the Michigan Department of Natural Resources. During the three- and four-day trips the classes are oriented to the physical parameters and the resource issues that will be the focus for the semester. This initial experience is designed to ground the ensuing course exercises in a realistic context for the students.

Freshman Discovery is not based on a structure of lectures, but follows a modified version of the interactive pedagogical method called Guided Design by having small groups of five or six students work through different resource issues. Weekly exercises focus on a broad range of resource management issues including fisheries, wildlife, forest resources and economic development. In this format the students are learning the problem solving process in the two-hour class periods and researching course content in their time away from class. Each exercise places students in the role of resource managers faced with a specific problem or assignment for which they must provide a management plan. The Sleeping Bear Dunes National Lakeshore case presents many management challenges in the areas of recreation, Native American fishing rights and compatible commercial development. The dunes are presently caught up in the controversy over returning some of the National Park Service lands to the states. The apparent conflict between oil drilling and the management of other resources, such as forests, wildlife, and recreation, is the primary management problem in the Pigeon River Country State Forest.

A presentation, or report, is made at the conclusion of each exercise. A panel of "hearing officers" (consisting of School faculty, resource professionals, graduate researchers, and visiting scholars) attends each of the oral presentations and critically evaluates the students' work. The hearing officers frequently play the role of Natural Resource Commission members or state and federal agency representatives. After four years of offering Freshman Discovery, over 50 percent of the School of Natural Resources faculty have participated as hearing officers in the course presentations, a number which has been increasing each successive year.

A resource library for both cases, the Sleeping Bear Dunes and the Pigeon River, has been compiled and is available for student research in the classroom. The case study library consists of primary documents, reference materials, as well as extensive visual documentation and personal interviews with key figures. In addition, a series of 3/4″ videotapes has been prepared that covers selected interviews with resource professionals or site images appropriate to each week's topic. This is supplemented by slide sets and audio tapes on both cases.

One of the goals of this multi-faceted approach to resource management education is to provide incoming first-semester natural resources students with an introduction to the breadth of the natural resource field and an experience in putting these diverse subject areas together in the context of a single case site. Students are assigned a pass-fail grade at the end of the course.

Integrative Field Studies, the second Integrative Studies Center sponsored course, provides students with the opportunity to apply newly acquired field skills to a resource management plan. Integrative Field Studies is taught at Camp Filibert Roth, the School's summer teaching and research facility, located in Michigan's Upper Peninsula. There are two successive summer sessions for students at Camp Roth. The courses offered during the first session include Aquatic Ecology, Entomology, Ornithology, Recreation Planning and Integrative Field Studies. All students attending the first session register for Integrative Field Studies and for two of the other classes. Integrative Field Studies opens the students' field experience at Camp Roth with exercises in mapping, orienteering, and basic field sampling. This forms the basis for a specific site inventory and the development of a management plan at the end of the six-week term. The course integrates the skills and knowledge gained in the other camp courses as students are divided into site teams. Seven or eight sites in the Ottawa National Forest are selected so each student group prepares a management plan for a unique site. The sites are chosen to include recreation along with other wildlife, forestry, fishery, cultural and historical features.

The final site project ties the term's work together as the teams prepare written and oral reports on their respective sites. In preparing the specific site plans the students frequently contact and meet with resource professionals from the U.S. Forest Service and the Michigan Department of Natural Resources. Surveys have also been conducted of the people recreating on or near student study sites. The mapping, measuring and orienteering exercises all come to life as students prepare their reports during the last exhausting week at Camp Roth.

The oral presentations, the last activity for students attending Session I, are given at the Sylvania Visitor Center on the Ottawa National Forest. In the past, representatives of the Forest Service have attended the student presentations and shared ideas and suggestions with the site teams. Students receive a letter grade at the end of the course.

This past summer, the Integrative Studies Laboratory was completed and opened for use at Camp Roth. Designed for use in conjunction with Integrative Field Studies, this newest addition to the School's Upper Peninsula campus houses a complete darkroom, a graphics workspace, and six conference rooms for student groups. Because of the isolation of Camp Roth, a workshop in slide-processing is conducted during the first session to enable students to produce their own slides for the final presentations.

The final presentations are videotaped and kept on the Ann Arbor campus for students to review on an informal basis. The videotapes are instructive in helping students improve future presentation organization and their own communication skills.

Following closely in the path outlined by Freshman Discovery and Integrative Field Studies is the Integrative Studies Studio, a "capstone" course for graduating seniors in natural resources. Like Freshman Discovery, the Studio also has a case site focus. The Integrative Studies Center, besides providing a base for the development of the new undergraduate courses, has also been home to several case studies. Coastal issues in the Great Lakes was selected as a focus for the development of a regional case study during the winter term 1980. After two years of evolution, the case was refined to a specific case site: the western shoreline of Lake Erie at Monroe, Michigan. This is the focus for the Studio because of the site's diversity of natural resource problems, the manageable size of the case site area, and its close proximity to the Ann Arbor campus. The Monroe site contains significant wetlands, state recreation areas, public and private marinas, urban development, three electric power generating stations (one of which is nuclear), industry, and agriculture, all of which, when combined, create complex management problems. There are four scenarios, or resource problems, that students address during the semester. Each is designed to build on subsequent exercises, leaving the student with a semester's experience in defining resource problems and providing possible solutions in the context of an actual site.

The Integrative Studies Studio is taught through a series of seminars, site visits and numerous guest lectures. The activities of the 11 students in the course are coordinated by a senior faculty member, assisted by another professor and two graduate teaching assistants. Faculty from wildlife management, fisheries management, forest resources, resource economics, and resource policy make presentations on the relevant issues at the Monroe site. In addition, students regularly meet with city and county planners, representatives from the Michigan Department of Natural Resources and other state agencies, and private consultants. The field visits include tours of industry, utilities, state and local parks, wetlands, and marinas.

Students individually present their scenario responses to a panel on the first exercise and then to the entire class on the subsequent three assignments. Videotape is used to record student presentations to continue the effort in developing students' oral communication skills. Written reports are also submitted for each of the scenarios. Students receive a letter grade at the end of the course.

These courses have received intense faculty commitment and require a special budget to assist with travel expenses and materials. Each course seeks to develop the students' ability to address complex resource management issues and improve student communication skills. All three courses are non-traditional in their approach to teaching. But, are they working?

There is good reason to believe that they are. An extensive program evaluation was initiated with receipt of the NSF grant in 1979. Conducted by the University's Center for Research on Learning and Teaching, researchers have tracked student performance, studied retention of students in the School of Natural Resources, surveyed faculty attitudes and measured student response to the courses. The researchers carefully selected a control group of students for the evaluation of student performance and retention in response to taking Freshman Discovery. Of the 36 faculty interviewed, 96 percent were aware of Freshman Discovery, the longest running course under the Integrative Studies Center program. More than two-thirds of the faculty reported consulting with the project director about the course. The greatest area of growth has been the continual increase in faculty serving as hearing officers—now more than 50 percent. Faculty that had opinions about course outcomes from Freshman Discovery predicted favorable results for students. About half of all those interviewed, and the majority of those expressing opinions, said that Freshman Discovery would increase student knowledge and satisfaction with School of Natural Resources teaching. An equal number stated that the course contributed to student awareness about the environment. More than 80 percent of the faculty considered Freshman Discovery a success and 69 percent considered it worth the effort.

Student reaction to Freshman Discovery was also measured. In general the class evaluations have placed the course in the top quarter of all classes taught at the University.

The positive written comments from students about Freshman Discovery indicated that the students learned to discuss issues and understand the complexity of environmental problems. Students pointed out that the course contributed to building group communication skills as well as strengthening individual self-confidence.

The student evaluations for Integrative Field Studies followed a positive trend, with the ratings for lectures, exercises and demonstrations all above average and the optional instruction sessions receiving especially high ratings. Students also praised the teaching staff of Integrative Field Studies, citing their enthusiasm, sensitivity to student difficulties with coursework, willingness to meet with students outside of class, and preparation for classes. Although the questionnaires used during the first offering of Integrative Field Studies were not a perfect match for the University's standard Instructor Designed Questionnaire, the Center for Research on Learning and Teaching researchers concluded that the positive rating placed the course in the upper 25 percent of all university courses. Integrative Field Studies also compared favorably to the other courses offered during the first session at Camp Roth.

No evaluation has been made of the Integrative Studies Studio since this is the first semester that the course has been offered. An extensive evaluation will be conducted at the end of this semester.

The Center for Research on Learning and Teaching study also tracked the performance of students from Freshman Discovery, matching them against a carefully selected control group of School of Natural Resources students. The analyses showed that over 90 percent of the students who enrolled in Freshman Discovery continued their studies in the School of Natural Resources, compared to 57 percent of students who did not take the course. The analyses also showed that students who took Freshman Discovery received better grades in subsequent School of Natural Resources courses than did students who did not take the course, with the experimental group averaging between 0.15 and 0.70 of a point higher out of a four-point scale. Finally, the analyses suggested that the differences between Freshman Discovery participants and nonparticipants were attributable to the course itself and not to such factors as uncontrolled differences in aptitude or motivation.

We are pleased by our successes in these courses, but we also heavily depend on the evaluations to direct our future efforts. The evaluations and surveys did identify a number of areas in which we needed to make changes or adjustments. Faculty were interested in the tremendous commitment of resources to Freshman Discovery: four faculty members (two next fall) and teaching assistants to a class of 60 first semester students, not to mention the involvement of faculty as hearing officers. Questions arose over the possibility of Freshman Discovery becoming a required course in the undergraduate curriculum and the challenge of handling 150+ students.

The School's commitment of space to the Integrative Studies Center for projects and courses also concerned some faculty members. Although the Integrative Studies Center has absorbed only one laboratory space, the related renovations of classrooms and a learning center left the appearance of a substantial annexation of space by the Integrative Studies Center.

Students in Freshman Discovery were most critical of the written assignments. Second to problems with written assignments were student problems in dealing with a teaching format that emphasized working in small groups. In response to student comments, the course exercises were rewritten during the summer of 1981, and a new set of Guided Design assignments were in place this fall. The Fall 1981 analyses and evaluation of the course and other aspects of the Integrative Studies Center will be completed at the end of the project.

The main student criticisms of the first offering of Integrative Field Studies were the grading process and a need for better organization of the course materials and time schedule. The grading process was refined for the summer session 1981 to address the first weakness. In response to an apparent problem in organization, the course schedule was modified in 1981 and a workbook was developed and used by students in the second run of Integrative Field Studies. The workbook was produced by a School of Natural Resources graduate student in cooperation with the Camp Roth and Integrative Field Studies faculty.

One must be an evolutionist in the world of education, especially when concerned with experiments in innovative teaching. Just as we pointed out our strengths, which a creationist might say were all there in the initial conception of the Integrative Services Center, we must adapt and adjust as we progress, even if it means letting go of some ideas along the way. The Integrative Studies Center courses have been evolving, changing year to year, as we improve our teaching, the materials, techniques and assignments. Many of our present strengths were not there in the beginning, but are now taking shape. We learn along parallel lines as the students learn to face complex resource management issues in the courses. The evaluations are positive and encourage our direction toward an integrative approach to resource management education. It's now time to reflect on the illustration of the camel and contemplate, with a cup of coffee in hand, the question—"One hump or two?"

Project Learning Tree and Project WILD, Resource Models for Education at the Elementary and Secondary Levels

Clifford R. Hamilton
Oregon Department of Fish and Wildlife, Portland

Upon entering college in pursuit of a career in resource management, most students have already completed 12 or more years of elementary and secondary school education. Well before completing high school, young people have already formed most of their prejudices, attitudes, beliefs, and ideals. Intellectual growth may have also begun to decline. (Mussen et. al. 1963).

Whether we are involved in the training of resource management professionals or raising the environmental literacy of our citizens, we cannot escape the reality that most of our personal traits have already formed before entering the higher education arena. From the perspective of the resource manager, there is ample evidence that education has thus far failed to develop a conservation ethic or understanding during those years (Hobart 1972). Recently, in testing performed by American Education Services, Inc. on behalf of the National Shooting Sports Foundation and the International Association of Fish and Wildlife Agencies, school-age youngsters reportedly exhibited "a disturbing lack of knowledge about the current status of wildlife species. . . ." The Foundation reported the study revealed that youngsters think white-tailed deer, elk and antelope are in danger of extinction and know very little about the role of wildlife management in conserving America's wildlife.

To be sure, some schools are providing a good natural resource background, but that number is clearly limited. Every state can boast of innovative programs covering wildlife conservation, forestry, soil and water management, or similar subjects. Most of these are at the secondary level. Resource management education programs at the elementary level are much harder to find. This is due to the necessarily basic nature of education in these grades.

At either level, wildlife and other natural resource classes are considered non-traditional classroom subjects. To cover these topics, most teachers must add them into a curriculum already packed with required material. Even teachers motivated to provide resource education will have a hard time fitting it in. This is not the fault of the teacher or the school system. If we are to assess blame, it belongs with the management agencies, both public and private. Agencies and organizations have produced an avalanche of literature, films, and resource packets nationwide. Much of the content is excellent. Little of it, however, is suitable for immediate use by teachers with their students. Much of it focuses on resource information like life histories, management activities, or a perspective on some resource-related issue. Teachers often view this material as technical and biased. To them it looks little different from that offered by any other special-interest group. Consequently, this add-on type of "education" material has had limited success in today's classrooms.

Wildlife and other resource subjects *can* readily become a part of the K–12 curriculum. These subjects *can* be a part of everyday classroom lessons. Elementary and secondary schools *can* be effective in developing knowledge, skills, and attitudes relating to good resource management. With the proper approach, much of this learning can be gained in classes not seemingly related to resources in any way. The approach must be different from that used in college classes or publicly-distributed literature. Materials targeted at schools must carry the means to translate concepts and information from the teacher to the student.

Resource management and other environmental education materials must be integrated or infused into existing curriculum areas like math, language arts, social studies, science, music and even physical education (VandeVisse and Stapp 1975). Integration into existing curriculum is the first basic rule for success in introducing nontraditional subjects into school classrooms. There are three others:

1. Bias must be eliminated or balanced.
2. Materials must be tested to insure usability.
3. Materials must be introduced through a workshop process.

Elaboration on these basic rules seems necessary. Because most teachers face a curriculum packed with required material, adding another subject like wildlife or conservation is usually impossible. It *is* possible to develop activities or lessons that teach resource concepts while accomplishing required learning in traditional subjects. Students can learn to calculate wildlife populations from data in math class as well as they can learn to add or multiply apples and baseballs. In the process they will indirectly learn some of the realities of wildlife population dynamics. Writing poems or songs about a favorite animal or tree can accomplish the requirements of a language arts or music class while subtly teaching appreciation and understanding of the resource. This is the process of integration. Teachers find it can also enrich their curriculum and make learning more exciting.

Bias, or the injecting of a dominant viewpoint must be eliminated or at least balanced by providing the opportunity for students to examine all sides of an issue. Submitting draft materials for review by a wide range of interests is one way to do this. It requires the developer's willingness to compromise and perhaps risk that a particular viewpoint will not be accepted by the teacher and students. Documentation of review and acceptance by a wide range of interests doesn't hurt either. If it looks and reads like just another special-interest pitch it will end up in the trash can!

Suitability for integration into existing curricula can only be confirmed by a good testing program. This process has regularly been omitted in agency-produced educational efforts. The process of testing is time consuming and often requires longer than the writing effort. Two forms of testing may be done. The first involves test uses by teachers to insure that the lesson can be done in the grades, time frame, and subject areas targeted. This test requires only a limited number of teachers representing a cross section of grade and subject areas. It is most necessary for acceptance by the education community. The second testing process involves an evaluation of what students learn by doing the lessons. This effort is much more involved and expensive. It requires careful research design and monitoring. Fortunately, it is viewed by most educators as being less vital to a program's credibility.

The fourth basic rule concerns introduction of program materials through teacher workshops. No educational materials should be distributed without a workshop covering use techniques and philosophies and their relationship to a school system's curriculum goals. Workshops not only prevent teachers from being overwhelmed by the material but acquaint them with local resource managers as well. This opens the door for a secondary benefit to the resource manager. Having received a balanced, usable package that enriches the classroom and excites students, the teacher now knows who to call for more information. This call-back or second wave gives the manager an opportunity to get a specific message directly into a receptive classroom. The opening would seldom be available without going through all the efforts and expense of producing the first package.

Workshops take time and a commitment of personnel. Obviously, just mailing out a packet would be a lot cheaper. So are the results. There is no free lunch in education either. We will get the results we pay for.

Project Learning Tree (PLT) is a highly successful, functioning model of the four-step approach to integrating nontraditional subjects into modern classrooms. PLT focuses on trees and the forest environment as a familiar base from which to explore the interrelationships between all living and nonliving things. The activity-based curriculum supplement materials are being used in over 30 states and three Canadian provinces. The American Forest Institute and the Western Regional Environmental Education Council (WREEC)[1] collaborated to develop the project materials for elementary and secondary teachers. Neither organization could have accomplished the effort alone. Together, this seemingly strange marriage could meet all the necessary steps for a successful project.

The model that PLT provides and the perception of need by another organization provided the connection for the beginning of a major new K–12 interdisciplinary, supplementary education program emphasizing wildlife. Project WILD is in its second year of development as a joint effort of WREEC and the Western Association of Fish and Wildlife Agencies. Like PLT, Project WILD will include instructional activities for teacher use. Activities are designed for integration into all major subject and skill areas presently included in kindergarten through high school curricula. Wildlife is not treated narrowly and the activities will provide a balanced and rich instructional resource for teachers.

Presently there is no comprehensive major wildlife education program operating in this country. Project WILD will fill some of this void. Activities were written cooperatively by a wide range of classroom teachers and other educators, resource agency personnel, members of private conservation groups and other community representatives. The curriculum framework on which the activities are based has been reviewed by hundreds of interested persons in the western states and several dozen nationally-based conservation and wildlife interest groups. Each activity is based on one or more concepts from the framework, ranging from simple awareness to responsible human actions toward wildlife and the environment. Activities do not take a stand on issues such as predators, hunting or land development. Instead they provide a means for teachers and students to investigate such issues, interpret data, and reach their own conclusions. Although being developed in the West, the concepts in the curriculum framework apply nationwide, if not worldwide.

[1]WREEC is a nonprofit organization of representatives from state departments of education and state resource management agencies in the 13 western states.

Activities in Project WILD are now receiving the first formative testing in Arizona and Washington. During the 1982–83 school year they will undergo an extensive field test and evaluation in a wide range of locations and conditions. In the participating states, introductory workshops for the completed materials will begin in the fall of 1983.

Project Learning Tree and Project WILD offer prime models for the process necessary to get any nontraditional subject into the classrooms of this nation. Wildlife are a source of fascination and interest to almost everyone. In the classroom, wildlife can be an especially useful tool for motivating students in traditional subjects like math, history or even music.

Success of PLT speaks strongly for the validity of the developmental model. The forward-looking spirit that brought the Western Association and WREEC together is in itself a model of cooperative development unrivaled among natural resource agencies nationwide. Participation of additional agencies and organizations as a sponsor or contributor remains open.

School-age youngsters between five and 18 years old comprise up to 25 percent of our population. Thus, school systems can directly reach approximately a quarter of the people in each state. An additional quarter or more of each state's population consists of parents of school-age children who can be indirectly influenced. Kindergarten through high school offers 13 years of time to educate potential future resource management professionals. It must not be overlooked in the total education process. Providing teachers with high quality, integratable, nonbias, tested, and readily usable material is the key.

Literature Cited

Hobart, W. 1972. What's wrong with conservation education. J. Environ. Ed. 3(4): 23–25.

Mussen, P. H., J. J. Conger, and J. Kagen. 1963. Child development and personality. 2nd ed. Harper and Row, New York.

Vande Visse, E., and W. Stapp. 1975. Developing a K–12 environmental education program. Pages 93–107 *in* McKinnis and Albrecht, eds. What makes education environmental? Environmental Educators, Inc., Washington, D.C. and Data Courier, Inc., Louisville, Ky. 470 pp.

Marine Mammals: Conflicts with Fisheries, Other Management Problems, and Research Needs

Chairman:
DOUGLAS G. CHAPMAN
Director
Center for Quantitative Science in
Forestry, Fisheries, and Wildlife
University of Washington, Seattle
Cochairman:
L. LEE EBERHARDT
Research Scientist
Battelle Northwest Laboratory
Richland, Washington

Assessment of California Sea Lion Fishery Interactions

Douglas P. Demaster
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
La Jolla, California

Daniel J. Miller
California Department of Fish and Game
Montery, California

Daniel Goodman
Scripps Institution of Oceanography
La Jolla, California

Robert L. DeLong
National Marine Mammal Lab, NWAFC
National Marine Fisheries Service
Seattle, Washington

Brent S. Stewart
Hubbs/Sea World Research Institute
San Diego, California

Introduction

The Marine Mammal Protection Act of 1972 (MMPA) dictates that all populations of marine mammals under U.S. jurisdiction have a determination made as to

The data contained herein should be considered provisional, and further changes may be necessary.

whether or not they are at optimum levels. The National Marine Fisheries Service has defined optimum to mean that the population level is between the maximum net productivity level (MNPL) and the maximum population level (K). This determination is referred to as an assessment. Initially the MMPA put a complete moratorium on the taking of any marine mammal by a U.S. citizen unless specifically exempted from the moratorium. Problems immediately arose between commercial fishermen and marine mammals, where marine mammals were found to become more and more brazen in their interactions with fishermen. This has been particularly true for the California sea lion. Recently, the MMPA has been amended to allow the non-intentional take of marine mammals by commercial fishermen, as long as the impacted population is determined to be at optimum levels. Currently, the necessary information is not available to make a determination for any of the marine mammal stocks that occur off the coast of California.

Assessments of previously exploited marine mammal populations have historically been based on estimates of the maximal population level (k), where k is generally estimated by back calculating to the pre-exploitation level from a record of annual harvests and an estimate of the current population size. The MNPL is then estimated as a fixed percentage of K. A complete record of harvests does not exist for California sea lions (*Zalophus californianus*), even though the population was dramatically reduced in the early 1920s (LeBoeuf and Bonnell 1980), and therefore back-calculating the historic population level is not possible. Direct estimation of the MNPL is not possible because the current population size and the density dependent mechanisms that regulate this population are not known.

In this paper we present an analysis of the interaction between California sea lions and California fisheries. This is in terms of dollars lost to the fishermen and the number of sea lions indirectly removed from the population. Because direct management of sea lions cannot take place until an assessment has been made, an analysis procedure, referred to as the dynamic response method (DRM), is also presented. The paper ends with a discussion of management options.

California Sea Lion Interactions in California Fisheries

A summary of Miller et al. (1982) is presented here (Table 1). It should be pointed out that Table 1 represents only damage by California sea lions and not total damage by pinnipeds. California sea lions cause damage to catch or gear in seven major fisheries. The largest dollar losses occur in the following fisheries: Commercial salmon trolling fishery, commercial sport-boat fishery, the Pacific herring fishery, and the halibut gill-net fishery. Of an estimated 1,560 (range 1,285 to 1,834) sea lion mortalities per year due to fishery interactions, over 952 (range 678 to 1,277) occur in the shark gill-net fishery. The commercial salmon trolling fishery and the halibut gill-net fishery each take roughly 200 animals. Precise estimates of sea lion abundance are not available, but minimum estimates range between 45,000 and 60,000 animals (LeBoeuf and Bonnell 1980). A take of 1,800 represents an annual harvest of 3.0 to 4.0 percent. Only the gill-net fisheries experience significant gear damage. Damage by sea lions to trammel-nets that are set for halibut was particularly severe (43 percent of total dollars lost in halibut fishing). The total damage to catch by California sea lions in all fisheries was estimated to be $394,886 in 1980, and the total damage to gear was $80,350. The total dollar value of losses

Table 1. Depredation rate, dollar loss, and take of sea lions in California fisheries. (Data from Miller et al. 1982. Where species-specific losses are not given, loss is prorated according to composition of take).

	% depredation	Value of fishery losses		*Zalophus* mortality
		Catch loss	Gear loss	
1. Commercial salmon troll fishery (1980)	1.90%	274,000	12,200	300
2. Salmon partyboat fishery (1980)	0.32%	6,000	360	0
3. Salmon recreational skiff fishery (1980)	0.02–0.18%	2,300	0	0
4. Recreational salmon fishery (river) (1979/80)	0	0	0	0
5. Partyboat fishery for bottomfish (1980)	?	27,000	10,730	0
6. Pacific herring fishery (1979/80)	0.46–0.62%	40,600	4,550	0
7. Gill net fisheries (1980)				
a. Shark	0	0	792	952
b. Halibut	6.94%	32,368	24,071	242
c. White seabass	2.00%	3,740	0	0
d. Rockfish	1.4%	2,600	0	15
e. White croaker	7.1%	2,978	1,000	0
f. Barracuda	2.2%	330	0	0
g. Bonito	6.5%	1,270	382	0
h. Flyingfish	6.4%	200	0	0
		43,486	26,245	1,487
8. Market squid fishery	0	0	0	10
9. Round-haul net fishery for anchovy and mackerel	0	0	0	20
10. Hook and line fishery (1980)	0.44%	1,500	0	0
11. Commercial trawl fishery	0	0	0	25
12. Klamath River gill-net fishery	?	?	?	7
Totals		$394,886	$80,350	1,571

due to fishery interaction with sea lions was $475,236. The annual total dollar value of losses due to all marine mammals in California was reported to be $598,690 (Miller et al. 1982).

One of the best series of data obtained in Miller et al.'s (1982) interaction study was in the commercial and recreational salmon fisheries. These fisheries are conducted during the peak of southern migratory movement (April–May) of sea lions along the nearshore area and when these animals are returning to central and northern California during the fall months. During spring, the salmon are spread throughout the area from Monterey to the Oregon border with some heavier aggregations of salmon moving about in relation to their food supply. The May salmon catch and California sea lion depredation indicate a more widespread but close to shore migratory pattern of sea lions, with depredation reported from 32 (57%) of the 50 catch block areas reported as high yield areas by salmon fishermen. During the spring southward migration there are more salmon taken off hooks by sea lions at a farther distance from hauling grounds than during the northward movement.

The post-breeding northern movement of sea lions is more spread out in both time and space. Interaction with salmon trollers, however, was primarily within 15 km (9.3 miles) of major hauling grounds. The juxtaposition of the hauling grounds of Little Jackass Creek, California (35 km [21.7] miles north of Fort Bragg) and the usual annual fall concentration of maturing salmon near that area results in significant losses of salmon due to depredation by sea lions. Over 43 percent of the total salmon taken off hooks by California sea lions along the California coast were lost in this area. When the number of fish stolen or damaged by catch block area is compared with the number of fish caught in these blocks, there is no clear-cut relationship between the occurrence of heavy catches and the degree of depredation. The only possible cause and effect relationship appears to be that high depredation rates occur when dense fish aggregates are near major hauling grounds.

The high concentration of southern migrating California sea lions during April–June in Monterey Bay occurring during intensive salmon fishing effort presents an opportunity to investigate relationships between number, size composition, and behavior of California sea lions and the catch and depredation rates. One of the more significant findings is that the number of California sea lions hauling out at the Monterey Coast Guard breakwater reached all time peaks in the 1980 and 1981 counts. Counts made at the breakwater by the Department of Fish and Game and Alan Baldridge (Hopkins Marine Station, pers. comm.) from 1967 through 1971 ranged from 400 to 800 animals during the spring peak. The 1980 May maximum count was 1,521 California sea lions, 914 of which were yearlings. The peak count in 1981 was in April and May with over 2,000 California sea lions tallied. About 500 of these were rafting in the water adjacent to the breakwater, precluding accurate determination of size composition. Large numbers were yearlings as in 1980.

Subadults in 1980 and 1981 were reported by local fishermen and researchers to be more abundant than previously observed in the Monterey Bay area. These young animals were exceptionally tame and curious and showed little fear of fishing boats. By July 1 all but a few of the adult California sea lions had departed for the rookery areas. Some of the yearlings remained for about two weeks before also moving out, presumably to the south. Ainley et al. (1977) reported concentrations of yearling California sea lions at the Farallon Islands for the first time in 1971 and subsequently recorded increasing numbers annually.

Depredation rates on salmon do not closely follow trends in the total number of salmon lost. The highest depredation rates for the entire California coastline on salmon trollers were recorded in Monterey Bay, yet the greatest numbers of lost fish were off northern California where there was a greater proportion of salmon in relation to numbers of sea lions. The Monterey Bay depredation rates were 3.31 percent, 4.26 percent, and 7.60 percent of the legal catch for May, August, and September, 1980 respectively.

There is a greater concentration of salmon in Monterey Bay during spring months than in fall. The total number of salmon taken off hooks by sea lions in May was higher than in September, but not in relationship to the numbers of animals present. There was twice the rate of depredation per fishing boat in Monterey Bay in September as in May, but only about one-tenth as many sea lions were present in September as in May. It appears that only a few of the California sea lions present may be involved in fishery interactions. During the intensive salmon trolling taking place in Monterey Bay in May, 1980, large numbers of sea lions did not leave the hauling grounds near the harbor in the morning to follow the vessels heading for the fishing areas. In fact, nearly all the sea lions had returned from their nighttime foraging bouts and were hauling out as the fishing vessels were passing by. On any given day when complaints were being voiced over the marine radio about sea lion problems, no more than about a dozen interactions could be accounted for, and some of these could have been repeated occurrences by the same animals. Therefore, a reduction in the number of animals present would probably not reduce depredation unless most of the animals present are removed or unless the few animals responsible for the damages could be identified and removed.

The Dynamic Response Method

The interaction between sea lions and California fisheries is expected to generate interest in management related activities that will mitigate losses by fishermen due to sea lions. However, the newly amended MMPA dictates that populations must be at optimum levels before mitigating measures can be taken. The return of pinniped management to the State of California can only proceed if the proposed populations are considered to be at optimum, and if the replacement yield has been determined. Because an assessment based on back-calculating historical population levels is not possible (historical harvest records are not available), and because direct estimates of the maximum population level are not available, alternate methodologies must be developed. The next section describes an assessment method that is based on a time series of population indexes.

A. Harvesting Dynamics and MNPL

The MNPL is a reasonable lower limit for the optimum sustainable population level because the MNPL is a breakpoint in the range of the population levels. At levels greater than the MNPL, a stock will come to a stable equilibrium under a quota harvest. Below the MNPL, a stock will not equilibrate under a quota harvest, but will decline to extinction or grow to exceed MNPL, depending on harvest rate, production, and the population size.

B. Direct Assessment of Current Dynamics

For the same reasons that make the MNPL a division line between favorable and unfavorable dynamic regimes, it should be possible to detect whether a population is above or below its MNPL from examination of its dynamics. We term this analysis a dynamic response assessment. The theoretical feasibility of a dynamic response assessment should be obvious from the fact that observations of the dynamics of the population could be described in terms of a stock/recruitment relationship. Furthermore, if the observations were used to establish the production curve, the peak of which is located at the MNPL, we could then ask whether the present level is above or below that estimate of MNPL. Thus, the dynamic response assessment is a special case of the general procedure of deducing the stock recruitment relationship from observations on dynamics.

There are two basic advantages to restricting the analysis to a qualitative dynamic response assessment, rather than answering the management question as a by-product of a complete program of estimating the stock/recruitment curve. The first advantage is that estimates of the full stock/recruitment curve involve extrapolations beyond the range of available observations. If our sole objective is to arrive at a qualitative "above or below" determination rather than actually to arrive at a quantitative estimate of what the value of the MNPL is, it is not necessary to postulate on the shape of the production curve outside of the observed range of population levels.

The second advantage is that the estimation of the stock/recruitment relation involves absolutely scaled estimates of population density (or estimates scaled in units of carrying capacity), whereas the simpler qualitative question can be addressed with data on rates alone. Thus the proposed assessment can be carried out with fewer data.

C. Principles of the Analysis

A fundamental feature of population models that are used to make assessments is a density dependence relationship that results in the per capita population growth rate being a decreasing function of population density. The production curve is a product of population density and per capita population growth, so the production curve is unimodal where the peak, the MNPL, corresponds to the point where the product of two functions—density, an increasing function of density, and per capita growth, a decreasing function of density—is maximal. Since the two functions are oppositely related to density, the product will be maximum at some intermediate density.

Another way of describing the unimodality of the production curve is in terms of its slope. At densities below MNPL, the slope is positive and at densities above the MNPL, the slope is negative. This relationship, when translated to a plot of time versus population level, dictates that the population growth curve is dependently convex up in the region below MNPL, so that the population will exhibit an acceleration in its growth rate in the approach to MNPL from below. It also means that the growth curve is convex down in the region above the MNPL, and the population will exhibit a deceleration in the growth away from MNPL in the direction of the unharvested equilibrium level.

Analysis of Pup Counts from San Miguel Island

These modes of describing the qualitative differences in the production curve above and below MNPL form the basis for the method of estimating, from recent dynamics, whether a given population is above or below its current MNPL. We will illustrate this method by considering an assessment of the San Miguel Island population of California sea lions over the past decade.

Most pinniped populations along the coast of California were drastically reduced by the early twentieth century. These populations have begun recovering under government protection, and most pinniped populations are currently thought to be increasing. Except for an incidental kill owing to fishery interactions, these populations are not harvested directly. Therefore, the population trajectories are those of free running populations that were initially far from the equilibrium and are now presumably approaching the equilibrium. Accordingly, there is reason to hope that the trajectories exhibit rather clearly the density dependent dynamics of population growth and are not dominated by environmental noise about an equilibrium.

Pup production of California sea lions has been annually estimated by counting neonates on breeding beaches. Their relationship to the size of the entire population depends on the nature of the density dependence of reproduction. We assume that, over the range of densities exhibited in our data, the fecundities are not dependent on density. Instead, we posit that the major mechanism of density dependence is through juvenile mortality, which expresses itself at some time after the pup census. Under this assumption, the pup counts may be interpreted as relative measures of population size.

Our criterion for dynamics above or below MNPL in a free running system not near equilibrium is simply acceleration or deceleration in the population growth rate. This is detected as upward or downward convexity in the relationship between a relative measure of population size (such as pup counts) and time. Given a minimal number of censuses, we may test for curvature by fitting a second-order polynomial and inquiring into the sign of the second-order term (i.e., if positive, population is below MNPL; and if negative, population is above MNPL).

This simple procedure is premised on the population not crossing from one side of the MNPL to the other during the period of observations. If the population does make that crossing, then one segment of the density-time plot will be convex up and the other will be convex down. If the shape is reasonably symmetrical, this will yield a zero or very small curvature measure in a second order fitting, but of course we will be hard pressed to detect zero curvature due to:

1. Excessive sampling error in the censuses;
2. Excessively slow acceleration or deceleration relative to the duration of the data record; and
3. Populations genuinely at or near MNPL.

It should be noted that this approach is conservative because a population that has only recently passed the MNPL will be assigned a positive second derivative. In fact, the second derivative will on average only be negative when there are as many years of data after the MNPL has been reached as before. This shortcoming can be circumvented by using the most recent data, but a minimum number of counts is necessary to provide a reasonable degree of precision in the assessment.

Results

The series of pup counts from San Miguel Island extends from 1971 through 1981 (Figure 1). Pup counts from the other pupping colonies in the Channel Islands are available (Table 2), but are not adequate for this type of analysis because they represent too short a time series or are composed of counts that are not comparable due to technique differences. Because the pup counts in DeLong et al. (1982) are

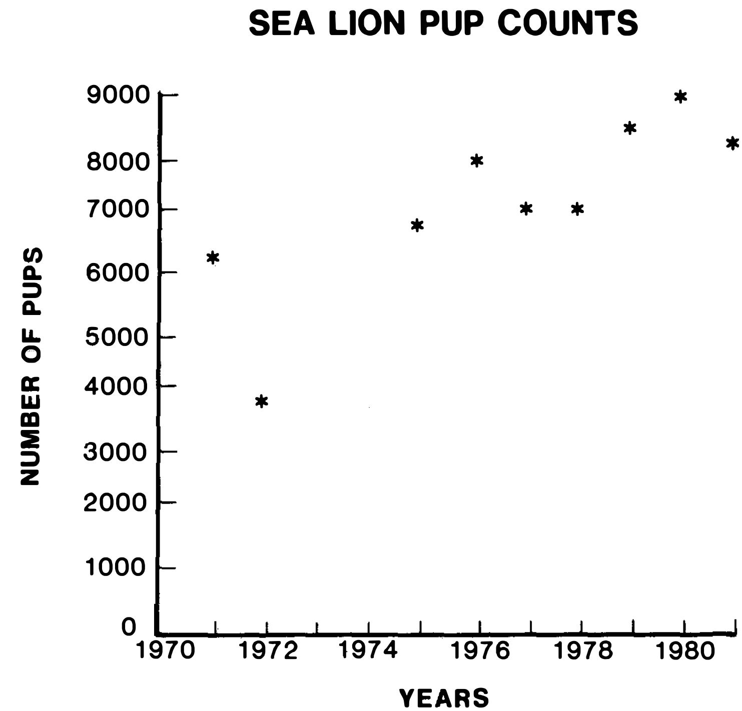


Figure 1. California sea lion pup counts from San Miguel Island (1971–1981). All counts are of live pups from censuses made during the last week of July.

composed of both single counts and averages of multiple counts, it it necessary to analyze the individual counts to get the proper weighting in the regression (Table 3). It is also conceivable that neonatal mortality or pre-parturient fetus mortality is density dependent, and therefore these sources of pup lossess should be included in an index where pup counts are used to index changes in the total population size. Information from DeLong et al. (1982) was used to construct three types of population indexes: total number of live pups in July, totals of pups plus neonatal deaths, and pups plus neonatal deaths plus premature births (Table 3). An analysis of the three population indexes in Table 3 is complicated by the unusually large number of premature pups in 1972. This is not considered to be a density dependent response. In the analysis, a second order polynomial was fitted to each of the three counts. Models were fitted both with and without the 1972 data (indicated by presence of asterisk in Table 4). The results (Table 4) indicate that the second derivative is negative in all but one case. The one model where the second derivative was positive is also the model that is the poorest indicator of trends in population growth. This is because estimates of total neonatal mortality are negatively biased. Therefore, our analysis indicates that at least the San Miguel population of California sea lions is past the MNPL and is exhibiting a detectable amount of growth rate retardation due to density dependent effects. If an expo-

Table 2. Peak pup production figures for *Zalophus californianus* in the Southern California Bight area.

	SMI	SNI	SBI	SCI	Other
1969		2697(1)			
1970		2271(1)			
1971	5285(6)	3500(6)			
1972	3501(6)				
1973					
1974					
1975	6236(2)	3800(2)	648(2)	608(2)	
	7103(6)				
1976	7130(2)	3533(2)	515(2)	413(2)	2(2) S. Cruz
	8084(6)				
1977	5304(2)	3773(2)	493(2)	351(2)	
	7413(6)				
1978	7100(6)		465(3)		
1979	8476(6)		625(3)		
1980	9279(6)	6288(4)	730(3)		
1981	8255(6)	6824(4)		666(5)	

SMI = San Miguel Island
SNI = San Nicolas Island
SBI = Santa Barbara Island
SCI = San Clemente Island
(1) = Odell 1971, Ground counts
(2) = LeBoeuf et al. 1978, Aerial surveys
(3) = Heath 1982, Ground counts
(4) = Stewart pers. comm., Ground counts
(5) = Oliver pers. comm., Ground counts
(6) = DeLong et al. 1982, Ground counts
Counts were made in July–August and do not include those pups that did not survive until the census.

nential equation is fit to the series of pup counts in Table 3, the resulting values of r vary between .04 and .06 (Table 4), which indicates that the annual rate of population change (λ) is between 1.04 and 1.06 from 1971 through 1981. If our assertion is correct, and the population growth rate is currently being reduced by density dependent effects, a growth rate of 5 percent per year must be considered a minimum estimate of the maximum rate of population change.

Management Implications

Until an assessment of the entire California sea lion population is made, it is doubtful whether management action will be taken to reduce or mitigate the impact of sea lions on fisheries in California. Even with an assessment that found sea lions above their MNPL, it is not clear what measures would be effective. Miller et al. (1982) present evidence that the total damage by California sea lions is not proportional to the number of sea lions in an area. They reported that an order of magnitude difference in the number of animals was associated with only a doubling of fishery interaction rates. They further suggest that fishery interactions are greatly affected by seasonal movement and hauling patterns. Therefore, reduction in

Table 3. Counts of live pups, neonatal deaths, and premature births for California sea lions on San Miguel Island from 1969 through 1981. (Data are from DeLong et al. 1982). If more than one count is available, both counts are given.

Year	A Pups	B A + neonatal deaths	C B + premature births
1971	5285	6633[a]	6981
1972	3501	4157[a]	5159
1975	7323	7416	7745
	6702	6795	7124
1976	8359	8505	8811
	7808	7954	8260
1977	7664	7766	8262
	7162	7264	7760
1978	7268	7462	7723
	6932	7126	7387
1979	8710	9032	9302
	8245	8567	8837
1980	9279	9307	9704
1981	8937	9218	9317
	7573	7854	7953

[a]Mortality studies were conducted on sample areas throughout the breeding season. Results indicated that most dead pups disappear within 21 hours after death. Therefore, neonatal mortality is far in excess of what is assessed from a single census taken at the time live pups are censused. Estimates of neonatal mortality for 1975 through 1981 are therefore substantially below actual mortality.

population size would likely have to be drastic to have any effect at all. Currently, most fishermen seem to consider the loss to marine mammals as overhead, or they simply avoid areas where marine mammals concentrate. Current research on mitigating marine mammal-fishery interactions is directed at developing non-lethal, acoustic deterrents; results are not yet available. In the future, a combination of harassment techniques, area closures, and tolerance will most likely encompass the management tools that are available. An important point raised by Miller et al. (1982) is that increased disturbance of rookery areas may result in a redistribution of sea lions, and areas currently not used for hauling or feeding may experience increased use. This may result in higher rates of marine mammal/fishery interactions in areas currently not experiencing such interactions. With this in mind, it is important to document existing movement patterns of sea lions and their changes in response to increasing disturbance from researchers, recreational enthusiasts, and commercial fishermen.

Acknowledgments

Without the contribution of a number of researchers, this paper would not have been possible. Ed Jameyson and Bud Antonelis were involved in collecting most of the sea lion pup censuses for San Miguel. Pam Youchem assisted in pup counts from San Nicolas Island. Counts from Santa Barbara Island were made by Carolyn Heath. Tim Gerrodette and Jay Barlow assisted in the dynamic response analysis. Mike Herder and John Scholl were major contributors to the final report of Miller et al. (1982) that was summarized in this review. We

Table 4. Analysis of second degree polynomial and exponential functions fitted to counts of pups (A), pups plus neonatal deaths (B), and pups plus neonatal deaths plus premature births (C). Data are from Table 2.

			A			B			C
2° polynomial	y	=	$3511 + 847x - 36x^2$	$\overset{*}{y}$	=	$6461 + 147x + 6x^2$	y	=	$5616 + 450x - 13x^2$
	r^2	=	.70	r^2	=	.50	r^2	=	.56
	$\overset{*}{y}$	=	$4846 + 543x - 19x^2$						
	r^2	=	.62						
Exponential	$\overset{*}{y}$	=	$4610\ e^{.06x}$	$\overset{*}{y}$	=	$5361.25\ e^{.05x}$	y	=	$6050.67\ e^{.04x}$
	r^2	=	.60	r^2	=	.54	r^2	=	.54

*1972 counts not included.

would also like to thank Lorraine Prescott and her staff for typing the manuscript, and Ken Raymond and his staff for preparing Figure 1. This manuscript was reviewed by Dr. L. Eberhardt, Dr. W. Perrin, Dr. T. Gerrodette, Dr. J. Barlow, and Dr. G. Sakagawa.

Literature Cited

Ainley, D. C., H. R. Huber, R. P. Henderson, T. J. Lewis, and S. H. Morrell. 1977. Studies of marine mammals at the Farallon Islands, California, 1975–76. Marine Mamm. Comm. Rept. MMC-75/02, NTIS PB 266 249. 32 pp.

DeLong, R. L., G. A. Antonelis, and E. Jameyson. 1982. California sea lion pup production, premature birth, and neonatal mortality on San Miguel Island, 1969–1981. National Marine Mammal Lab., Northwest and Alaska Fishery Center, Seattle, Wash. (in prep.)

Heath, C. 1982. California sea lions on San Nicolas and Santa Barbara Island, California. Final Contract Report (81-ABC-00145). 49 pp.

LeBoeuf, B. J., and M. L. Bonnell. 1980. Pinnipeds of the California Channel Islands: Abundance and distribution. Pages 175–496 in D. Power, ed. The California Islands: Proceedings of a Multidisciplinary Symposium.

LeBoeuf, B. J., M. L. Bonnell, M. O. Pierson, D. J. Dettman, and G. D. Farrens. 1978. Pinnipeds: Numbers, distribution, and movements in the Southern California Bight. NTIS PB-295932 (Sect. 1).

Miller, D. J., M. J. Herder, and J. P. Scholl. 1982. California marine mammal-fishery interactions study, 1979–1981. Draft final Report (79-ABC-00149). 311 pp.

Odell, D. K. 1971. Censuses of pinnipeds breeding on the California Channel Islands. J. Mammal. 52: 187–190.

Marine Mammal-Fisheries Interactions in Oregon and Washington: An Overview

Robert D. Everitt and Richard J. Beach
Washington State Department of Game
Olympia

Introduction

The waters of the Pacific Northwest support an abundant and diverse marine mammal fauna. These waters also support large populations of anadromous fishes that represent a significant economic resource (especially the salmonids) to the human residents of the states of Oregon and Washington. Most anadromous fishes occupy the surface water layer (less than 60m [197 ft.]) where they may be accessible as prey items for certain marine mammal species (Fiscus 1980). Consequently, marine mammals have often been perceived as competitors with man for these fish stocks. Of more immediate concern to local fishermen and resource managers alike is the longstanding adverse interactions between marine mammals and man on the fishing grounds. These interactions include actual fish loss or damage and gear damage inflicted by marine mammals and the incidental mortality or injury (either accidental or intentional) of individual marine mammals.

The adversary relationship that these interactions has created between local marine mammal populations and fishermen has been around as long as the fishery itself. However, as fish resources have become less abundant through a combination of overfishing and habitat loss (as related to hydroelectric development, logging, mining, agricultural practices, etc.) and legislation protecting marine mammals more stringent, the individual fisherman has felt a growing frustration with his inability to control marine related losses. Resource managers have also been concerned with the potential impacts of resource depletion and incidental take upon the marine mammal populations involved. These concerns have resulted in some steps being taken by resource agencies to identify and quantify the magnitude of the problem and explore potential mitigation measures available.

In this paper we will summarize what is known of the status of stocks of those marine mammal species known to be directly involved in interactions; review what is known of these interactions historically and the management activities directed to reduce them; discuss current research programs and existing research needs; and present our thoughts on potential management considerations for the future.

The Marine Mammals Involved

Owing to its location near the boundaries of the subarctic and subtropical waters, the Pacific Northwest is home for or is frequented by a variety of marine mammal populations (Scheffer and Slipp 1948). The nearshore waters of Oregon and Washington support resident populations (most notably of pinnipeds) as well as providing migratory routes for others (e.g. the Gray Whale, *Eschrichtius robustus*). Fiscus (1980), in a review of marine mammal-salmonid interactions in the North Pacific, presented a list of marine mammals known to inhabit those waters. By excluding the truly arctic species and adding a few recent records, we see that at least 29 species of marine mammals occur in the waters of Oregon and Washington (Table 1). Of these, only a few have been implicated or documented as directly interacting with local fisheries. The status of the more important of these populations is highlighted below. Many of the other species are documented predators on salmonids to varying degrees, but the impact this predation has upon the commercial fishery is unknown (Fiscus 1980).

Everitt et al. (1980) described seven marine mammal species as common to the inland waters of Washington, and these presumably are the more common species in coastal waters as well. Of these, the three near-shore pinniped species, California sea lion (*Zalophus californianus*), northern sea lion (*Eumetopias jubatus*), and harbor seal (*Phoca vitulina*), are most often implicated in fishery interactions.

Of the common cetaceans, the gray whale (*E. robustus*), killer whale (*Orcinus orca*), Dall porpoise (*Phocoenoides dalli*), and harbor porpoise (*Phocoena phocoena*) all have been documented as occasionally or rarely interacting with fish-

Table 1. Marine mammals of Pacific Northwest waters.

Species	Known to interact with local fisheries[a]
California sea lion (*Zalophus californianus*)	X
Northern sea lion (*Eumetopias jubatus*)	X
Northern fur seal (*Callorhinus ursinus*)	
Sea otter (*Enhydra lutris*)	
Harbor seal (*Phoca vitulina*)	X
Northern elephant seal (*Mirounga angustirostris*)	
Gray whale (*Eschrichtius robustus*)	X
Minke whale (*Balaenoptera acutorostrata*)	
Sei whale (*B. borealis*)	
Fin whale (*B. physalus*)	
Blue whale (*B. musculus*)	
Humpback whale (*Megaptera novaeangliae*)	
Right whale (*Eubalaena glacialis*)	
Saddleback dolphin (*Delphinus delphis*)	
Pacific whiteside dolphin (*Lagenorhynchus obliquidens*)	
Northern right whale dolphin (*Lissodelphis borealis*)	
Whitehead grampus (*Grampus griseus*)	
False killer whale (*Pseudorca crassidens*)	
Shortfin pilot whale (*Globicephala macrorhynchus*)	
Killer whale (*Orcinus orca*)	X
Harbor porpoise (*Phocoena phocoena*)	X
Dall porpoise (*Phocoenoides dalli*)	X
Sperm whale (*Physeter catodon*)	
North Pacific giant bottlenose whale (*Berardius bairdii*)	
Goosebeak whale (*Ziphius cavirostris*)	
Bering seal beaked whale (*Mesoplodon stejnegeri*)	
Archbeak whale (*Mesoplodon carlhubbsi*)	

[a]Includes documented fish damage, gear damage, or incidental kill associated with a fishery in the Pacific Northwest.

eries. These interactions are usually in the form of entanglement and subsequent gear damage, often resulting in the death of the animal involved. Such instances are thought to be rare and the numbers of animals involved so small as to be of less concern to resource managers at the present time than the problems experienced with common pinnipeds.

California Sea Lion

The population center for this species is in the southern waters of California and Baja California, with no breeding documented north of the Farallon Islands (central California). A northerly shift in distribution of males occurs at the conclusion of the breeding season in the late summer, with a few animals traveling as far as Vancouver Island (Bigg 1973, Mate 1975). This species reaches maximum abundance in Oregon and Washington in winter, and about 4,000 animals occur north of California during this period (NMFS 1980). It has been estimated that approximately 3,500 of these animals can be found off Oregon and less than 400 occur in Washington's waters (Mate 1976, Everitt and Jeffries 1979, D. Snow, Oregon Dep. Fish and Wildl., pers. comm.).

It is during the fall and winter months that direct interactions with nearshore gillnet fisheries and California sea lions become most acute. Because of the large size and power of these animals, they are capable of completely removing salmon from nets and inflicting serious damage to gear (Everitt et al. 1981). While occasionally an entanglement results in the drowning of an animal, most lethal take is the result of shooting or clubbing.

Northern Sea Lion

In North America the northern sea lion ranges from the Aleutian Islands to California, with the majority of the population centered in Alaskan waters. Breeding occurs throughout its range, though no rookeries are known from Washington. The population in Oregon appears to be stable with 3,000 animals, some of which are breeding in the state (NMFS 1980).

In Washington, post breeding movements result in a seasonal (winter) abundance of about 600 animals (Everitt and Jeffries 1979). Apparently the northern sea lion population has been declining in recent years in the far southern portion of its range and in the eastern Aleutian Islands (Fiscus 1979, Braham et al. 1980). Populations in other portions of its range, including Oregon and Washington, have remained relatively stable or their status is unclear (Fiscus et al. 1981).

Northern sea lions interact with gillnet fisheries much the same way as do California sea lions, but fewer animals are involved (Everitt et al. 1981). A few reports of northern sea lions damaging the gear of offshore trollers have been documented, and the recovery of a trolling hook from the stomach of a beached specimen from the Washington Coast also attests to this interaction. However, interactions with these offshore fisheries appear to be not all that significant at this time.

Harbor Seal

The harbor real ranges along the Pacific Coast, and several subspecies occupy coastal habitats around the world. In Oregon and Washington the harbor seal may be the most abundant marine animal and is the only breeding pinniped in Washington State. Extensive aerial surveys of harbor seal hauling out areas and pupping grounds have been made in Washington recently, and statewide surveys of Oregon have been made regularly for this species since the mid-1970s. The limitations of this methodology (as discussed by Eberhardt et al. 1979) as a means of estimating harbor seal population size results in conservative estimates of actual abundance, but are useful as indications of population trends. In Oregon, minimum estimates of the harbor seal population range from 2,500–3,000 animals and in Washington the estimates exceed 8,000 animals, including animals from the Columbia River (NMFS 1980, Everitt et al. 1981, R. Brown, Oregon State Univ., pers. comm.). These figures are higher than past estimates and suggest increases from the exploited populations of the past. Recent data collected from coastal breeding areas have shown a yearly increase in pup production (average 17% per year for 5 years) in three Washington estuaries (Beach et al. 1982). In Oregon, pup production has increased annually by about 7 percent (D. Snow, pers. comm.). This suggests that absolute population levels may actually be increasing, at least in some areas. However, the possibility does exist that these increases are merely the result of more thorough survey coverage in later years (Calambokidis et al. 1979).

Harbor seals are more likely to be involved in adverse interactions with a fishery than other marine mammal species. Harbor seals have been implicated not only in coastal gillnet fisheries, but also in gillnet, purse seine, and set net fisheries in Washington's inland waters (Mate 1980). Although the extent of these interactions with inside fisheries is more suspected than documented, good documentation for coastal interactions has recently been collected (detailed below) and suggests significant economic losses are attributable to this species.

Historical Interactions and Management

Where a marine mammal population of any appreciable size co-exists with an active (usually commercial) fishery, one can expect that adverse interactions, either real or perceived, are likely to occur. This was certainly the case as commercial exploitation of the abundant anadromous fish stocks began in the Pacific Northwest. Historical information is lacking, but it appears the greatest impact of seals and sea lions upon fisheries was the actual damage inflicted on netted fish and gear. Recent estimates of losses in Alaska's Copper River and Prince William Sound fisheries were as high as $900 per boat in 1978 (Matkin and Fay 1979). Prior to current research on the outer coast of Washington and Oregon, no real dollar estimate of loss was available for the Pacific Northwest. From market samples of the lower Columbia River taken in 1972–1978, a small percentage (1–2%) of fish showed seal damage (Hirose 1977, Mate 1980). These estimates were considered low since any heavily damaged (unsaleable) fish would not show up in a market sample.

Another clue to the potential chronic nature of pinniped (seals and sea lions) damage comes from data collected during pre-season test fisheries on the Columbia River. All forms of pinniped damage affected an average of about 13 percent of the test catch during sampling from 1972–1980 (Hirose 1977, Everitt et al. 1981). A test fishery does differ somewhat from an actual commercial fishery in terms of timing, effort, gear, etc., and it is difficult to evaluate the two. However, since pinniped damage was observed in a significant degree in the test fishery, one can assume that some damage continues during the following commercial seasons.

Because of this type of damage in the commercial catch and the perceived competition for the free swimming salmonid resource, limiting harbor seal and sea lion population size became the over-riding management philosophy in the early 1900s. Seals and sea lions were classified as predatory wildlife by both Washington and Oregon and until the 1970s were subject to kill, capture, or harassment at any time (Newby 1973, Johnson and Jeffries 1977). Actual bounties were paid from the 1920s until 1960 in Washington, from 1925–1933 throughout Oregon, and from 1936–1972 on the Columbia River in Oregon (Pearson and Verts 1970, Johnson and Jeffries 1977). Oregon hired a seal hunter from 1954–1970 to shoot and harass seals during commercial fishing periods in the Columbia River.

The effect of these programs undoubtly resulted in a decline in pinniped abundance. In Washington, over 9,500 harbor seals were bountied, and Oregon recorded bounties paid for over 10,600 pinnipeds (Mate 1980). Certainly, the reported bounties significantly underrepresent the actual take since many animals would be struck and lost (Scheffer and Slipp 1944, Newby 1973). Harassment of animals by hunters, particularly during breeding periods, may also have contributed to a population decline.

While the elimination of a portion of the pinniped population may have contributed to a reduction in fishery interactions, the actual control programs also had the effect of limiting pinniped movements upriver (Fisher 1952). During a survey of the lower Columbia River in the late 1960s, only a few harbor seals were observed, and the largest concentration of animals did not exceed 80 (Pearson and Verts 1970). This study concluded that harbor seals were not permanent residents in the estuary and that, in Oregon, their preferred habitat had shifted to remote offshore reefs and islands. The state hunter operating on the Columbia River felt that continued harassment resulted in many animals leaving the estuary (W. Puustinen, pers. comm.).

Because of public concern with conservation of marine mammals, the State of Washington enacted legislation protecting marine mammals in 1970, and in 1972 the Federal Government enacted the Marine Mammal Protection Act (MMPA). The MMPA put into effect regulations that took a new view of the place of marine mammals in the ecosystem. In effect, marine mammals were recognized as an important component of the ecosystem, entitled to share marine resources with man. Among other things, the MMPA established sanctions against the take or harassment of any marine mammal, which ended the Oregon bounty program and removed all marine mammal management authority from the states. The law provided for waivers of the moratorium and return of management, subject to federal approval; as yet no state other than Alaska has successfully pursued this provision.

Aside from nearly complete protection afforded marine mammals by the MMPA, no real management programs have been instituted by the responsible federal agencies in Oregon and Washington. Both states have been under contract to assist with the enforcement of several provisions of the Act and to provide limited support at strandings of marine mammals; however, funding for these contracts has been recently withdrawn. Certain provisions of the MMPA that call for determinations of population status and other biological parameters have spawned an increased research effort in the Pacific Northwest. Much of the funding for these projects has come through federal sources, while a few have been supported by state or private agencies. Most projects focused on pinnipeds, though some work on cetaceans (notably killer whales) has also been reported. Everitt et al. (1979) provides a bibliography that includes most of this recent (as well as earlier) work.

Current Research

Mate (1980) identified the Columbia River and adjacent estuaries as areas of significant adverse interactions in need of investigation. In 1980, the National Marine Fisheries Service (Northwest Region and Northwest and Alaska Fisheries Center) contracted Washington and Oregon to develop and implement a marine mammal-fisheries interaction research program in that area. Additional funds to support this project were forthcoming through the Pacific Northwest River Basin Commission, the Marine Mammal Commission (MMC), and the Center for Environmental Education.

The objectives of the project, which has entered its third year, are to: evaluate the nature and extent of marine mammal-fisheries interactions in the Columbia River and adjacent waters; continue recent efforts to evaluate marine mammal populations along portions of the coasts of Washington and Oregon; and investigate selected biological parameters of these populations. To encompass the broad scope of these objectives, a variety of methodologies have been employed, including dockside and field interviews with fishermen (Matkin and Fay 1979); aerial censusing (Eberhardt et al. 1979); radiotagging and tracking of harbor seals (Brown 1980, Pitcher and McAllister 1981); collection of stranded and incidentally killed marine mammals (Stroud and Roffe 1979); and field evaluation of possible methods to reduce interaction.

Early results from the initial two years of study have documented a significant marine mammal interaction with the gillnet fishery, especially near estuary mouths and/or in areas of high harbor seal and California sea lion abundance. Feeding habits analysis indicates that pinnipeds are opportunistic feeders and may be concentrating in estuaries in response to seasonally abundant prey items. Initial radio tracking data indicate that harbor seals move seasonally to preferred pupping and nursing areas. To date, 173 stranded and incidentally killed marine mammals of 14 species have been recovered and examined. Investigations are being planned to evaluate methods to repel pinnipeds from gillnets using small explosives (seal bombs) and sonic harassment.

In order to evaluate the significance of direct interactions to the fisheries and marine mammal populations involved, over 3,000 interviews with fishermen were conducted during the 1980–1981 seasons. Sampling was stratified by week, port, and fishing area. Two independent, systematic surveys adapted from Matkin and Fay (1979) were conducted: dockside interviews (where fish catch was examined) and field interviews (where interactions were observed). Using a multipurpose form, data were recorded on the frequency and severity of fish and gear damage and incidental take, as well as gear type and fishing effort information.

Results from 1980 fishing seasons, as reported in Everitt et al. (1981), indicate that interactions between pinnipeds and troll fisheries were very rare, while negligible damage was reported by sport fishermen targeting on surf species, salmon, and steelhead. The gillnet fisheries in the estuaries, on the other hand, experienced significant interaction and/or damage.

Harbor seals were responsible for the most damage to gillnet catches, although California sea lions caused extensive gear damage when present in the Columbia River during the winter chinook salmon runs. Fishing operations at estuary mouths, adjacent to haul out areas, or in restricted channels were the most severely impacted. Damage to gillnetted salmon was especially severe when overall salmon runs (and thus catches) were low. This was especially true of the Grays Harbor summer chinook fisheries, in which 25–30 percent of the catch was damaged. In contrast, a much larger chinook salmon run in the Columbia River resulted in a successful one day fishing season that incurred only a 1.4 percent damage rate. Longer, more sustained fisheries in Willapa Bay and the Columbia River in 1980 experienced damage to 10 and 5 percent of the catch, respectively; high enough to be considered an economic liability to the fishermen. The minimum financial loss to fishermen during the 1980 gillnet fishery from damaged fish alone was over $100,000 for all the areas included in the study. The economic loss due to damaged but saleable fish, salmon completely removed from nets, and the damage to the nets themselves caused by marine mammals is currently being assessed.

In 1980 gillnetters experienced 0.6–2.2 cases of marine mammal caused gear damage and 0.3–3.2 cases of marine mammal entanglement for every 100 hours fished. This level of take resulted in the death of at least 51 harbor seals, plus an additional 425 instances of non-lethal harassment. During the winter chinook season on the Columbia River in 1981, 50 instances were noted of California sea lions causing damage to fishing nets. However, only 7 of these large animals became entangled and of these only 4 died or were killed. The impact of this incidental mortality upon the populations involved is still under investigation.

Aerial surveys from Netarts Bay (Oregon) to Grays Harbor (Washington) have been conducted to further refine pinniped distribution patterns and abundance. These surveys have counted 200 California sea lions and 250 northern sea lions during periods of maximum abundance. Harbor seals are the most abundant species in this area, with an estimated 6,000–8,000 animals present from Tillamook Bay to the northern point of the Olympic Peninsula. Near-shore rocks and reefs of the Olympic coast, as well as low sand bars in the coastal estuaries (Grays Harbor, Willapa Bay, Tillamook Bay, and Netarts Bay) provide more than 100 regularly used haul out sites. Populations appear to be reproductively healthy and increasing in these estuaries, as indicated by a substantial yearly increase in pup counts (Beach et al. 1982).

Johnson and Jeffries (1977) describe an inverse relationship between maximum counts of harbor seals in the Columbia River and adjacent estuaries of Grays Harbor and Willapa Bay, suggesting that these animals represent one population. Tagging efforts are now underway to test this hypothesis and determine seasonal movements and activity patterns relative to aerial censusing, identify regional population stocks and boundaries, and provide data to better estimate regional populations.

As of fall 1981, 60 harbor seals have been captured on two major haul out areas in the Columbia River. In 1981, radio transmitters were fitted to ankles of 11 adult males and 19 females (12 females were pregnant at the time of tagging). Thirty additional harbor seals (7 males, 6 pregnant females, and 17 non-pregnant females) received only flipper tags and pelage marks in that year.

Capture techniques involved rapidly setting 13 inch (33 cm) mesh capture net (72 fathoms × 4 fathoms) adjacent to a sand bar. This inevitably frightened the harbor seals into the water and some into the net. The ends of the net were hauled ashore by two boats and the net was gathered in beach seine fashion, entrapping a number of seals. In order to trap seals within the "bite" of the net, this operation had to be completed within 4 minutes. In 14 attempts using this method, from 1 to 26 seals were captured in 9 of the sets. The entangled seals were pulled up onto the beach, cut from the nets, and placed in separate hoop nets where a variety of measurements were taken. The animals were then tagged and/or fitted with radio transmitters. Radio tags continue to be monitored via aerial surveys, ground monitoring, and remote recording stations placed on the Columbia River, Willapa Bay, Grays Harbor, and Tillamook Bay.

Of the 30 seals that were radiotagged, 28 have been resighted. Nineteen of these animals were observed in estuaries outside the Columbia River. Initial analysis of these observations indicate: (1) daily movements among Columbia River haul out sites in the spring; (2) seasonal use of specific haul out sites in the Columbia River; (3) interchange of seals between the Columbia River and Willapa Bay, Grays Harbor, and Tillamook Bay; and (4) seasonal movement of parous females from the Columbia River to nursery areas in Willapa Bay and Grays Harbor for parturition and lactation.

Eleven of 18 pregnant seals (all originally tagged in the Columbia River) were resighted with pups in Grays Harbor or Willapa Bay. A female seal was resighted in Willapa Bay on September 11, 1981 and in Tillamook Bay on September 18, 1981; a linear distance of 114km (70.8 miles). Two other female seals were observed to move from the Columbia River to Willapa Bay, a distance of 42km (26 miles), in less than one 12-hour tidal cycle.

In another phase of the project, marine mammal carcasses recovered from the gillnet fishery or found along beaches were processed in a standardized manner. Of particular interest was the harbor seal sample, which was represented by 73 specimens. The cause of death in most of these specimens (43%) was attributable to man (gunshot, drowning, etc.).

Harbor seal feeding habits information in this project are being derived from two separate sources (scat collected from haul out areas and gastrointestinal contents of stranded animals). For both data sets, techniques described by Pitcher (1980) and Treacy and Crawford (1981) have been used to assure maximum retrieval of identifiable material from the samples. Presently, only a subsample of 177 scats from the Columbia River, representing almost year-round coverage (June 1980 to April 1981), has been analyzed for prey preferences. Temporal analysis showed harbor seal preference for anadromous or seasonally abundant estuarine prey species: euchalon in January, lampreys in April, and several species of crustaceans in June.

The initial two years of study have focused on intensive documentation and data gathering. The next phase of the project will be directed towards complete data analysis and problem-solving and will include (1) final analysis and integration of existing data on fisheries interactions, populations, and feeding habits collected from 1980–1982; (2) evaluation of methods to reduce marine mammal-fisheries interactions; (3) development of an adjusted harbor seal population index; (4) identification of the portion of the pinniped population involved in fisheries interactions; and (5) quantification and trophic level analysis of expanded food habits data and supportive data from captive harbor seal research.

A separate research effort has been underway through Oregon State University's (OSU) Marine Science Center (Newport, Ore.). Surveys of pinniped abundance in Oregon have been conducted since 1968 and have resulted in current population estimates for seals and sea lions in Oregon. In addition, a multi-year program in Netarts Bay has been examining the harbor seal population there as it relates to a nearby chum salmon hatchery. This work has resulted in further contributions of information on harbor seal prey preference and provided some pioneering work with radio telemetry of this species (Brown 1980).

The ongoing work that OSU is presently involved with (under the direction of Dr. Bruce Mate) that is most relevant to the subject at hand is a program to develop acoustic harassment systems for marine mammals. The progress of this work was recently reported to a workshop convened by the MMC to review ongoing fisheries interaction work (Contos 1982). Presently, the methodology under investigation allows fish to pass the acoustic barrier, but excludes marine mammals, which have higher hearing ranges.

The basic approach is to produce a sound loud enough that harbor seals (the subject of the experiments) can at first discern and, as they move closer, begin to experience discomfort that causes them to turn away. A device has been designed and is just now being tested with some encouraging preliminary results. Funding limitations have slowed the technological efforts needed to refine the system.

Research Needs

The ongoing programs outlined in the preceding section will go a long way towards developing the kinds of data needed to actually identify the problem areas and provide some options for dealing with those problems. There still remain several important gaps in our knowledge that need to be filled before these problems can be fully addressed in all areas of the Pacific Northwest.

Anecdotal accounts from commercial fishermen fishing the inland waters of Washington (Strait of Juan de Fuca and Puget Sound) have suggested that there may be a marine mammal-fishery interaction problem that is comparable to those in coastal estuaries. Primary marine mammal species suspected of involvement are the harbor seal, harbor porpoise, and Dall porpoise. A project to investigate this possibility is needed. Further research recommendations for this area, made by Everitt et al. (1980), still require implementation.

Everitt et al. (1981) and Beach et al. (1982) have suggested that adverse interactions between marine mammals and sport fisheries is insignificant on the Columbia River and adjacent waters. However, this generalization may not be true for all areas of Washington and Oregon. Mate (1980) discusses the potential impact of increasing pinniped populations in areas where local economies are dependent upon recreational fisheries. This problem may be most acute in certain coastal estuaries of Oregon including the Rogue, Umpqua, Siletz, Siusula, and Alsea rivers. Complaints have not been as prevalent in similar areas of Washington, and the problem, if any, is considered to be minimal. D. Snow (Oregon Dep. Fish and

Wildlife, pers. comm.) has indicated that California sea lions and harbor seals are depredating the sport crab fishery (removing bait and damaging gear) to a significant degree in Yaquina Bay, Coos Bay, Alsea and Siusula estuaries. An investigation(s) into these potential trouble areas in Oregon is needed.

Examination of an important fishery for adverse marine mammal interactions has essentially been ignored in both states to date. We refer to the commercial and subsistence Indian fisheries in coastal, river, and inland waters. If adverse interactions occur in this fishery, nothing is known of the economic impacts to the fishery, marine mammal species involved (if any), or impacts to marine mammal populations. This is an area that deserves attention from research and management programs alike.

Long term research programs are needed to continue the evaluation of the indirect interactions between marine mammals, fish stocks, and commercial fisheries. In addition, monitoring of pinniped populations should be continued for the foreseeable future, with the ultimate goal of determining optimum sustainable population (OSP) levels (as defined by the MMPA).

While we know that problems exist with some fisheries and might exist with others, little is known of what can be done to mitigate these problems, if in fact they are significant enough to demand mitigative measures. Continued support of efforts to develop, deploy, and test the effectiveness of mitigative devices (e.g. acoustic apparatus) should be continued.

Management Considerations

Management of marine mammals in the states of Oregon and Washington rests essentially in the hands of the Federal Government at the present time. Any immediate management activities would and should be initiated by the responsible federal agencies. Two needs appear most critical at the present time: (1) a determination of OSP for seals and sea lions must be made and efforts should be directed towards maintaining populations at that level (habitat protection, increased enforcement where necessary, hauling area protection and acquisition, etc.); and (2) mitigation of impacts should begin for the Columbia River and adjacent waters using non-lethal options.

Recent developments in both state wildlife agencies may make eventual return of management authority to Oregon and Washington a desirable goal. New legislation by both states has provided funding bases for the development of nongame wildlife programs, which conceivably could encompass portions of a marine mammal management program. In Washington, development of a management program would follow the general outline provided by a statewide plan (Washington Dep. of Game 1981) and could be summarized as follows: monitor population trends and develop ongong inventories; manage habitat (for pinnipeds this would include hauling areas) for protection at critical times (e.g., reproductive periods); cooperate with other land management agencies in developing long term habitat protection plans; emphasize enforcement when and where appropriate; and provide for public education and information. Special efforts would have to be undertaken to properly address problems unique to fisheries interaction issues, such as monitoring mitigation programs and continued documentation. Management of the entire ecosystem, of which marine mammals are a part, would be an important element of a successful program. This would include considering man's impact on the ecosystem (through fishing, developments, etc.) as important variables in maintaining marine mammal population stability within that system. These efforts would have to be wholly or partially supported by federal funds (as allowed by the MMPA) since presently the state is unable to expand any program without compensating funds and as such is not pursuing a return of management authority for marine mammals.

At the present time, any management of marine mammals by Oregon would take place through the Marine Region, Newport, Oregon in conjunction with the nongame program. Currently Oregon, like Washington, is waiting to see what action or needed regulation will be promulgated by federal agencies. Not until a clear signal of federal intent is known will the states take the initiative to pursue management alternatives with any vigor. Ideally, all agencies involved at both state and federal levels should cooperate to plan and implement realistic programs most beneficial to the wildlife resources involved.

Conclusion

The Pacific Northwest supports large populations of marine mammals that are in economic conflict with man in certain areas. At what cost can these conflicts be allowed to continue? Marine mammals are appealing to a large segment of Americans who demand that populations be protected. On the other hand, others call just as vigorously for protection from economic ruin. Clearly, these two needs can and must be addressed.

Sweeping generalities do not suffice. Because a problem is known to exist between commercial salmon gillnetters and harbor seals on the coast does not mean the same is true for an inland bay. Local documentation is required, and if and when it has been attained, mitigation should follow. Such measures, if undertaken in an orderly manner based on fact rather than emotion, will benefit not only a fishery (by reducing damage), but also the marine mammal species involved (by reducing incidental take). Mitigation taken with an eye to management of the ecosystem as a whole can be a compromise that all should be able to accept.

The problem is with us now. It will not go away if ignored. It needs to be addressed aggressively by the responsible agencies in cooperation with all user groups. To fail to do so would be, at the very least, a retreat from our public responsibility. But more importantly, it would represent a betrayal of the resources that we, as wildlife managers, are charged to protect.

Acknowledgements

Many individuals contributed to the preparation of this paper. Their information, review, and comments were invaluable to us. Particular thanks are due to the staff of the Marine Mammal Project: Anne Geiger, Steve Jeffries, and Steve Treacy. We wish also to thank Doug Chapman, Bob Hofman, Bob DeLong, Garry Garrison, Anne Geiger, Murray Johnson, Mike Kuttel, Robin Brown, John Patterson, and Dale Snow who took time from their busy schedules to review this manuscript. Deborah Kuttel provided typing and editorial review.

Literature Cited

Beach, R., A. Geiger, S. Jeffries, and S. Treacy. 1982. Marine mammal-fisheries interactions on the Columbia River and adjacent waters, 1981. Second annual report: November 1,

1980-November 1, 1981. NWAFC Processed Rep. 82-04. Nat. Marine Fish. Serv., Seattle, Wash. 186 pp.
Bigg, M. A. 1973. Census of California sea lions on southern Vancouver Island, British Columbia. J. Mammal. 54: 285–287.
Braham, H. W., R. D. Everitt, and D. J. Rugh. 1980. Northern sea lion population decline in the eastern Aleutian Islands, Alaska. J. Wildl. Manage. 44: 25–33.
Brown, R. F. 1980. Abundance, movements, and feeding habits of the harbor seal, *Phoca vitulina,* at Netarts Bay, Oregon. M.S. Thesis. Oregon State University, Corvallis. 69 pp.
Calambokidis, J. A., R. D. Everitt, J. C. Cubbage, and S. D. Carter. 1979. Harbor seal census for the inland waters of Washington. Murrelet 60: 110–112.
Contos, S., ed. 1982. Workshop on marine mammal-fisheries interactions. Report to the U.S. Marine Mammal Commission for contract MMC-81/07. Publ. No. PB82-189507. Nat. Tech. Info. Serv., Springfield, Va. 64 pp.
Eberhardt, L. L., D. G. Chapman, and J. R. Gilbert. 1979. A review of marine mammal census methods. Wildlife Monogr. No. 63. The Wildlife Society, Washington, D.C. 46 pp.
Everitt, R., R. Beach, A. Geiger, S. Jeffries, and S. Treacy. 1981. Marine mammal-fisheries interactions on the Columbia River and adjacent waters, 1980. Wash. Game Dep. Olympia. 109 pp.
Everitt, R. D., C. H. Fiscus, and R. L. DeLong. 1979. Marine mammals of northern Puget Sound and the Strait of Juan de Fuca: a report on investigations November 1, 1977 to October 31, 1978. U.S. Dep. Commer., NOAA Tech. Memo. ERL MESA-41. Environ. Res. Lab., Boulder, Colo., Jan. 1979. 191 pp.
Everitt, R. D., C. H. Fiscus, and R. L. DeLong. 1980. Northern Puget Sound Marine Mammals. DOC/EPA Interagency Energy/Environment R & D Program Report. EPA-600/7-80-139. Env. Protect. Agency, Washington, D.C. 134 pp.
Everitt, R. D. and S. J. Jeffries. 1979. Marine mammal investigations in Washington State. Page 18 *in* Abstracts from presentations of the Third Biennial Conference of the Biology of Marine Mammals, Seattle, Wash. Oct. 1979.
Fiscus, C. H. 1979. Interactions of marine mammals and Pacific Hake. Marine Fisheries Review. 41(10): 1–9.
_____. 1980. Marine mammal-salmonid interactions: a review. Pages 121–132 *in* W. J. McNeil and D. C. Himsworth eds. Salmonid ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis.
_____, D. Rugh, and T. Loughlin. 1981. Census of northern sea lions (*Eumetopias jubatus*) in Central Aleutian Islands, Alaska, June 17–July 15, 1979. NOAA Tech. Memo. NMFS F/NWC-17. Nat. Tech. Info. Serv., Springfield, Va. 109 pp.
Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Bull. 93. Fish. Res. Board. Can. 58 pp.
Hirose, P. 1977. Incidence of seal-damaged salmonids sampled from the lower Columbia River gillnet fishery, 1972–1976. Information report 77-4. Oregon Dep. of Fish and Wildlife, Portland. 6 pp.
Johnson, M. L., and S. J. Jeffries. 1977. Population evaluation of the harbor seal (*Phoca vitulina richardii*) in the waters of the State of Washington. Report to U.S. Marine Mammal Commission for contract MM5AC019. Publ. No. PB270376. Nat. Tech. Info. Serv., Springfield, Va. 27 pp.
Matkin, C. O., and F. H. Fay. 1980. Marine mammal-fishery interactions on the Cooper River and in Prince William Sound, Alaska, 1978. Report to U.S. Marine Mammal Commission for contract MM8AC-013. Publ. No. PB80-159536. Nat. Tech. Info. Serv., Springfield, Va. 71 pp.
Mate, B. R. 1975. Annual migrations of the sea lions, *Eumetopias jubatus* and *Zalophus californianus* along the Oregon coast. Rapp. P-V Reun. Cons. Int. Explor. Mer. 169: 455–461.
_____. 1976. History and present status of the California sea lion, *Zalophus californianus*. Food Agric. Org. U.N., Adv. Comm. Mar. Resour. Res., FAO ACMRR/MM/SC/39. 6 pp.
_____. 1980. Workshop on marine mammal-fisheries interactions in the northeastern Pacific.

Report to U.S. Marine Mammal Commission for contract MM8AC003. Publ. No. PB80-175144. Nat. Tech. Info. Serv., Springfield, Va. 48 pp.
National Marine Fisheries Service. 1980. Report on stock assessment and incidental take of marine mammals involved in commercial fishing operations. National Marine Mammal Laboratory Report. NOAA, Seattle, Wash. 88 pp.
Newby, T. C. 1973. Changes in the Washington State harbor seal population, 1942–1972. Murrelet 54: 4–6.
Pearson, J. P., and B. J. Verts. 1970. Abundance and distribution of harbor seals and northern sea lions in Oregon. Murrelet 51: 1–5.
Pitcher, K. W. 1980. Stomach contents and feces as indicators of harbor seal, *Phoca vitulina,* foods in the Gulf of Alaska. Fishery Bull. 78: 796–797.
Pitcher, K. W., and D. C. McAllister. 1981. Movements and haulout behavior of radio-tagged harbor seals, *Phoca vitulina*. Can. Field-Natur. 95: 292–297.
Scheffer, V. B., and J. W. Slipp. 1944. The harbor seal in Washington State. Amer. Midl. Natur. 32: 373–416.
——— . 1948. The whales and dolphins of Washington State with a key to the cetaceans of the west coast of North America. Amer. Midl. Natur. 39: 257–337.
Stroud, R. K., and T. J. Roffe. 1979. Causes of death in marine mammals stranded along the Oregon coast. J. Wildl. Diseases. 15: 91–97.
Treacy, S. D., and T. W. Crawford. 1981. Retrieval of otoliths and statoliths from gastrointestinal contents and scats of marine mammals. J. Wildl. Manage. 45: 990–993.
Washington Dep. of Game. 1981. Nongame wildlife program plan: a guide to the management of Washington's nongame wildlife resource. Wash. Game Dep., Olympia. 70 pp.

Interactions of Northern Fur Seals and Commercial Fisheries

Charles W. Fowler
National Marine Mammal Laboratory
Seattle, Washington

Introduction

Under international agreement, the northern fur seal (*Callorhinus ursinus*) is managed with the objective of obtaining a maximum sustainable yield. Currently the harvest is restricted to subadult males; however, between 1956 and 1968 the fur seal population of the Pribilof Islands was subjected to a harvest of females. This harvest was justified, in part, as an attempt to stimulate the production of greater quantities of harvestable animals (Chapman 1981). A reduction in the population occurred during this period as can be seen in Figure 1. As described in York and Hartley (1981), the female harvest itself provides an explanation for part of this reduction, but cannot account for more than about 70 percent of the decline in the numbers of pups born. It was expected that the population would increase following the termination of the harvest of females in 1968, yet no increase occurred.

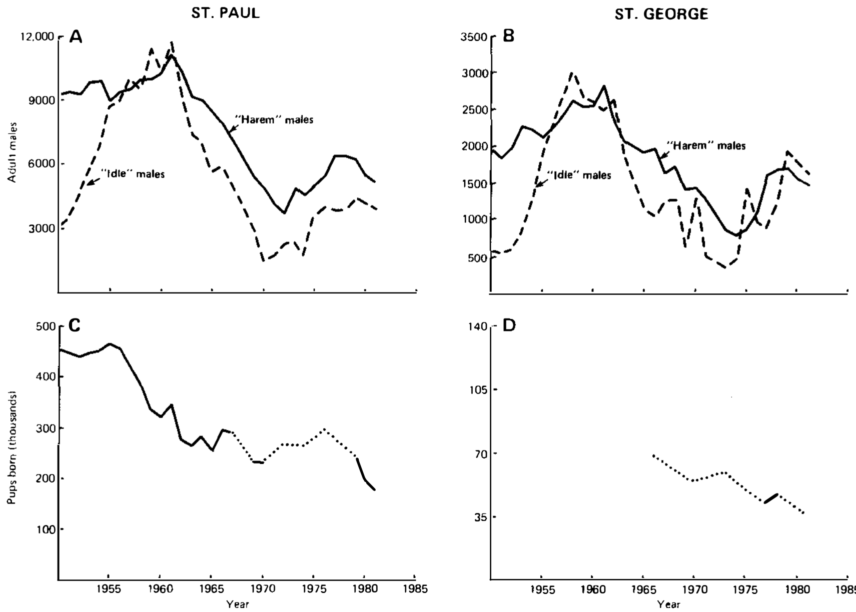


Figure 1. Observed declines in the fur seal population of the Pribilof Islands as indicated by numbers of pups and large males for both St. Paul and St. George Island, 1950–1981. Dotted lines are for periods during which data are not available for consecutive years. (From Lander 1980, Kozloff in preparation).

Currently the entire Pribilof population is declining as evidenced by declines in numbers of pups, harvestable males, and adult males on both islands. Other populations of this species in the western Pacific are also showing evidence of a decline, based on data published in the annual proceedings of the North Pacific Fur Seal Commission in recent years. In summary, the Pribilof population has shown (1) a greater decline between 1956 and 1968 than can be easily explained by the female harvest alone, (2) no increase following the termination of the female harvest, and (3) a current trend toward smaller population levels. In view of these dynamics, both managers and scientists are faced with the problem of providing an explanation.

Several explanations for the decline in the Pribilof fur seal population have been advanced. Over time, minor changes have occurred in the management regime, giving rise to the possibility that modifications in the harvest strategy may provide an explanation. Most of these modifications have involved relatively small changes in the length limits and season length applied in the harvest and would thus have affected only the male component of the population.

It is possible that increasing levels of toxic substances in the environment may explain the decline. However, current information indicates that the level of measured toxic substances in the tissues of fur seals have not increased. The incidence of disease appears to have remained the same or declined, but increases in predation may have occurred.

During the years over which the fur seal population declined (1956 to the present), the Bering Sea became subject to the effects of relatively intense fishing pressure (see Bakkala et al. 1979). Of particular importance is the pollock (*Theragra chalcogramma*) fishery, which became large and economically important between about 1964 and 1972. Data from this fishery indicated that the pollock population underwent significant changes during this period (Smith 1981). It is because of such changes and the presence of other fisheries in the eastern North Pacific that the decline in the fur seal population is often explained as an effect of commercial fisheries.

The ways in which commercial fisheries may have affected the fur seal population fall into several categories. The decline may have occurred as a result of a reduction in the amount of prey consumed by fur seals (i.e., through reduction in numbers or changes in size composition of the prey). It may have happened as a result of a restructuring of the ecosystem in response to developing fisheries, especially if this resulted in the reduction of prey species consumed by fur seals. Finally, the decline may be a result of the direct impact of fisheries on the fur seals, such as through entanglement and incidental taking. Entanglement is a term that refers to fur seals becoming wrapped or caught in debris that has been discarded or lost. A large part of this debris involves trawl net material. Incidental taking involves the capture of fur seals in fishing gear while it is being actively fished.

In this paper I review information related to the indirect effects of commercial fisheries on fur seals (i.e., through the reduction of food resources available to fur seals) and compare it with information concerning the direct impact of fisheries on fur seals (the issue of entanglement and incidental take). The indirect effects will be evaluated through a review of the feeding ecology of fur seals and of information dealing with changes that have occurred within the population. The direct effects will be addressed through a review of information on direct taking and through a review and analysis of information on net debris and entanglement rates. In all cases the review is restricted to information on the population of northern fur seals of the Pribilof Islands.

Indirect Interactions

Diet

From 1958 to 1974, Canada and the United States cooperated in pelagic field research to study the distribution, migration, and feeding habits of northern fur seals in the Bering Sea and eastern North Pacific Ocean. These investigations established that fur seals feed upon well over 100 species of fishes and cephalopods in the eastern North Pacific and Bering Sea (Kajimura 1982). Added to this is the list of prey species found in the western North Pacific. Within this large list of prey species, a smaller subset forms the principal prey species of importance to the fur seal. Table 1 shows a list of the principal prey species utilized by fur seals in the eastern Bering Sea and eastern North Pacific Ocean from 1958 through 1974. There is a strong tendancy for the composition of the fur seal diet to be related to geographic location.

Kajimura (1982) shows that time (time of day or season) is also an important factor in determining the composition of the fur seal diet. At any one time, for any particular location, however, it is not uncommon to find that one species comprises a relatively large portion of the stomach contents in sampled fur seals. For example, anchovy (*Engraulis mordax*) off the coast of California often comprised 50 percent (by volume) of the sampled stomach contents. For those fur seals that remain off California into May, however, it is not uncommon for Pacific whiting (*Merluccius productus*) to comprise over 50 percent of the stomach contents. In the Bering Sea, capelin (*Mallotus villosus*) and pollock were found to be the most prevalent species in July and August. These two species often accounted for over 25 percent of the contents of fur seal stomachs, at times comprising as much as 75 percent.

Consumption Rates

McAlister (1981) estimated that 476 thousand metric tons of fish are consumed by fur seals each year in the Bering Sea and Aleutian Island area of Alaskan waters. This estimate is based on information concerning the metabolic rates of fur seals combined with information concerning the fur seal's population characteristics such as the age structure, migratory patterns, and distribution. Further analysis of the information presented in McAlister (1981) reveals that fur seals consume approximately 21 percent of all fish consumed by marine mammals in the eastern Bering Sea and Aleutian Island area; this translates to approximately 1.2 percent of the standing stock biomass of fishes in this area.

Opportunistic Feeding

As has been shown by Kajimura (1982), the feeding behavior of fur seals is opportunistic in nature. As fur seals follow their migratory route from the Pribilof Islands to waters off Washington, Oregon, and California, their diet changes. These

Table 1. Principal forage species utilized by fur seals in the eastern North Pacific Ocean and the eastern Bering Sea, 1958–74 (from Kajimura 1982).

	Area						
Forage Species	California	Oregon	Washington	British Columbia	Gulf of Alaska	Western Alaska	Bering Sea
Fish:							
Clupea harengus pallasi	—	—	x	x	x	x	x
Engraulis mordax	x	x	x	—	—	—	—
Oncorhynchus spp.	—	—	x	x	x	x	—
Mallotus villosus	—	—	x	—	x	x	x
Thaleichthys pacificus	—	—	x	x	—	—	—
Cololabis saira	x	x	—	x	—	—	—
Gadidae	—	—	—	—	—	—	x
Gadus macrocephalus	—	—	—	x	—	—	—
Merluccius productus	x	x	x	x	—	—	—
Theragra chalcogramma	—	—	—	x	x	x	x
Trachurus symmetricus	x	—	—	—	—	—	—
Sebastes spp.	x	x	x	x	x	—	—
Anoplopoma fimbria	x	—	x	x	—	x	—
Pleurogrammus monopterygius	—	—	—	—	x	x	x
Ammodytes hexapterus	—	—	—	—	x	x	x
Cephalopods:							
Loligo opalescens	x	x	—	x	—	—	—
Onychoteuthis sp.	x	x	x	—	—	—	—
Onychoteuthis borealijaponicus	—	—	—	—	x	—	—
Gonatus sp.	—	—	—	—	x	—	—
Berryteuthis magister	—	—	—	—	x	x	x
Gonatopsis borealis	—	—	—	—	—	—	x
unidentified squid	—	—	—	—	x	—	—

changes appear to be in direct response to the availability and abundance of prey species in the areas through which the fur seal passes.

As further evidence for opportunistic feeding, Kajimura (1982) examined the occurrence of various prey species in the stomachs of fur seals and compared them with the abundance of the prey species as indicated by fishery surveys in the waters off California and in the Bering Sea. The species found to be most abundant in the fur seal stomachs were most abundant in the areas where the fur seals were collected. Within areas, but over time, as the composition of the prey community changed, so also did the composition of the fur seal diet as indicated by the contents of fur seal stomachs sampled.

Response by Fur Seals

It is difficult to reconstruct the response of fur seals to changes that may have occurred in the North Pacific and Bering Sea ecosystems resulting from the development of commercial fisheries. It is possible, however, to look for the effects of such changes. To examine existing information for evidence of competition with fisheries we must assume that if food resources are reduced to the point of producing a decline in the rate of consumption, fur seals will exhibit responses manifested in various attributes such as growth rates, size at birth, age at maturation, or survival. This is a safe assumption since we know that, in general, when faced with reduced consumption rates, animals are negatively affected. We would thus expect that a reduction in available food resources by commercial fisheries would result in a negative impact on the population of seals and probably cause a decline in their numbers. The available information on northern fur seals, however, does not support this explanation for the decline.

For example, as demonstrated by Lander (1979a), fur seal pups, born during the period following the first major reduction of the fur seal population were born at greater weights than pups born during the period when the population was at its peak. The weight of pups born during the 1950s was approximately 10 percent less than the weight of pups born during 1958 and 1975. As shown in Figure 2A, current data indicated that pups continue to be born at heavier weights than in the 1950s.

As also shown in Figure 2A, the weight of pups at approximately 7 weeks of age has remained relatively constant over the years 1957 to 1980 with a possible tendency to increase between 1961 and 1980.

As found by Bigg (1979), females that were sampled during the pelagic research between 1958 and 1974 showed a tendency to grow more rapidly during years following the decline created by the female harvest. The highest growth rates occurred during the period of peak growth of the pollock fisheries in the Bering Sea. The growth rates are particularly high during this period when compared to those years during which the fur seal population was at its peak in numbers and production.

Work by Hartley (in Kozloff in preparation) indicates that the growth rate of males also increased. Based on data concerning the length of 3-year-old males taken in the harvest during the third week of July on St. Paul Island, there appears to have been an increase in body lengths of animals of this age over the period 1962 to 1971.

Changes in growth that occurred between 1948 and 1979 are also shown in the

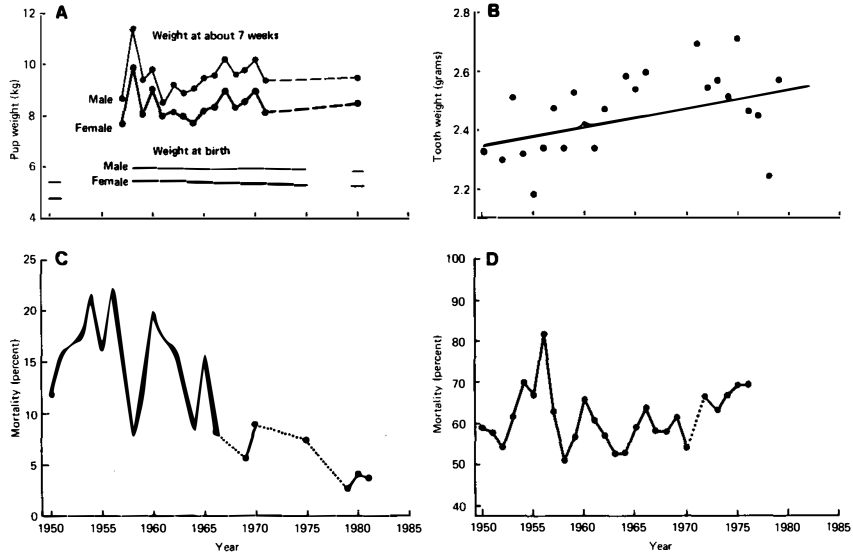


Figure 2. A. Mean weight of pups on St. Paul Island on or about 1 September from 1957 to 1971 and 1980 (National Marine Fisheries Service 1972, and Mike Goebel, personal communication) and mean weight at birth for several periods (from Lander 1979a and Mike Goebel, personal communication). B. Mean maxillary canine tooth weight for 3-year-old males sampled on, or about, 15 July 1950 to 1979 (based on work by Hartley as reported in Kozloff in preparation). C. Pup mortality on St. Paul Island prior to leaving land as calculated from data in Lander (1979b). D. Mortality of males after leaving land but prior to the age of 2 years from data in Lander (1979b). Dashed and dotted lines are for periods during which data were not available for consecutive years.

weight of teeth. Maxillary canine teeth were sampled randomly from 3-year-old males in the harvest on or about 15 July. Using a subsample of eight teeth for each year, a significant increase in tooth weight was found during this period (Figure 2B). The underlying assumption that tooth weight and body size are correlated was verified by Hartley through an analysis of tooth weight as regressed upon body length (Kozloff in preparation). Similar work by Antonelis, York, and Kajimura (also in Kozloff) supports this conclusion.

Mortality of pups on land shows a decline in parallel with the decline in pup abundance (Figure 2C). This apparent density-dependent change covers the period of years during which any effect of a fishery on resource levels would be thought to cause an increased mortality rather than a decline.

Any reduction in available food resources might be expected to result in an increase in the time required for foraging. Such a relationship cannot be established from data on female fur seal feeding cycles. Data from several years between 1962 through 1976 show only the possibility of a slight decline in the duration of feeding cycles (Gentry et al. 1977). This, along with the changes reviewed above, does not support the hypothesis that a lack of food created by the commercial fisheries has caused the decline.

By contrast, however, mortality between the time pups leave the islands and the time they reach 2 years of age shows signs of having increased recently. There is no indication of change up through the 1970 year class except for the high levels of the mid 1950s (shown by year class in Figure 2D as based on Lander 1979b). However, the most current data (provided by Anne York, personal communication) indicate an increase in mortality in year classes following 1970. Further analyses indicate that this mortality of young males at sea may have progressively changed over time. In this analysis, estimated mortality due to natural causes is shown to have declined while estimated mortality due to other causes has increased (Fowler 1982). The decline in natural mortality would have been expected as a density dependent phenomenon following a reduction in the population. The increase in observed mortality may be due to entanglement as one of the potential direct interactions with fisheries as explained below.

Synthesis

If the ecosystem inhabited by a population is subject to a disturbance that has a negative effect at the population level, it is natural to expect that the individuals within that population will show parallel signs of negative effects. Such effects would be manifested in reduced pregnancy rates, reduced growth rates, reduced weight at birth, and increased mortality. As reviewed above, most of the information that bears on the reaction of fur seals to the indirect effects of commercial fisheries indicated that individual fur seals show signs of better environmental conditions now than they did prior to the development of the fisheries. That is, neonatal survival is much higher following the development of fisheries than it was before. An increase in weight at birth may have occurred. Feeding cycles have either not changed or show small declines in length, and growth rates have increased. Survival at sea seems to be the only factor that has declined. But this change is inconsistent with increased growth rates (as well as the several other factors) as an indicator of resource levels and must be kept in mind as a possible cause of the decline independent of any lack of food resources.

Given the diversity of species that serve as alternative prey for fur seals, it is rather difficult to argue that a reduction in the populations of a few species would create problems for seals. This is especially true if reductions in one species result in increases in others through reduced competition. Since fur seals are opportunistic (Kajimura 1982), it seems reasonable to expect them to be able to shift the composition of their diet within the size range of prey consumed. If this is a valid line of reasoning, it is not unexpected that there is little evidence to support the hypothesis that there has been a reduction in food resource levels.

Given the lack of evidence for a negative influence through competition with commercial fishing as reviewed above, the possibility that fisheries have improved conditions for fur seals cannot be ruled out. Swartzman and Harr (1980), in fact, argue that changing the age structure of the pollock population increased the availability of smaller pollock, thus increasing food resource levels (i.e., the numbers of the preferred size) available to fur seals.

Direct Interactions

The information presented above leaves us with a dilemma. How can conditions show signs of apparent improvement for individual fur seals while the population itself shows evidence of a decline? If the increase in mortality at sea is extrinsic to the population, and is causing the decline, the responses of individuals can be interpreted as density dependent changes expected at reduced population levels. In other words, the decline itself may be caused by mortality that is unrelated to the levels of food resources. Such factors as entanglement or incidental take, for example, would reduce the population in the face of abundant resources. This could result in there being more resources per individual and local densities of prey might even increase. Such changes would then be expected to elicit density dependent responses having precisely the nature of those described above. As reviewed by Fowler et al. (1980), populations of large mammals in general tend to show changes such as these in response to reduced population levels.

In the following sections I review information indicating that the fur seal population is declining as a result of direct interactions with fisheries in the form of mortality caused primarily by becoming entangled in debris, especially fragments of trawl nets.

Incidental Mortality

Incidental mortality (or incidental take) is a common problem in many fisheries and is subject to governmental regulations. Examples include the dolphins caught in the yellowfin tuna fishery, porpoise caught in the Japanese high seas salmon gillnet fishery, and sea turtles caught in shrimp fisheries. As has been outlined by Kajimura (1976) and Jones (1980, 1981, 1982) fur seals are also taken incidentally in some commercial fisheries. At this time it is impossible to produce a reliable estimate of the total mortality rate caused by the incidental taking of fur seals. However, Jones (1980, 1981, 1982) has estimated that between 100 and 1,000 fur seals are currently taken each year in the Japanese high seas salmon gillnet fishery. The numbers taken in this fishery may be declining due to shifts in the areas fished relative to the fur seals' distribution.

There are many other fisheries involved in the North Pacific and Bering Sea and further work is needed to determine the degree to which fur seals are killed as a result of incidental taking. Reviews of this general problem (Northwest and Alaska Fisheries Center 1980, Kajimura 1976, Jones 1982) indicated that, although the incidental take of fur seals in fisheries is a problem, there is doubt that it is a primary contributing factor in observed declines.

Entanglement in Debris

Since the early 1960s, fur seals on the Pribilof Islands have been observed with pieces of debris caught on their bodies. Presumably this occurs as a result of encounter at sea with floating materials enhanced by play behavior, curiosity, feeding on other attracted species or by attempts to use such debris in haulouts (Fiscus and Kozloff 1972).

Since 1965 the incidence of fragments of nets on animals taken in the harvest of subadult males on the Pribilof Islands has been monitored (Figure 3). The portion of these animals that exhibit entanglement in such debris has remained fairly constant over the past several years. These data alone, however, do not allow for an estimate of the rate at which animals actually die due to entanglement. Since a large portion of the entangled animals are caught in net debris, it is possible to

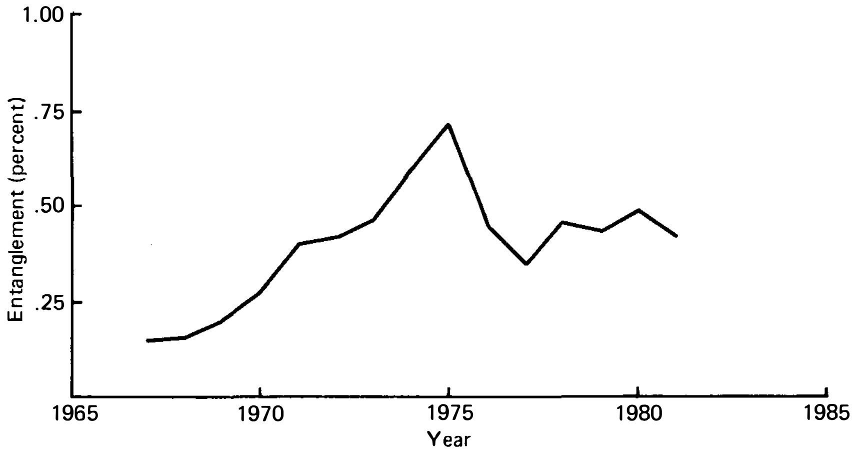


Figure 3. The percentage of the harvested animals taken on St. Paul Island that were entangled in debris from 1967 to 1981. (From Lander 1980, Kozloff in preparation.)

examine information on the nature of debris washed up on beaches in relation to net fragments observed on entangled animals to begin to get a preliminary perspective on this problem.

Merrell (1980) conducted a study of debris found on beaches of Amchitka Island, Alaska. Approximately 83 percent of this debris was trawl net fragments as determined by weight. Using published information concerning the rate at which plastics were discarded in the open ocean, Merrell (1980) estimated that approximately 1,645 metric tons of plastic material were dumped into the Bering Sea and Aleutian Island area each year in the early 1970s. Of this, approximately 1,445 metric tons would consist of trawl gear debris with an average weight per fragment of approximately 10 kg (22 lbs.) as based on Merrell's data. This being the case, there were approximately 145,000 trawl fragments discarded each year. Depending on the rate at which trawl material is washed ashore, it is not inconceivable that several hundred thousand pieces of netting material were afloat in that part of the Pacific Ocean and Bering Sea during the period of this study and possibly even today. Depending upon the degree to which ocean currents tend to concentrate or to disperse net fragments in the vicinity of the feeding areas and migration routes of fur seals, this could pose a substantial problem.

To estimate the magnitude of this problem today, we can use the existing information on the nature of discarded or lost net fragments, in combination with similar information concerning the fragments which appear on entangled seals that are seen on the Pribilof Islands. To do so we can make use of a simple model of the population of entangled animals. Since we do not see those that die due to being entangled in large pieces of net material, the model deals only with those that become entangled in relatively small pieces of net debris. Results of such calculations can then be adjusted to compensate for size of net fragments based on information about the size composition of net fragments both in the ocean and on entangled seals.

We begin by assuming that the number of animals entangled in small pieces of net, N, remains relatively constant over a year's time. By assumption, then

$$\frac{dN}{dt} = 0$$

We don't know how much of the population at large (P) becomes entangled in any unit time, but if the rate of entanglement is c and the total mortality rate of entangled seals is m, then

$$\frac{dN}{dt} = cP - mN = 0 \tag{1}$$

where P is the mean size of the total population of entangled animals.

From (1) we see that

$$c = \frac{mN.}{P} \tag{2}$$

If we then assume that the sample of harvested males represents a sample of both N and P (i.e., assume that the ratio of entangled to unentangled seals is the same in the harvested population as in the population at large) we can estimate N/P from data on the observed rate of entanglement. Recent data (Joe Scordino, personal communication) indicated that about 0.4 percent of the males are currently entangled in net debris. These data also indicated that about 75 percent of the entangled animals show wounds in which the debris has cut through the skin and blubber, occasionally penetrating into muscle tissue. Thus if we assume that there is a 75 percent mortality (including mortality due to other causes) within the population of animals entangled in small net fragments over a 6-month period, we can estimate m. This is done by setting the survival (0.25 for ½ year) equal to $e^{-.5m}$. An initial (and obviously tentative) estimate of m is thus 2.77; from (2), then we have $c = (.004)(2.77) = 0.0111$ as an initial estimate of the fraction of animals that become entangled in small net fragments each year.

Based on the assumptions above, then, we have accounted for entanglement in small fragments of net but not for entanglement in larger pieces. We can complete the picture by assuming that animals caught in larger net debris cannot survive long enough to return to the islands (or, in the case of females, are prevented from successfully reproducing). This is a safe assumption in that fur seals have been observed at sea entangled in large pieces of debris (e.g., see Fiscus and Kozloff 1972). In at least one case two seals were observed simultaneously in the same large piece of trawl net (Jones 1982, Bouchet, personal commmunication) and could make little progress in capturing food. As observed by Fiscus and Kozloff (1972), cases of entangled animals hauling out on land at times and places unexpected for fur seals have occurred. This is indicative of the stress entangled animals suffer, which must be greater for larger pieces of net. It is likely that large pieces of net serve to draw more attention through the fish they attract and certainly serve better as potential haulout sites. Large pieces also obviously present larger numbers of openings in which seals can become entangled. As shown below, however, there are very few large pieces of net on the animals that return to land.

Information on the size distribution of net fragments has been collected both for entangled seals and for fragments that wash up on beaches. As demonstrated in Fowler (1982), these data can be used to estimate the proportion of entangled animals that become entangled in large fragments. In this case, the mean weight of fragments on animals observed on the Pribilof Islands in 1973 was 370 grams (13 ounces) (Sanger 1974). The mode for these fragments was 150 grams (5.3 ounces) and the maximum was about 2 kg (4.4 lbs.). Approximately 60 percent (by count) of the material washed up on the beaches of Amchitka Island was of greater size than the maximum observed by Sanger (1974) (Merrell 1980 and personal communication, 1982). Additionally, approximately half of the larger weight categories of net material observed both on beaches and seals were proportionately underrepresented in the fragments found on seals (again by count). If the net material on beaches is representative of that at sea, this implies that about 80 percent (60 percent plus 1/2 of 40 percent) of the entangled seals die and are not represented in the population of entangled seals observed on the islands.

If we assume that the probability of entanglement is independent of net fragment size, then the portion of the population that becomes entangled in large fragments is at least four times as high as for small fragments. From $c = 0.0111$ this rate is then: $4c = 0.0444$ or over 4 percent of the population each year. These are animals that become entangled and cannot make it back to the islands. Adding to these the animals that become entangled in small fragments and eventually die (0.011 of the population), we see that about 5.5 percent of the population will be estimated to die each year due to net fragments alone. About one-third of the observed entangled animals are entangled in plastic bands. If they exhibit mortality rates comparable to those entangled in small net debris, the total entanglement rate will be almost 5.9 percent.

The weakest assumption in these calculations is that of the time over which a 75 percent mortality would occur (corresponding to the 75 percent injured animals). Table 2 shows calculations based on alternative periods, including those outlined above (time = 6 months). Given the severity of the wounds created by entanglement, the actual mortality rates are probably higher than assumed above, making it likely that 75 percent of the entangled animals die in as few as 2–4 months.

Discussion

The analysis above is based on several assumptions that need further study. But there are many reasons why the assumptions behind the estimates in column 5 of Table 2 are conservative and make them lower bounds to the estimated mortality due to entanglement. For example, animals have been observed entangled in pieces of gill net at sea, yet the net entangled animals hauling out on the Pribilof Islands are entangled almost entirely in trawl net material. Females are known to travel over much longer distances than the males in their annual migrations. Not only are they thus potentially exposed to more debris, but their chances of returning to the islands are reduced. Not only were large fragments (over 5 lb [2.3 kg]) more numerous in Merrell's study, they also constituted over 90 percent of the weight of net material found on the beaches of Amchitka Island. Large fragments of net probably exhibit a higher probability of attracting seals and a higher probability of entanglement. Entanglements observed at sea involve large fragments of net and include at least one case of more than one seal caught in the same fragment of

Table 2. Estimates of mortality rates within the Pribilof Island fur seal population created by entanglement in debris as related to various estimates of the survival (and mortality) rates of entangled animals.

Time (months) for mortality of 0.75	m^a	Monthly survival of animals in small net fragments	Annual rate of entanglement: In small net fragments (percent)	Annual rate of entanglement: In large net fragments (percent)	Total mortality due to entanglement (percent)
2	8.32	0.50	3.33	13.31	17.75
4	4.16	0.71	1.67	6.65	8.87
6	2.77	0.79	1.11	4.44	5.92
8	2.08	0.84	0.83	3.33	4.44
10	1.66	0.87	0.67	2.66	3.55
12	1.39	0.89	0.56	2.21	2.96

[a]A yearly instantaenous total mortality rate of animals entangled in small fragments of net (annual survival is e^{-m}).

trawl gear (Fiscus and Kozloff 1972, Jones 1982, Bouchet, personal communication). Large fragments tend to concentrate more fish of interest to seals, serve as potential "haulout platforms," and have more openings in which a seal can insert its head during play or in chasing prey (Fiscus and Kozloff 1972). Some gear is lost through being caught on the bottom. Nothing is known about whether or how often seals dive to feed near such debris and become entangled.

It is possible that a reduction in pregnancy rates has contributed to the decline observed in the population of northern fur seals. This is an alternative explanation to be compared to the extrinsic sources of mortality as emphasized in this paper. The result (a decline) would be the same in each case. However, based on physiological considerations, a depressed birth rate would be inconsistent with the increased growth rates, increased birth weights and other factors indicating that individual fur seals are showing many signs of good health. The empirical information concerning pregnancy rates shows little evidence of change (York 1979, Bigg 1979). There is a possibility that the age at maturation increased slightly in the year classes up to and including the 1956 year class (York 1982), but no trend is clear. It is possible to argue that age at maturation has declined since 1956 as shown by Fowler (1982) using correlations developed by York (1979) and Lander (1979b). Based on these sparse bits of information, it is doubtful that pregnancy rates have declined since 1956, but the possibility should not be ruled out.

It should be pointed out that the information presented in this paper should not be used to argue that the carrying capacity of the fur seal ecosystem has not been reduced. It can only be used to argue that a reduction in the carrying capacity for fur seals is not supported as a cause of the decline in the numbers in the population. Except for arguments by Swartzman and Harr (1980), it remains possible that the carrying capacity is lower than it was in the 1950s. The information presented in this paper simply leads us to the conclusion that the population is below the current carrying capacity of the ecosystem. Owing to the complexity of this issue and the lack of relevant information, the present carrying capacity is difficult to evaluate.

Summary and Conclusions

Starting about 1956 and proceeding to 1968, the fur seal population on the Pribilof Islands underwent a decline which, to a large but limited extent, is explained by the effect of the harvest of females that occurred during that period (York and Hartley 1980). The population did not recover from that reduction nor did it exhibit a tendency to produce harvestable males in greater abundance. The lack of recovery of the fur seal population following the female harvest and the current decline in the fur seal population are of particular concern. This problem developed concurrently with the growth of commercial fisheries in the Bering Sea and North Pacific Ocean. It is thus tempting to blame these problems on changes in the Bering Sea and the North Pacific ecosystems created by commercial fisheries. The most common cause-and-effect mechanism invoked in explaining this decline has been a hypothetical reduction of food resource levels available to the fur seals.

The available evidence concerning trends within the fur seal populations of the Pribilof Islands, however, does not support this hypothesis. During the same period, changes that occurred within the population tend to support the conclusion that conditions for fur seals improved. It is thus difficult to support the conclusion that changes within the fur seal's biotic ecosystem deteriorated in such a way as to create the lack of response following the female harvest and the current decline. Moreover this possibility cannot be supported on the basis of information concerning the feeding ecology of fur seals. They are opportunistic in their feeding strategy, making it likely that a reduction in prey of one type would cause a change in the composition of the diet rather than a significant reduction in consumption.

In view of the evidence concerning the positive changes that have occurred within the population, it became necessary to examine the argument that the population has undergone a decline created by extrinsic mortality. The evidence indicated that mortality at sea increased since 1956. The positive changes can then be interpreted as density dependent responses typical of other species of large mammals (Fowler et al. 1980). If such is the case, we are faced with the problem of defining the nature of mortality that would create the reduction. In view of the information concerning the abundance and character of net debris in the areas occupied by fur seals, combined with information concerning the nature of net fragments on entangled fur seals, it may be that the lack of recovery and the current decline of fur seal population is, in large part, due to entanglement in debris.

The precise degree to which the direct effects of fisheries influence fur seal population dynamics has yet to be reliably estimated. We know some mortality is caused by the incidental taking of fur seals directly in fishing operations, and that much of the entanglement observed in the population involves materials other than fragments of nets. Mortality caused directly as a result of fisheries operations may be responsible for a large part of the observed declines. Considering the current rate of decline of the population, in combination with the information in Table 2, 5 percent or more of the fur seal population may die each year due to the direct effects of fisheries. At current levels for the Pribilof Islands, this would be over 50,000 seals per year.

At the very least, the information presented above serves as a strong argument for the need to undertake further research concerning the importance of entanglement and incidental taking. It should also underscore the need to curtail the discarding of debris into the ocean.

Acknowledgements

Robert DeLong deserves special credit for the concept of comparing net material on beaches with that on fur seals. I was fortunate in not having to conduct a field survey because of the data kindly provided by Joe Scordino and Theodore Merrell. These individuals also provided helpful comments on various drafts of this paper. Similar consideration is deserved by: Hiroshi Kajimura, Michael Tillman, Thomas Loughlin, George Antonelis, Linda Jones, Patrick Kozloff, Gordon Swartzman, Robert Francis, Howard Braham, Ronald Ryel, and Clifford Fiscus. I thank Michael Goebel for the current information on pup sizes. Anne York provided current information on mortality at sea and was especially helpful in providing commments on the quantitative aspects of the paper, as was Jeffrey Breiwick.

References Cited

Bakkala, R., W. Hirschberger, and K. King. 1979. The groundfish resources of the eastern Bering Sea and Aleutian Islands regions. Marine Fisheries Review. 41(11):1–24.

Bigg, M. A. 1979. Preliminary comments on female growth by length in female northern fur seals. Pages 158–166 *in* H. Kajimura, R. H. Lander, M. A. Perez, A. E. York, and M. A. Bigg, eds. Preliminary analysis of pelagic fur seal data collected by the United States and Canada during 1958–74. Paper submitted to the 22nd Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission.

Chapman, D. G. 1981. The northern fur seal—an example of complexity. Pages 193–204 *in* P. A. Jewell and S. Holt, eds. Problems in management of locally abundant wild mammals. Academic Press, New York. 353 pp.

Fiscus, C. H., and P. Kozloff. 1972. Fur seals and fish netting. Pages 124–132 (Appendix E) *in* Fur seal investigations, 1971. Unpublished manuscript, Nat. Mar. Mammal Lab., Northwest and Alaska Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle Wash.

Fowler, C. W. 1982. Entanglement as an explanation for the decline in northern fur seals of the Pribilof Islands. Background paper submitted to the 25th Annual Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. 24 pp.

______, W. T. Bunderson, M. B. Cherry, R. J. Ryel, and B. B. Steele. 1980. Comparative population dynamics of large mammals: A search for management criteria. Mar. Mammal Comm. Rep. MMC-77/20. Available from U.S. Dep. Commer., Nat. Tech. Info. Serv., Springfield, Va. as NTIS PB8O-178627. 330 pp.

Gentry, R. L., J. H. Johnson, and J. Holt. 1977. Behavior and biology, Pribilof Islands. Pages 26–39 *in* Fur Seal Investigations, 1976. Unpubl. rep., Nat. Mar. Mammal Lab., Northwest and Alaska Fish. Cent., Nat. Mar. Fish. Serv., NOAA, 7600 Sand Point Way N.E., Seattle, Wash.

Jones, L. L. 1980. Estimates of the incidental take of northern fur seals in Japanese salmon gillnets in the North Pacific, 1975–1979. Background paper submitted to the 23rd Annual Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. 15 pp.

______1981. Incidental take of northern fur seals in Japanese salmon gillnets in the North Pacific Ocean, 1980. Background paper submitted to the 24th Annual Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. 6 pp.

______1982. Incidental take of northern fur seals in Japanese gillnets in the North Pacific Ocean in 1981. Background paper submitted to the 25th Annual Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. 16 pp.

Kajimura, H. 1976. Interrelationships of northern fur seals ((*Callorhinus ursinus*)and actively fished gear. Background paper submitted to the 19th annual meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission. 7pp.

______. 1982. The opportunistic feeding of northern fur seals (*Callorhinus ursinus*) in the

eastern North Pacific Ocean and Bering Sea. Ph.D. Thesis. Tokvo University, Tokyo, Japan. 148 pp.
Kozloff, P. In preparation. Fur seal investigations 1981. Processed report. Northwest and Alaska Fisheries Center, Seattle, Washington.
Lander, R. H. 1979a. Fur seal growth. Pages 143–157 *in* H. Kajimura, R. H. Lander, M. A. Perez, A. E. York and M. A. Bigg, eds. Preliminary analysis of pelagic fur seal data collected by the United States and Canada during 1958–74. Paper submitted to the 22nd Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission.
______. 1979b. Role of land and ocean mortality in yield of Alaska fur seals. Fish. Bull. U.S. 77:311–314.
______. 1980. Summary of northern fur seal data and collection procedures. Vol. 1. Land data of the United States and Soviet Union (Excluding tag and recovery records). Available U.S. Dep. Commer., Nat. Tech. Info. Serv., Springfield, Va. as NTIS PB81-106502.
McAlister, W. B. 1981. Estimation of fish consumption by marine mammals in the Eastern Bering Sea and Aleutian Island area. (Unpubl. draft report, 88 pp.) Nat. Mar. Mammal Lab., Northwest and Alaska Fish. Serv., NOAA, Seattle, Wash.
Merrell, T. R. 1980. Accumulation of plastic litter on beaches of Amchitka Island, Alaska. Mar. Environ. Res. 3:171–184.
National Marine Fisheries Service. 1972. Fur seal investigations, 1971. Unpubl. rep. Nat. Mar. Mammal Lab., Seattle, Wash. P. 74.
Northwest and Alaska Fisheries Center. 1980. A report based on the workshop on stock assessment and incidental take of marine mammals involved in commercial fishing operations. Unpubl. rep. Nat. Mar. Mammal Lab., Seattle, Wash. 102 pp.
Sanger, G. A. 1974. On the effect of fish net scraps and other oceanic debris in northern fur seals. Background paper submitted to the 17th Annual Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. 5 pp.
Smith, G. B. 1981. The biology of walleye pollock. Pages 527–551 *in* D. W. Wood and J. A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources. Vol. I. U.S. Dep. Commer., Nat. Ocean. Atmos. Admin., Office Mar. Poll. Assess. 625 pp.
Schwartzman, G., and R. Harr. 1980. Exploring interactions between fur seal populations and fisheries in the Bering Sea. Mar. Mammal Comm. Rep. MMC-80/01. Available from U.S. Dep. Commer., Nat. Tech. Info. Serv., Springfield, Va., as NTIS PB81-133688. 60pp.
York, A. E. 1979. Analysis of pregnancy rates of female fur seals in the combined United States-Canadian pelagic collections, 1950–74. Pages 50–122 *in* H. Kajimura, R. H. Lander, M. A. Perez, A. E. York, and M. A. Bigg, eds. Preliminary analysis of pelagic fur seal data collected by the United States and Canada during 1958–74. Paper submitted to the 22nd Annual Meeting of the Standing Scientific Committee, North Pacific Fur Seal Commission.
______. 1982. Age at first reproduction of the northern fur seal. Background paper submitted to the 25th Annual Meeting of the Standing Scientific Committee of the North Pacific Fur Seal Commission. 23 pp.
______, and J. R. Hartley. 1981. Pup production following harvest of female northern fur seals. Can. J. Fish. Aquat. Sci. 38:84–90.

Status of Alaska Sea Otter Populations and Developing Conflicts With Fisheries

Ancel M. Johnson
U.S. Fish and Wildlife Service
Denver Wildlife Research Center
Anchorage, Alaska

Introduction

Although sea otters (*Enhydra lutris*) have been a relatively insignificant resource in Alaska during the twentieth century, the situation is changing. Remnant populations that recolonized most of their historic range are becoming recognized as a potentially valuable economic resource and as a competitor with some important shellfish fisheries. It is appropriate that sea otters should again become an important Alaskan resource because they were so significant in the initial exploration and settlement of Alaska by non-natives. In this paper I review changes in distribution and population abundance since 1740, recent changes in human attitudes toward sea otters, and review our understanding of the biological characteristics of sea otters that are particularly important to managing populations.

Pre-1911 Populations

An era of intensive fur hunting and exploration began soon after crew members that survived Bering's famous last voyage to North America returned to Kamchatka. By the end of the era, sea otter populations were greatly reduced and the west coast of North America was no longer uncharted wilderness. Because the history of this early fur trade and the fate of the sea otter populations have been described by a number of authors, I will only briefly summarize them here. Lensink (1960) estimated that during the 126 years of Russian occupation of Alaska (1741–1867) about 800,000 sea otters were taken by all nationalities. During this period, exploitation was initially uncontrolled; but by the early nineteenth century it was apparent to managers of the Russian-American Company, which had been given exclusive hunting rights, that the taking had to be regulated or the resource would be eliminated. Apparently, hunting was regulated some time after 1820. Hooper (1897) stated that the native hunters were held to strict quotas allotted to the various hunting districts during this period and the take recorded by the Russian-American Company suggests harvests were regulated to obtain a sustained yield. The annual take varied from a few hundred to about 2,000 from the 1840s through 1865. During this period of controlled hunting, sea otter populations apparently partially recovered.

Another period of uncontrolled hunting began with the purchase of Alaska by the United States. This time uncontrolled hunting continued until sea otters had been eliminated from all but a few remote areas. The number of otters taken for the four decades between 1871 and 1910 was 40,283, 47,842, 6,467, and 572, respectively (Lensink 1962), clearly indicating that the sea otter population was greatly reduced and that hunting was no longer profitable. Kenyon (1969) concluded that in 1911 there were remnant populations of sea otters in seven areas of

Alaska, scattered throughout most of the sea otter's range in Alaska. Only the coast to the east and south of Prince William Sound was without colonies. It is likely that otter populations remaining in 1911 consisted of widely scattered animals with larger groups in the seven specific areas identified by Kenyon. The total number of otters in 1911 is not known, but probably no more than several hundred remained.

There is no way to develop a reliable estimate of the total number of sea otters in Alaska before exploitation. Kenyon (1969) concluded that the number was probably no more than 100,000 to 150,000, but could have been as high as 637,500. Kenyon's lower figure was based on the assumption that there were 30,000 otters in the late 1960s occupying about one-fifth of the total range. Based on additional surveys, it appears that Kenyon's estimate of 30,000 was low. Schneider (1978) estimated 100,000 to 120,000 otters in 1972 with probably one-half or more of the range reoccupied. Therefore, I conclude that the population in 1740 was probably somewhat greater than 200,000.

Post-1911 Population

Very little information was accumulated on sea otter populations until the 1930s. By then reports of sea otter sightings were becoming frequent. Population surveys began in the Rat Islands in the Aleutian Chain in the early 1930s (Eyerdam 1933) and by the early 1960s much additional information had accumulated. Lensink (1962) and Kenyon (1969) summarized these data, which show that sea otter populations had responded well to protection and had increased to about 40,000; populations in the central Aleutians showed signs of being at carrying capacity. At the time, the only large segment of the historic range that did not contain otters was southeast Alaska. From 1964 through 1972 the State of Alaska translocated otters to southeast Alaska (Schneider 1978) and surveys there in 1975 indicated that reproducing colonies had become established in four areas (Jameson et al., 1982).

Since 1972, when the Marine Mammal Protection Act took management authority from the States, there has been no complete survey of the sea otter range. Limited information from studies in specific areas and from other sightings of sea otters supports the conclusion that sea otters are increasing in recently occupied areas, that there are some sea otters in all of the historic Alaskan range, and, except for southeast Alaska, populations are likely to be at or near carrying capacity within the decade. The populations in southeast Alaska probably total about 1,000 now and can be expected to increase several fold, probably not reaching maximum levels for several decades.

Lensink (1960) noted that counts of the Amchitka Island population indicated an annual increase of about 19 percent during the early stages of recovery, and this later decreased to near 5 percent. Assuming that the aggregate of all existing populations, in various stages of recovery, are increasing at a rate well below the highest level estimated for the Amchitka Island population, a reasonable estimate of the annual rate of increase for the entire population is probably near the lowest level, about 5 percent. Assuming further that Schneider's estimate of 100,000 to 120,000 was correct for the early 1970s, then the present population numbers 150,000 and 200,000 animals.

Biology

Knowledge of sea otters was recently summarized by Estes (1980). I will descirbe only those biological attributes and ecological relationships that are of obvious importance to management; namely, movement, segregation, vital statistics, feeding habits, and ecological effects of feeding.

Movements of sea otters are poorly understood. Observations of expanding populations have shown that large numbers of otters will move from an island with a high density to an adjacent island with few or no otters (Kenyon 1969, Lensink 1962). We do not know if similar "mass" movements will occur between islands or areas with approximately equal densities of otters when the entire range is occupied. Based on 29 recoveries of tagged otters, Kenyon tentatively concluded that the home range of the sea otter during at least a 3-year period may include about 5 to 10 miles (8–16 km) of coastline and that males have a larger home range than females. In Prince William Sound, Alaska, I observed that tagged adult females may limit their movements to a small area of 3 or 4 km^2 (1.2–1.5 square miles) for several days, but, within a season, regularly move their area of use several kilometers so that their seasonal or yearly range includes several square kilometers. Adult males show a similar pattern, except seasonally, some males may move their daily area of use by as much as 88 km (54.7 miles). The long movements of adult males have been from territories occupied during the peak of the mating season to "male areas" used during the remainder of the year. Limited data suggest that young males also move to male areas after they become independent at 6 to 12 months of age. No data exist showing movements of individual young females, and limited observations suggest that they remain near the area where reared. Sea otter populations are not migratory.

Another attribute of sea otters that is important to management planning is the tendency of the sexes to segregate (Kenyon 1969, Schneider 1978). The tendency to segregate, in combination with their gregarious habits, results in the formation of pods that may contain several hundred otters. Females are rarely found in these males pods. The area used by these pods is predictable, although the pods may move a few kilometers and change in size seasonally. The greatest changes in these male pods have been observed at the periphery of the range (Kenyon 1969, Lensink 1962, Johnson, unpubl. data). Apparently, the male areas show the least change in well-established populations.

Although we have general knowledge of natality and mortality, we do not have data showing age specific rates. Females give birth to their first pup when three to five years old (Schneider 1972). Based on the condition of ovaries and uterine horns of a large collection of female otters, Schneider concluded the typical reproductive cycle of females was two years. However, observations of marked females and a small collection of females in Prince William Sound suggest that most females there have an annual reproductive cycle, and Loughlin et al. (1981) reported two tagged females in California had annual cycles. Observations of females in aquaria show that they are capable of an annual cycle. The length of the reproductive cycle may be related to population status; females in populations at or near maximum levels may have a two-year cycle, as indicated by Schneider's data, and those below that level have a high percentage of females with an annual cycle.

Little is known of the magnitude or specific causes of natural mortality. Mortality appears to be low in populations that are becoming established and increases as populations reach a maximum level. The increase is primarily of young animals and apparently is related to decreased food quality and availability (Kenyon 1969). In Alaska the loss of sea otters to predators appears to be insignificant.

Feeding habits of sea otters are well known (Estes et al. 1981). Although otters take numerous species for food, only a few groups of species appear to be of major importance. These include clams, mussels, crabs, sea urchins, and in some areas slow-moving fishes.

Of particular importance to management are the ecological effects of sea otter foraging on nearshore communities. In the absence of sea otters, dense mature populations of several otter prey species developed. Most noticeable of these are the sea urchin populations in the Aleutians and clam and mussel populations in several areas. Estes and Palmisano (1974), Estes et al. (1978), and Dayton (1975) noted that, where sea otter populations had become reestablished in the Aleutians, the size and abundance of sea urchins were reduced, macroalgal assemblages were robust, and nearshore fishes relatively more abundant than in areas without sea otters. The depressing effect of sea otter foraging on abalone (*Haliotis* spp.) and pismo clam (*Tivela stultorum*) populations in California is also well documented (Lowry and Pearse 1973, Miller 1974, and Miller et al. 1975).

Developing Sea Otter-Fishery Conflicts

Until recently, sea otters have been absent or at low levels in the vicinity of human populations in Alaska. This situation is now changing, and the impacts of sea otters on some shellfish populations are becoming of concern to human residents in several areas.

In addition, people are aware that the sea otter is now well established in most of its historic range in Alaska and that they are a resource of potentially significant economic yield. This is particularly important to people living in remote regions where economic opportunities are limited. The combination of perceiving sea otters as a competitor and not being able to take them for their pelts is causing an increasing feeling of resentment and animosity toward sea otters and resource management agencies.

How significant is the competition between sea otters and human users for shellfish resources? Major sea otter prey species that are frequently taken by humans include butter clams (*Saxidomus giganteus*), little neck clams (*Protothaca* spp.), soft shell clams (*Mya* spp.), razor clams (*Siliqua patula*), and dungeness crabs (*Cancer magister*). Other prey species occasionally taken by humans include *Spisula* spp., *Macoma* spp., *Clinocardium* spp., *Tresus capax*, and sea urchins. Small tanner crabs, *Chionoecetes* spp., and king crabs, *Paralithodes* spp., are taken by sea otters and are of primary importance to the crab fishery in Alaska. Abalone are a preferred prey of sea otters, but are taken by humans in significant numbers only in southeast Alaska. Small scallops are taken by sea otters but it is not known if otters compete with humans for these. Of the species listed, it is likely that sea otters have or will reduce the availability of butter clams, little neck clams, razor clams, and abalone. It is clear from studies in California that sea otters have greatly reduced the size and availability of similar species occurring there (Miller 1974, and Miller et al. 1975). Also it appears likely that sea otters will reduce the availability of dungeness crabs, although the actual effect of sea otters on crab populations has not been clearly demonstrated.

The intensity and importance of competition between sea otters and human users varies by area. In many areas of Alaska, several species of clams and dungeness crabs are taken for commercial, recreational, and subsistence use. In southeast Alaska, abalone are taken commercially and locally for recreational and subsistence use. The edible mussel *(Mytilus edulis)* and sea urchins common throughout the sea otter range in Alaska are primary prey species, but are taken infrequently by humans. Residents of Atka Island and the southern Kenai Peninsula consider sea otters competitors for food resources. The importance of the competition is difficult to evaluate. In many areas of Alaska, dense beds of large old clams (mature populations) developed during the long period when sea otters were absent. These clam beds are considered of great value to local residents and in a few remote areas are a significant food source. In some areas, such as Prince William Sound, clamming and crabbing are important subsistence and recreational activities, and commercial crabbing for dungeness crabs is economically important. In 1981, two years after large numbers of sea otters began using the area immediately around Cordova in northeast Prince William Sound, this area was closed to all taking of clams and crabs to protect low stocks. In southeast Alaska, the commercial abalone fishery has increased dramatically in the recent past, and, although the yield is a relatively small 200,000 to 300,000 pounds (90,720–136,080 kg) per year, it is economically important to local communities (Balog 1980, Timothy Koeneman, Alaska Dep. of Fish and Game, pers. comm.).

In addition to being competitors, sea otters are also a minor nuisance to fishermen because they occasionally become entangled in nets. Matkin and Fay (1980) estimated that about 70 otters became entangled in nets in Prince William Sound and Copper River Delta salmon fisheries during the 1978 season. Most of these were released and probably cause only minor net damage.

Discussion

In the previous section, the adverse effects of increasing sea otter populations were discussed; however, it should not be inferred that these are the only effects of the increased populations. Sea otters now occur in several readily accessible areas, and public viewing and photography are becoming important. As the opportunity to observe and photograph sea otters increases and the opportunities for observing sea otters become more widely known, this use will certainly increase. Nevertheless, the adverse affects are real and will also increase.

In the late 1960s and early 1970s the State of Alaska was in the initial phase of developing management of sea otters. These efforts were stopped by passage of the Marine Mammal Protection Act of 1972. By 1972 the State had conducted several surveys of the sea otters' range; it had taken about 2,000 sea otters in an experimental harvest, accumulating substantial biological data from these collections. It also had established reproducing sea otter populations in southeast Alaska and had assisted Oregon and Washington and British Columbia with translocations. Since 1972, the Fish and Wildlife Service has continued support of sea otter studies begun in the mid 1950s, but there has been no significant progress on management development.

Our knowledge of sea otters, although still lacking in several important areas, is sufficient to suggest that a rather wide range of population management objectives are attainable. These objectives can include maintaining populations at naturally occurring maximum levels in areas where recreational use (observing and photography) are high; allowing a sustained yield for pelts where economic use is desired; and reducing populations in areas where competition for shellfish resources is unacceptably high. Additional knowledge of dispersal and movements is required to precisely predict the size of the area of influence of management actions. However, based on our present knowledge, all of these objectives are attainable within Alaska. This is not to imply that two substantially different management objectives could be attained in two adjacent areas.

The sea otter appears to be one of the most manageable of the marine mammals. Because sea otters are not migratory, meaningful management units can be delineated; sea otters are relatively easy to count; sea otters are at or near carrying capacity in parts of their range; they are partially segregated by sex and can be live captured in nets, making it possible to have highly selective taking by sex. Further, they float when killed, greatly reducing chances of hunting loss. Comparing these attributes with those of other marine mammals suggests sea otter populations could be managed relatively easily.

Of most concern now is the obvious change in human attitudes toward sea otters and managing agencies. For example, when I began studying sea otters in Prince William Sound in 1975, not one of the many persons with whom I spoke expressed animosity toward sea otters; most were pleased that the sea otter population was increasing. Since then, sea otters have moved into the important clamming and crabbing areas of northeastern Prince William Sound. During the past two years, local residents have reported decreased availability of clams and dungeness crabs, and sea otters are blamed for the decrease. Many people express hostility toward sea otters openly and talk about "taking matters into their own hands," i.e., shooting otters. To add to the problem, the sea otter population in the Sound is apparently nearing maximum level, and increased natural mortality is evident from the increased number of sea otter carcasses found on the beaches. The result is that there is a growing animosity toward sea otters and resentment of managing agencies that do not allow taking of an economically valuable resource. I believe an active management program would greatly improve this undesirable situation.

References Cited

Balog, J. 1980. Fishing with a pry bar: Southeastern's Pinto Abalone. Alaska Magazine, August 1980: 32–35.

Dayton, P. K. 1975. Experimental studies of algal canopy interactions in a sea otter-dominated kelp community at Amchitka Island, Alaska. Fish. Bull. 73: 230–237.

Estes, J. A. 1980. Enhydra lutris. Mammalian Species No. 133. Amer. Soc. of Mammal. Pp. 1–8.

Estes, J. A., R. Jameson, and A. M. Johnson. 1981. Food selection and some foraging tactics of sea otters. Pages 606–641 *in* J. A. Chapman and D. Pursley, eds. Worldwide Furbearer Conference Proceedings, Vol. 1. Univ. of Maryland Press, College Park.

Estes, J. A., and J. F. Palmisano. 1974. Sea otters: their role in structuring nearshore communities. Science 185: 1058–1060.

Estes, J. A., N. S. Smith, and J. F. Palmisano. 1978. Sea otter predation and community organization in the western Aleutian Islands, Alaska. Ecology 59: 822–833.

Eyerdam, W. J. 1933. Sea otters in the Aleutian Islands. J. Mammal. 14(1): 70–71.

Hooper, C. L. 1897. A report on the sea otter banks of Alaska. Doc. No. 1977. U.S. Treas. Dep. Washington, D.C.

Jameson, R. J., K. W. Kenyon, A. M. Johnson, and H. M. Wight. 1982. History and status of translocated sea otter populations in North America. Wildl. Soc. Bull. In press.

Kenyon, K. W. 1969. The sea otter in the eastern Pacific ocean. N. Amer. Fauna 68: 1–352.

Lensink, C. J. 1960. Status and distribution of sea otters in Alaska. J. Mammal. 41: 172–182.

________. 1962. The history and status of sea otters in Alaska. Unpubl. Ph.D. Dissert. Purdue Univ., Lafayette, Ind. 186 pp.

Louglin, T. R., J. A. Ames, and J. E. Vandevere. 1981. Annual reproduction, dependency period, and apparent gestation period in two California sea otters, *Enhydra lutris*. Fish. Bull. 79(2): 347–349.

Lowry, L. F. and J. S. Pearse. 1973. Abalones and sea urchins in an area inhabited by sea otters. Mar. Biol. 23: 213–219.

Matkin, C. D. and F. H. Fay. 1980. Marine mammal-fishery interactions on the Copper River and in Prince William Sound, Alaska, 1978. Marine Mammal Commission, Final Report No. MMC-78/07, Washington, D.C. Pp. 1–71, i–vii.

Miller, D. J. 1974. The sea otter, *Enhydra lutris*, its life history, taxonomic status, and some ecological relationships. Mar. Res. Leaflet 7. California Dep. Fish and Game, Sacramento. 13 pp.

________, J. E. Hardwick, and W. A. Dahlstrom. 1975. Pismo clams and sea otters. Mar. Tech. Rep. 31. California Dep. Fish and Game, Sacramento. 49 pp.

Schneider, K. B. 1972. Reproduction in the female sea otter. Proj. Prog. Rep., Fed. Aid in Wildl. Restoration, Proj. W-17-4. Alaska Dep. Fish and Game, Juneau. 36 pp.

________. 1978. Sex and age segregation of sea otters. Final Rep., Fed. Aid in Wildl. Restoration, Proj. W-17-4 through W-17-8. Alaska Dep. Fish and Game, Juneau. 45 pp.

Swicegood, Lcdr. S. P. 1936. Amchitka sea otter survey expedition. Unpubl. memo to Commanding Officer, U.S. Coast Guard Cutter *Chelan*, 31 Aug. 1936. USFWS. files, Anchorage, Ak. 5 pp.

Documentation and Assessment of Marine Mammal-Fishery Interactions in the Bering Sea

Lloyd F. Lowry
Alaska Department of Fish and Game, Fairbanks

Introduction

The nature and extent of interactions between marine mammals and fisheries have received increased attention in recent years (e.g., FAO 1978, Mate 1980, IUCN 1981). With few exceptions (Mate 1980), interactions of concern involve commercial fisheries that, in contrast to recreational and subsistence fisheries, typically harvest large quantities of fish and or shellfish and often operate in areas that support large marine mammal populations. Such interactions can be conveniently considered as two major types listed below:

1. Direct or operational interactions
   a. marine mammals cause damage to a fisherman's gear and/or catch
   b. marine mammals are injured or killed as a result of contact with fishing gear or fishermen
2. Indirect or biological interactions
   a. predation by marine mammals reduces the quantity of a target species that is available to a fishery
   b. harvests by a fishery reduce the amount of prey available to marine mammals
   c. marine mammals function as hosts for parasites that may reduce marketability of commercial fishes

Operational interactions are in most cases readily observed, localized in extent, and comparatively easy to document and quantify. In contrast, indirect interactions are not well documented, occur over broad areas (i.e., entire ecosystems), and are conceptually complex and difficult to quantify (IUCN 1981). In this paper I will deal only with indirect interactions that primarily involve the dynamic responses of marine mammals and fisheries to changes in fish stock abundance and characteristics. The area being considered is the Bering Sea, including the waters surrounding the Aleutian Islands.

Exploitation of marine mammal and fish populations has been a major factor in the exploration, colonization, and development of the Bering Sea region. Although these resources have been utilized by indigenous peoples for several thousand years, it was not until the 1600s and 1700s that the abundance of seals, sea otters, walruses, and whales was "discovered" by Europeans (Fay 1981). Over the next two centuries, populations of several species were harvested to the point of commercial extinction, while at least one, the Steller sea cow *(Hydrodamalis gigas)*, became biologically extinct. Through a series of domestic and international laws and treaties, a framework for the conservation and management of marine mammal populations was slowly developed. Most recently, the Marine Mammal Protection Act of 1972 (PL 92-522) has attempted to provide guidelines for the protection and management of marine mammals in the United States, with the stated primary objective of maintaining the "health and stability of the marine ecosystem."

Commercial exploitation of Bering Sea fish stocks did not begin until after the peak of marine mammal harvests. Small catches of Pacific cod *(Gadus macrocephalus)* and halibut *(Hippoglossus stenolepsis)* were made in the late 1800s, but substantial harvests did not occur until early in the twentieth century (Pruter 1973). Cod and halibut, along with salmon *(Oncorhynchus* spp.*)*, were the principal target species prior to 1940. After World War II, a major diversification occurred in the fisheries, resulting in exploitation of many new species, including yellowfin sole *(Limanda aspera)*, walleye pollock *(Theragra chalcogramma)*, Pacific ocean perch *(Sebastes alutus)*, Atka mackerel *(Pleurogrammus monopterygius)*, herring *(Clupea harengus)*, sablefish *(Anoplopoma fimbria)*, shrimps *(Pandalus* spp.*)*, king crabs *(Paralithodes* spp.*)*, and tanner crabs *(Chionoecetes* spp.*)*. Domestic fishing has been regulated primarily by the federal government, while after 1960 the State of Alaska developed management programs for salmon, herring, shrimp, and crab fisheries. Foreign fisheries were in some instances regulated by domestic legislation and international agreements that were generally not adequate to prevent overexploitation and decline of stocks (Pruter 1973). The Magnuson Fishery Conservation and Management Act of 1976 (PL-94-265) established a 200-mile Fishery Conservation Zone in seas adjacent to the United States and provided a framework for management of existing commercial fisheries and development of fisheries for species not presently utilized commercially.

Natural history studies of Bering Sea marine mammals have documented the importance of commercially harvested species in marine mammal diets (e.g., Scheffer 1950, Lowry et al. 1979). Preliminary estimates of the quantities consumed indicated that annual consumption of commercial fish species by marine mammals exceeded the amount harvested by the fisheries (McAlister and Perez 1976). Considering the magnitude of the trophic interaction between marine mammals and commercially important fishes in the Bering Sea, an ecosystem-based approach to management of finfish and shellfish populations is obviously desirable. Since ecosystem-based management is encouraged by provisions of both the Marine Mammal Protection Act and the Fishery Conservation and Management Act (Hammond 1980), an attempt was made to consider marine mammal food requirements in the development of the Bering Sea/Aleutian Islands groundfish fishery management plan. This attempt was only partially successful due to the lack of adequate data and models with which to analyze and simulate the possible interactions. In response, the North Pacific Fishery Management Council, in conjunction with the Marine Mammal Commission, entered into a contract with the Alaska Department of Fish and Game to provide a summary and evaluation of data on foods and population status of Bering Sea marine mammals. This paper is a brief summary of part of the results of that review and evaluation. Emphasis will be on the documentation of interactions and conceptual assessments that can be made with existing data. The use of models to simulate and perhaps predict characteristics of interactions will be discussed in detail in reports of work currently in progress.

Results and Discussion

Documentation of Bering Sea Interactions

As one would expect, the earliest observations of stomach contents of marine mammals in the North Pacific and Bering Sea showed that marine fishes and shellfishes were major items in their diets. However, prior to 1950, few studies documented marine mammal foods in any quantitative fashion. Soviet commercial harvests of ice seals provided some data on foods on those species (e.g., Fedoseev 1965, Shustov 1965, Gol'tsev 1971, Kosygin 1971), while experimental and opportunistic observations added data on foods of fur seals, sea lions, and harbor seals (e.g., Scheffer and Sperry 1931, Imler and Sarber 1947, Scheffer 1950). Interestingly, although several samples were collected at areas and times when salmon were present, fishes of the cod, herring, and smelt families were usually the major prey. Nonetheless, due to acknowledged direct interactions with salmonid fisheries and a perceived competition for resources, harbor seals and sea lions in particular were subject to bounties and control programs in some areas to reduce their effects on fisheries (see Mate 1980). Such control programs were terminated by 1970. Further studies of foods of pinnipeds generally confirmed the dietary importance of herring, smelts, and cods (see summaries by Pitcher 1981, Lowry and Frost 1981, Perez and Bigg 1981).

General information on foods of cetaceans became available with the examination of animals taken in commercial harvests (e.g., Tomilin 1957, Zimushko and Lenskaya 1970). This has been supplemented by information from animals, particularly small cetaceans, which are taken by subsistence hunters (e.g., Seaman et al., in prep.), caught in fishing gear (e.g., NMML 1981), or washed up dead on shore (Scheffer 1953). In general, zooplankton and small schooling fishes have been found to be the major prey of cetaceans, and, given the offshore distribution of most species and their observed foods, interactions with fisheries have appeared slight. A notable exception involves belukha whales in Bristol Bay. There, a systematic study (summarized in Lensink 1961) documented the consumption of smolt and adult salmon by belukhas in the Kvichak and Nushagak River estuaries. Calculations indicated that belukhas consumed 2.7 percent of the sockeye *(Oncorhynchus nerka)* runs in 1954 and 1.0 percent in 1955, which was considered significant, especially in light of the depleted status of stocks. This led to the development of a nonlethal acoustic system that was used to displace the whales from the rivers at critical times (Fish and Vania 1971). With improved management and recovery of sockeye stocks, use of this system has been discontinued.

Major changes in the pattern of exploitation of Bering Sea fish stocks occurred during the period following the end of World War II (Bakkala et al. 1981), of which the development of the groundfish fishery is probably most significant. The aggregate catch of groundfish by all nations increased from 12,500 metric tons in 1954 to over 2.2 million metric tons in 1972; the 1972 harvest was 176 times greater than that in 1954. In addition, due at least in part to depletion of stocks of other target species (Pruter 1973), the percentage of pollock in the harvest increased from 0 to 83 percent during that period (Bakkala et al. 1981). This increase in harvests from the Bering Sea can be largely attributed to human population increases and changing protein consumption patterns. In addition to population increases in the two major nations involved in the groundfish fishery, Japan and the Soviet Union, the catches of whales, which have been used as a source of protein and other products by those two nations, have decreased markedly since 1960. The percentage (by weight) of whales in the world marine resource harvest decreased from 10.2 percent in 1949–50 to about 1 percent in 1973–74 (FAO 1978). This decrease is due both to reduced whale catches and to increased harvests of other marine resources.

The increased harvests of Bering Sea groundfish, particularly pollock, and the improved data base on marine mammal foods suggested a major potential competition for resources (McAlister and Perez 1976, Lowry et al. 1979). Frost and Lowry (1981a) documented the presence of pollock in the diet of 11 species of marine mammals and 13 species of seabirds. Calculations by McAlister and Perez (1976) indicated 2,853,000 metric tons of finfish were consumed annually by pinnipeds in the Bering Sea, an amount considerably in excess of the harvest by fisheries. Two questions could then be formulated, each of which could be applied either specifically to pollock and their predators or to the entire suite of Bering Sea marine mammals and fisheries. First, is predation by marine mammals impacting the harvests that can be taken by commercial fisheries? Second, is the take by commercial fisheries affecting food availability and therefore population status of marine mammals?

The magnitude of consumption of commercial fish resources by Bering Sea marine mammals is without doubt substantial (McAlister and Perez 1976, McAlister 1981). In fact, food consumption by marine mammals has been judged significant enough that levels of apex predator consumption (including marine mammals, birds, and elasmobranchs) have been used as primary inputs for a dynamic numerical ecosystem model (DYNUMES) of the Bering Sea (Laevastu and Favorite 1977). However, perhaps due to the lack of documented fish stock depletion attributable to marine mammal predation, this factor has not been included as an interactive variable in fish stock fluctuations, which have instead been considered as regulated by fisheries, environmental factors, and lower trophic level interactions. Observations of sea otters in California (Lowry and Pearse 1973) and walruses in the Bering Sea (Fay and Lowry 1981) demonstrate the ability of marine mammals to deplete at least local stocks of fishable resources. Calculations by Winters and Carscadden (1978) for the North Atlantic have assumed that potential yields to fisheries are a direct function of marine mammal abundance.

The second question is more complex and is supported by a less well developed array of observations, data, and theory. In order to postulate that the actions of a fishery affect populations of marine mammals, four criteria must be met. First, the removals of forage species by the fishery, in combination with other predators, must affect forage stocks differently than predation alone. Second, changes in forage abundance must affect intake of food by marine mammals. Third, a change in food intake must result in a change in vital parameters (e.g., growth, survival, reproduction) of individual marine mammals. Fourth, changes in individual parameters must affect population parameters such as abundance and productivity. If these four linkages must be established in order to quantitatively demonstrate the existence of a significant interaction between marine mammals and fisheries in the Bering Sea, such interactions have not been documented. Instead, however, attempts have been made to correlate observed population characteristics of marine mammals with observed fisheries or presumed changes in fish stock characteristics. Such studies dealing with fur seals (Swartzman and Haar 1980) and sea lions (Braham et al. 1980) have not succeeded in conclusively documenting causal relationships.

Despite the lack of adequate documentation for the Bering Sea, information from other areas suggests responses of marine mammals to changes in their food supply. The evidence is based on the assumption that a reduction in population size of the principal or competing species changes the relationship of the population to its food resources in such a way as to eliminate or reduce the effects of food limitation. Marine mammal populations should then respond to the increased food availability by increased productivity and/or survival, and, in the absence of continued excessive harvesting, the population size should increase. In the North Atlantic, a reduction in the harp seal population during 1952 to 1972 was accompanied by a significant increase in fertility rate (from 85 to 94 percent) and decrease in mean age at maturity (from 6.5 to 4.5 years) (Bowen et al. 1981). These responses should have increased productivity, and indeed the population size has increased in spite of continued harvesting. A second example involves the antarctic ecosystem, where a single species of krill *(Euphausia superba)* is the principal food of many species of birds and marine mammals. Recent increases in populations of several krill predators, including penguins *(Aptenodytes patagonica* and *Pygoscelis* spp.*)*, crabeater seals *(Lobodon carcinophagus)*, and fur seals *(Arctocephalus* spp.*)*, are thought to be the result of an increase in availability of krill brought about by the reduction of large whale populations that had formerly consumed great quantities of that species (Laws 1977).

Thus, the available information suggests that populations of some marine mammal species can be limited by food availability and that individual and population parameters will respond to changes in levels of available food. It must be noted that the major factor is the relationship between abundance of predator and prey populations rather than the absolute size of either. That is, a reduction in a marine mammal population while abundance of prey remains constant would have a similar effect to enhanced prey abundance with a constant mammal population. In order to facilitate such considerations, some investigators have found it useful to consider this relationship in terms of per capita food availability.

Conceptual Assessments of Probable Interactions

In the absence of ecosystem models and exact numerical data on functional relationships within the Bering Sea ecosystem, a conceptual evaluation of the probable magnitude of marine mammal-fishery interactions can be made using information on the occurrence of commercial species in marine mammal diets and a general understanding of trophic relationships. Preliminary evaluations, based on descriptive food habits data, have been given by Lowry et al. (1979), Fiscus (1980), and Frost and Lowry (1981b); preliminary food webs involving Bering Sea pinnipeds have been presented in Lowry and Frost (1981); and estimates of the quantitative composition of the diet of marine mammal species are available in McAlister (1981).

A second major consideration in such conceptual assessments is the relationship of existing marine mammal populations to the point at which their abundance is limited by food (carrying capacity or K). Although direct information on this subject is not readily available, data on population size relative to historic levels and present trend in abundance can generally be approximated. Such information can be combined with available data on diet composition, feeding strategy, and the importance of the Bering Sea as a feeding area to produce a numerical assessment for each marine mammal species of the likelihood of significant interaction with present commercial fisheries. This has been done by assigning ranked values to feeding characteristics, based on whether they suggest a probable interaction with fisheries, and to population size and trend values, based on whether they indicate probable food limitation (Table 1). A species that is stenophagous on commercially exploited prey, uses the Bering Sea as a major feeding area, and is at or above carrying capacity would receive high ranks (maximum total of 15). Conversely, a mobile and omnivorous species that consumes prey not exploited by fisheries, feeds only briefly in the Bering Sea, and is below carrying capacity would receive low ranks (minimum total of 5).

Results of such an analysis, considering all factors combined (Table 2), produce six categories of species, with total rank values ranging from 13 (highest probability of significant interaction) to 8 (lowest probability of interaction). Characteristics of species in each of the categories will be briefly discussed.

Category 1

Based on this assessment, the species for which there is greatest potential for interaction are the northern fur seal, Steller sea lion, and harbor seal. For all three species the Bering Sea is a major feeding area, and commercially exploited fishes (principally pollock, herring, and salmon) comprise substantial portions of the diet (McAlister 1981, Lowry and Frost 1981). In addition, although they are somewhat opportunistic, much of their intensive feeding may be limited by the proximity of terrestrial hauling areas. Based on available data, populations are probably at levels close to carrying capacity, and reductions in prey abundance would be likely

Table 1. Criteria for assigning ranked values of the likelihood of marine mammal-fishery interactions in the Bering Sea. Low values indicate that the described characteristics suggest a low probability of significant interactions.

	Feeding			Relation to carrying capacity	
Rank value	Composition of the diet	Feeding strategy	Importance of Bering Sea as feeding area	Relative population size	Population trend
1	Feed principally on noncommercial species	Omnivorous with high mobility of predators and prey	Important only for a small fraction of annual nutrition or feeding available elsewhere	Greatly reduced	Increasing
2	Feed moderately on commercial species	Moderately diverse diet (opportunistic)	Moderately important	Slightly reduced	Stable
3	Feed heavily on commercial species and use size classes similar to those targeted on	Stenophagous or with low mobility of predators and prey	Major feeding area without other regular or optional feeding grounds	Comparable to historic	Declining

Table 2. Ranked values of the likelihood of marine mammal-fishery interactions in the Bering Sea, based on characteristics of feeding and population status.

Species/group	Feeding			Status		Total
	Diet composition	Feeding strategy	Bering Sea importance	Relative size	Population trend	
MYSTICETE CETACEANS						
Gray whale *(Eschrichtius robustus)*	1	3	3	3	1	11
Fin whale *(Balaenoptera physalus)*	2	1	2	1	2	8
Minke whale *(B. acutorostrata)*	2	1	2	1	2	8
Blue whale *(B. musculus)*	1	3	1	1	2	8
Sei whale *(B. borealis)*	1	3	1	1	2	8
Humpback whale *(Megaptera novaengliae)*	2	1	2	1	2	8
Bowhead whale *(Balaena mysticetus)*	1	3	1	1	2	8
Right whale *(B. glacialis)*	1	3	1	1	2	8
ODONTOCETE CETACEANS						
Sperm whale *(Physeter catodon)*	1	1	2	2	2	8
Belukha *(Delphinapterus leucas)*	3	2	2	3	2	12
Beaked whales Family Ziphidae	1	1	3	3	2	10
Killer whale *(Orcinus orca)*	2	1	1	3	2	9
Dall's porpoise *(Phocoenoides dalli)*	2	2	2	2	2	10
Harbor porpoise *(Phocoena phocoena)*	3	1	3	3	2	12
PINNIPEDS						
Northern fur seal *(Callorhinus ursinus)*	3	2	3	2	3	13
Steller sea lion *(Eumetopias jubata)*	3	2	3	2	3	13
Pacific walrus *(Odobenus rosmarus)*	1	3	3	3	1	11
Harbor seal *(Phoca vitulina)*	3	2	3	3	2	13

Table 2. (cont'd.)

Species/group	Feeding: Diet composition	Feeding strategy	Bering Sea importance	Status: Relative size	Population trend	Total
Spotted seal *(P. largha)*	2	2	2	3	2	11
Ribbon seal *(P. fasciata)*	2	2	3	2	1	10
Ringed seal *(P. hispida)*	1	1	2	3	2	9
Bearded seal *(Erignathus barbatus)*	2	1	2	3	2	10
CARNIVORES						
Polar bear *(Ursus maritimus)*	1	2	1	3	2	9
Sea otter *(Enhydra lutris)*	2	2	3	3	2	12

to affect ingestion rates and population productivity. Interestingly, it has already been speculated, although not proven, that fisheries have affected fur seals and sea lions (Braham et al. 1980, Swartzman and Haar 1980).

Category 2

Species in this category also rely on the Bering Sea as an important feeding area and are thought to be presently near carrying capacity. In the case of the sea otter, the probability of interactions with fisheries is lessened slightly due to a moderate proportion of commercial species in the diet (Kenyon 1969). Although belukha and harbor porpoise forage extensively on commercial species (Frost and Lowry 1981b), their mobility may reduce the probability of significant interactions.

Category 3

In the case of the spotted seal, probability of interaction with fisheries is considered less than for the previously mentioned species due to the moderate proportion of commercial species in the diet and the fact that much of the population resides in the Bering Sea only during winter and spring (Lowry and Frost 1981). The other two species, the gray whale and walrus, share a number of common characteristics. Population sizes of both are at, if not above, historical levels and may still be increasing (Reilly et al. 1980, Fay, in press). The Bering Sea is a major feeding area for both, and they show little feeding plasticity, specializing in comparatively sedentary invertebrates that are of no present commercial importance (Frost and Lowry 1981b, Lowry and Frost 1981). Nonetheless, commercial fishing or other activities that either directly or indirectly affect populations of their prey could have major effects on the status of walrus and gray whale populations.

Category 4

Species in this category exhibit a variety of characteristics. Although the Bering Sea is probably an important feeding area for beaked whales, they feed only slightly on commercial species (Frost and Lowry 1981b) and may be opportunistic and highly mobile. Placement of Dall's porpoise in this category rather than the previous one is based on the judgment that the Bering Sea is of only moderate importance for feeding, an assumption that may prove false. In any event, the population is probably somewhat reduced due to mortality caused by direct fishery conflicts (NMML 1981) and is less likely to be food limited. The Bering Sea is an important feeding area for ribbon seals, and a moderate portion of their known diet consists of commercially harvested fishes (Lowry and Frost 1981). However, their population size, although increasing (Burns 1981), may still be somewhat below historical levels. Bearded seals are highly omnivorous and include only a moderate proportion of commercial species in their diet (Lowry and Frost 1981).

Category 5

The three species in this category, killer whale, ringed seal, and polar bear, do not depend extensively on commercially harvested species, depend only in part on the Bering Sea for their annual nutrition, and are relatively mobile and opportunistic in their feeding.

Category 6

This category includes the sperm whale and all species of baleen whales except the gray whale. Populations of the included baleen whales are all greatly reduced, which suggests that they are presently far below the point of food limitation. Species that eat commercially exploited fishes (fin, minke, and humpback whales) are highly mobile and opportunistic, while the prey of stenophagous species (blue, sei, bowhead, and right whales) are not commercially harvested (Frost and Lowry 1981b). Based on available information, the sperm whale is relatively euryphagous and concentrates its feeding on noncommercial species.

Conclusions

Although it is clearly known that many, although by no means all, species of marine mammals in the Bering Sea consume finfishes and shellfishes that are also commercially harvested, interactions between marine mammals and fisheries in the area have been poorly documented and assessed. Even in the case of the fur seal and sea lion, species that consume a large proportion of commercial species and for which reasonably good population data are available, biological interactions with commercial fisheries cannot be conclusively demonstrated. However, in other areas, including the Antarctic and North Atlantic, good information exists to show that marine mammal populations are at times food limited and can respond to changes in per capita food availability.

Based on a review of data on feeding and population status, an assessment of the likelihood of each marine mammal species interacting with existing commercial fisheries can be made. Results of such an assessment suggest a relatively high probability of interaction for the following species: northern fur seal, Steller sea lion, harbor seal, belukha, harbor porpoise, and sea otter. Future studies designed to investigate marine mammal-fishery interactions in the Bering Sea should be directed toward those species.

Acknowledgments

The compilation, review, and evaluation of available data on feeding and status of Bering Sea marine mammals were supported by the North Pacific Fishery Management Council and the U.S. Marine Mammal Commission (Contract No. 81-4). Susan Hills has been largely responsible for the collection and compilation of the data. Much of the data-collecting and background research was supported by the National Oceanic and Atmospheric Administration through the Outer Continental Shelf Environmental Assessment Program and by the Federal Aid in Wildlife Restoration Program. Kathryn J. Frost and John J. Burns have had substantial and valuable input into the data and concepts presented in this paper. The manuscript was typed and edited by Kathleen Valentine.

References Cited

Bakkala, R., K. King, and W. Hirschberger. 1981. Commercial use and management of demersal fish. Pages 1015–1036 *in* D. W. Hood and J. A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources, Vol. 2. Off. Marine Pollution Assessment, NOAA. Distrib. by Univ. Washington Press, Seattle.

Bowen, W. D., C. K. Capstick, and D. E. Sergeant. 1981. Temporal changes in the reproductive potential of female harp seals *(Pagophilus groenlandicus)*. Can. J. Fish. Aquat. Sci. 38:495–503.

Braham, H. W., R. D. Everitt, and D. J. Rugh. 1980. Northern sea lion population decline in the eastern Aleutian Islands. J. Wildl. Manage. 44:25–33.

Burns, J. J. 1981. Ribbon seal—*Phoca fasciata*. Pages 89–110 *in* S. H. Ridgway and R. J. Harrison, eds. Handbook of marine mammals, Vol. 2. Academic Press, London and New York.

FAO. 1978. Mammals in the seas. Report of the FAO advisory committee on marine resources research, working party on marine mammals. FAO Fish. Ser. 5, 1:1–275.

Fay, F. H. 1981. Marine mammals of the eastern Bering Sea shelf: an overview. Pages 807–811 *in* D. W. Hood and J. A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources, Vol. 2. Off. Marine Pollution Assessment, NOAA. Distrib. by Univ. Washington Press, Seattle.

———. In press. Ecology and biology of the Pacific walrus *Odobenus rosmarus divergens* Illiger. N. Amer. Fauna No. 74. U.S. Fish Wildl. Serv., Washington, D.C.

———, and L. F. Lowry. 1981. Seasonal use and feeding habits of walruses in the proposed Bristol Bay clam fishery area. Unpubl. final rep., Contract No. 80-3, North Pacific Fishery Manage. Council, Anchorage, Alaska. 61 pp.

Fedoseev, G. A. 1965. Food of the ringed seal. Izv. TINRO 59:216–223. In Russian.

Fiscus, C. H. 1980. Marine mammal-salmonid interactions: a review. Pages 121–132 *in* W. J. McNeil and D. C. Himsworth, eds. Salmonid ecosystems of the North Pacific. Oregon State Univ. Press, Corvallis.

Fish, J. F., and J. S. Vania. 1971. Killer whale, *Orcinus orca,* sounds repel white whales, *Delphinapterus leucas*. Fish. Bull. 69:531–535.

Frost, K. J., and L. F. Lowry. 1981a. Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fish. Bull. 79:187–192.

———. 1981b. Foods and trophic relationships of cetaceans in the Bering Sea. Pages 825–836 *in* D. W. Hood and J. A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources, Vol. 2. Off. Marine Pollution Assessment, NOAA. Distrib. by Univ. Washington Press, Seattle.

Gol'tsev, V. N. 1971. Feeding of the common seal. Ekologiya 2:62–70. In Russian.

Hammond, K. A. G. 1980. Fisheries management under the Fishery Conservation and Management Act, the Marine Mammal Protection Act and the Endangered Species Act. Final Rep. U.S. Marine Mammal Comm. Contract No. MM1300885-3. 52 pp.

Imler, R. H., and H. R. Sarber. 1947. Harbor seals and sea lions in Alaska. Spec. Sci. Rep. No. 28. U.S. Fish Wildl. Serv., Washington, D.C. 23 pp.

IUCN. 1981. Report of IUCN workshop on marine mammal/fishery interactions, La Jolla, Calif., 30 March–2 April. ICUN, Gland, Switzerland. 68 pp.

Kenyon, K. W. 1969. The sea otter in the eastern Pacific Ocean. N. Amer. Fauna No. 68. Bur. Sport Fish. and Wildl., Washington, D.C. 352 pp.

Kosygin, G. M. 1971. Food of the bearded seal, *Erignathus barbatus nauticus* (Pallas), of the Bering Sea in the spring–summer period. Izv. TINRO 75:144–151. In Russian.

Laevastu, T., and F. Favorite. 1977. Preliminary report on dynamical numerical marine ecosystem model (DYNUMES II) for eastern Bering Sea. Processed rep., Northwest and Alaska Fish. Cent., Nat. Mar. Fish. Serv., Seattle, Wash. 81 pp.

Laws, R. M. 1977. Seals and whales of the southern ocean. Philos. Trans. R. Soc. London, Ser. B. 279:81–96.

Lensink, C. J. 1961. Status report: beluga studies. Unpubl. rep. Div. Biol. Res., Alaska Dep. Fish and Game, Juneau. 20 pp.

Lowry, L. F., and K. J. Frost. 1981. Feeding and trophic relationships of phocid seals and walruses in the eastern Bering Sea. Pages 813–824 *in* D. W. Hood and J. A. Calder, eds. The eastern Bering Sea shelf: oceanography and resources, Vol. 2. Off. Marine Pollution Assessment, NOAA. Distrib. by Univ. Washington Press, Seattle.

Lowry, L. F., K. J. Frost, and J. J. Burns. 1979. Potential resource competition in the southeastern Bering Sea: fisheries and phocid seals. Pages 287–296 *in* B. R. Melteff, ed. Proc. 29th Alaska Sci. Conf., Fairbanks, 15–17 August 1978. Univ. Alaska Sea Grant Rep. No. 79-6.

Lowry, L. F., and J. S. Pearse. 1973. Abalones and sea urchins in an area inhabited by sea otters. Mar. Biol. 23: 213–219.

Mate, B. R. 1980. Workshop for marine mammal-fisheries interactions in the eastern Pacific. Final Rep. Marine Mammal Comm. Contract No. MM8AC-003.

McAlister, W. B. 1981. Estimates of fish consumption by marine mammals in the eastern Bering Sea and Aleutian Island area. Draft rep., Nat. Marine Mammal Lab., Northwest and Alaska Fish. Cent., Nat. Mar. Fish. Serv., Seattle, Wash. 87 pp.

______, and M. A. Perez. 1976. Ecosystem dynamics, birds and marine mammals. Processed rep., Northwest and Alaska Fish. Cent., Nat. Mar. Fish. Serv., Seattle, Wash. 29 pp.

NMML. 1981. Report on studies of the incidental take of marine mammals, particularly Dall's porpoise, *Phocoenoides dalli,* in the Japanese salmon fishery. Northwest and Alaska Fish. Cent., Nat. Mar. Fish. Serv., Seattle, Wash. 70 pp.

Perez, M., and M. Bigg. 1981. An assessment of the feeding habits of the northern fur seal in the eastern North Pacific Ocean and eastern Bering Sea. Draft rep., Northwest and Alaska Fish. Cent., Nat. Mar. Fish. Serv., Seattle, Wash. 47 pp.

Pitcher, K. W. 1981. Prey of the Steller sea lion, *Eumetopias jubatus,* in the Gulf of Alaska. Fish. Bull. 79:467–472.

Pruter, A. T. 1973. Development and present status of bottomfish resources in the Bering Sea. J. Fish. Res. Board Can. 30:2373–2385.

Reilly, S., D. Rice, and A. Wolman. 1980. Preliminary population estimate for California gray whale based on Monterey shore censuses, 1967/68 to 1978/79. SC/31/Doc 37. Rep. Int. Whaling Comm. 30:359–368.

Scheffer, T. H., and C. C. Sperry. 1931. Food habits of the Pacific harbor seal, *Phoca richardii.* J. Mammal. 12:214–226.

Scheffer, V. B. 1950. The food of the Alaska fur seal. Wildl. Leafl. 329. U.S. Fish and Wild. Serv., Washington, D.C. 16 pp.

______. 1953. Measurements and stomach contents of eleven delphinids from the northeast Pacific. Murrelet 34:27–30.

Seaman, G. A., L. F. Lowry, and K. J. Frost. In prep. Foods of belukha whales *(Delphinapterus leucas)* in western Alaska.

Shustov, A. P. 1965. The food of ribbon seals in the Bering Sea. Izv. TINRO 59:178–183. In Russian.

Swartzman, G., and R. Haar. 1980. Exploring interactions between fur seal populations and fisheries in the Bering Sea. Final Rep. U.S. Marine Mammal Comm. Contract No. MM1800969-5. Natl. Tech. Info. Serv., Springfield, Va. 67 pp.

Tomilin, A. G. 1957. Cetacea. *In* V. G. Heptner, ed., Mammals of the USSR and adjacent countries. In Russian.
Winters, G. H., and J. E. Carscadden. 1978. Review of capelin ecology and estimation of surplus yield from predator dynamics. Int. Comm. Northwest Atl. Fish. Res. Bull. 13:21–30.
Zimushko, V. V., and S. A. Lenskaya. 1970. Feeding of the gray whale ((*Eschrichtius gibbosus* Erx.) at foraging grounds. Ekologiya 1:26–35. In Russian.

Marine Mammal-Fishery Interactions: A Report From an IUCN Workshop

D. M. Lavigne
Department of Zoology, University of Guelph, Guelph, Ontario, Canada

Introduction

During the last decade it has become obvious that the world's oceans do not represent an unlimited reservoir of protein for feeding the ever increasing human population. Concomitant with this realization, it has become increasingly popular to view marine mammals as man's competitors for limited resources in the oceans. Some marine mammals even have been accorded the status of pests (Harwood and Lavigne 1981) because they interfere with fishing operations by damaging catches or gear or both.

Understanding and resolving such conflicts between marine mammals and fisheries is of some practical importance for several reasons. For example, claims that marine mammals are pests or competitors are supported by documented or perceived losses of revenue to the fishing industry concerned. Such claims are frequently used to press for preventive culling programs of otherwise protected species and to justify the initiation, continuation, or escalation of intensive hunting of others. These actions are then opposed by individuals and organizations concerned with the well-being and preservation of marine mammals.

Apparent conflicts between marine mammals and fisheries have become so widespread in recent years that a number of scientific meetings have been held to examine the situation (Mate 1980, Matkin and Fay 1980, Anon. 1981a, 1981b, the present symposium). The present paper attempts to summarize the results of one such workshop, organized by the Committee on Marine Mammals of the International Union for the Conservation of Nature and Natural Resources (IUCN) and held in April 1981 (Anon. 1981a). This workshop tried to clarify the true nature and extent of existing marine mammal-fishery interactions, to anticipate where such interactions were likely to arise in the future, to evaluate to what extent control of marine mammals would benefit fisheries, and how the effects of any control measures implemented should be tested and monitored.

Terms of Reference

The terms of reference for the Workshop were:

1. To examine the ecological relationships involved in the actual or perceived competition between marine mammals and fisheries, including a review of information on historical changes.
2. To develop an approved methodology to determine the nature and extent of the problem, including economic aspects, of marine mammal consumption of marine resources.
3. To develop a methodology for assessing how commercial fisheries may be conducted, including the setting of quotas, to avoid depletion of marine mammal populations dependent on them.
4. To assess the problems of calculating, from fish consumption by marine mam-

mals, potential changes in fishery yields arising from changes in the numbers of marine mammals and other top predators.

5. To catalogue and identify particularly acute problems (apart from incidental catch) involving marine mammals and fisheries.
6. To indicate areas where problems may arise in the near future.

In addressing the terms of reference, the participants made no assumptions about relative economic or other social values assigned either to fisheries activities or to the conservation of marine mammals. Discussions were based on a number of working papers prepared specifically for the workshop, in addition to relevant information available in the published literature.

Classification of Marine Mammal-Fishery Interactions

Conflicts between marine mammals and fisheries generally result from either operational or ecological interactions. Operational conflicts arise when marine mammals cause damage to fishing gear or catches, and when marine mammals are injured or killed as a result of incidental or accidental interactions with fishing gear or fishermen. Ecological conflicts may result when economically-important fish species serve as intermediate hosts for parasites of marine mammals; they may also occur when the predatory activities of marine mammals overlap with fishing interests.

Scope of the Workshop

Not all topics listed in the terms of reference were given equal attention because of time limitations. Operational interactions were only briefly reviewed, leaving the bulk of the time to concentrate on problems associated with the biological interactions betwen marine mammals and fisheries, in particular, those related to the predatory activities of marine mammals on commercially-exploited prey species. In summarizing the report of the meeting below, I have avoided discussion of detailed case studies; these are summarized in the report itself (Anon. 1981a) and in the background documentation and working papers listed therein.

Workshop Conclusions

Operational Interactions

It is clear that many species of marine mammals are a nuisance to fishermen. They may damage fish in gear or remove parts of the catch entirely, and damage gear in the process. They may also accidentally collide with fishing gear and cause damage. These interactions result in direct losses to fishermen as well as those associated with lost fishing time, either for removing marine mammals from gear or repairing the gear itself. In the process, marine mammals may be injured or killed.

Actual costs of damage to gear are generally small in comparison to those associated with loss of fishing time while gear is being replaced or repaired. Loss to fishermen through damaged catches may be substantial, although this is very often difficult to quantify accurately. Similarly, accurate statistics on the number of marine mammals injured or killed in conflicts with fisheries are rarely available.

Additional marine mammals are deliberately shot by fishermen attempting to protect their gear or catch. Frequently the numbers of marine mammals killed are not significant in terms of the effect of population size. In other cases, endangered species may be involved, as in the case of the humpback whale *(Megaptera novaenglia)* off Newfoundland (Harwood and Lavigne 1981).

The above problems are essentially operational in nature, and are usually local in occurrence. Solutions to these problems are largely operational as well. In many cases the problem can be solved, or at least eased, by relatively simple changes in gear, fishing techniques, or the location of fishing effort, as has been demonstrated in the case of the tuna-porpoise problem in the eastern Pacific (Allen 1981).

Where problems of this nature persist, it may be necessary to institute compensation programs to offset economic losses to fishermen. In some cases, public education programs aimed at changing the attitudes of fishermen towards marine mammals may be warranted (Harwood and Lavigne 1981).

Ecological Interactions

When a marine mammal is perceived to be interacting with a commercially-exploited fishery resource, usually through predation, several questions arise concerning the effect of the marine mammal on the commercial resource. These include (Anon. 1981a):

1. What effect is the marine mammal having on the abundance of the resource and hence on the fishery for it?
2. In what circumstances, and by what amount, would the yield of the resource be enhanced if marine mammal abundance were to be reduced or otherwise controlled?
3. How can a given level of marine mammal abundance be achieved by a management program assuming such is desired as a matter of policy?

Of course, it is also necessary to consider the possible effects of commercial fisheries on marine mammal populations, and this leads to another question:

4. In what circumstances is a change in abundance or a prey species (the resource) likely to affect the abundance and viability of the predatory marine mammal population?

Underlying all these questions is the general problem of how predator-prey interactions may be detected and measured in the real world. What is lacking at the present time is a satisfactory body of theory on marine mammal/fishery interactions to serve as a basis for assessments and for identifying important areas where further empirical data are most urgently needed.

Some analysis of this kind was attempted during the workshop, based on the assumption that predation by a marine mammal population could be treated as if it were equivalent to additional units of effort in a fishery. This approach was, however, recognized as over-simplistic, further emphasizing the need to develop a more general theory to apply to predator-prey interactions in the marine environment. In the absence of an adequate theoretical framework, most of the discussion focussed on a variety of available case studies covering the spectrum of current ecological conflicts between marine mammals and fisheries.

Marine mannals frequently carry a heavy burden of parasites that, at some stage of their life-cycle, may also infest commercially-exploited fish populations. The best known example involves the codworm *(Phocanema decipiens)*. This nematode is frequently found in the muscle tissues of North Atlantic fish, in particular, in cod *(Gadus morhua)*, thereby reducing the value of the flesh. Several marine mammals, including grey seals *(Halichoerus grypus)*, harbor seals *(Phoca vitulina)*, harp seals *(P. groenlandica)*, and harbor porpoises *(Phocoena phocoena)*, serve as intermediate hosts for this parasite. Yet, although grey seals in the United Kingdom appear to have doubled in numbers in the last two decades, no marked increase in occurrence of codworm has been noted in cod catches (Parrish 1979). Thus, despite the fact that such host-parasite relationships are claimed by some to constitute a serious marine mammal/fishery interaction, quantitative evidence is presently lacking.

At the present time, any discussion of the ecological relationships involved in actual or perceived competition between marine mammals and fisheries must also remain tentative and qualified. In many cases there is not even conclusive evidence that perceived conflicts are real. With the exception of the sea otter *(Enhydra lutris)* (Estes 1981) there is not a single substantiated case to support the frequently stated claim that marine mammals are capable of successfully competing with man for commercially-exploited fisheries. There are several reasons for this. For example, food requirements of marine mammals, including consumption rates of particular prey species are not well documented; nor is the size/age composition of prey consumed by marine mammals, compared to that taken by a fishery, usually available. Incidentally, most published consumption rates of marine mammals appear to be over estimates (Lavigne et al., in press, Gallivan, in press), giving the impression that any potential problem will be even more serious than it possibly could be. Furthermore, many marine mammals are opportunistic in their feeding habits, and much of their diet may be comprised of numerous noncommercial fish or invertebrate species, or they may feed in areas where there are no fisheries at all. In addition, temporal and spatial relationships between marine mammals and fisheries are not well understood and, in some cases, complex trophic relationships obscure interactions between an individual marine mammal population and a particular fishery.

Assessment becomes particularly complex when a marine mammal eats several kinds of valuable fish species that compete with, or are themselves predatory on, others. To complicate matters further, some of the noncommercial species taken by marine mammals are also competitors with, predators of, or parasites of commercially-important species. The familiar problems of assessing the demography and dynamics of individual marine mammal and prey populations also frustrate the evaluation of marine mammal-fishery interactions.

Regardless of these difficulties, there have been numerous suggestions that marine mammal populations be reduced or controlled at some level in order to reduce competition between marine mammals and fisheries. The implicit assumption is that a reduction of a marine mammal population will result in a decrease in food consumption by that population and that the "surplus food" so liberated will be available to the fishery. Yet, when a marine mammal population is so reduced, intraspecific competition will be reduced, and per capita food consumption should increase accordingly, other things being equal. Such density-dependent responses are necessary if there is to be a sustainable yield, or "surplus production," from an exploited population. Therefore, a decrease in a marine mammal population will not result in a proportionate decrease in food consumption. Furthermore, any surplus prey liberated by a reduction in a marine mammal population does not become totally available to a fishery. Such prey are vulnerable to death from natural causes, including comsumption by other marine predators: fish, sea birds, and other marine mammals. In conclusion, only some proportion of the so-called surplus prey made available by the reduction of a marine mammal population will become available to the fishery, and depending on the dynamics of trophic interactions and the nature of the fishery, this proportion could be small. Finally, economic considerations may further reduce any perceived benefits of culling a marine mammal population (e.g., Williams 1981).

Therefore, although superficially it may seem logical to reduce predator populations—in this case marine mammal populations—when fisheries are experiencing decreased yields, there is presently little evidence to support such action. In most cases it is clear that the decline in fisheries has not resulted from increased competition with marine mammals, but from failures to manage adequately the fisheries themselves.

Although there is presently no evidence that marine mammals can effectively compete with man for common prey species, there is evidence, mostly indirect, that fisheries can affect marine mammal populations. Marine mammals respond to changes in food supplies, and fisheries clearly have impacts on the availability of the prey species they exploit. Indeed, there are numerous examples where both a fish stock and its associated fishery have collapsed. In the case of the Northwest Atlantic harp seal there is evidence of a marked decrease in stored energy (blubber) in whelping females since the collapse of the capelin *(Mallotus villosus),* fishery in 1978 (Innes et al. 1978, Lavigne 1978, 1979). Such changes in the seal population are also correlated with the change in the distribution patterns of baleen whales in the inshore waters off Newfoundland, which has led to a serious increase in collisions of whales with fishing gear (Lien and Merdsoy 1979, Lien and Gray 1980, Lien and McLeod 1980, Harwood and Lavigne 1981). In both cases it is premature to talk about cause and effect relationships, but the implication that the collapse of an important prey population has contributed to such changes is a hypothesis worthy of further examination.

A related consideration, and one which has not received much attention to date, involves evolutionary considerations (Holt and Lavigne 1982). Predators have evolved in an ecosystem producing certain concentrations of prey items, distributed in time and space. If those concentrations are no longer available, i.e. the carrying capacity has been reduced, then the marine mammal population will not be able to achieve previous population levels. If the marine mammal population has been depleted and subsequently protected, under these circumstances it is unlikely to recover to its former level. Obviously one would expect the marine mammal population to adapt somewhat to the new conditions, perhaps by seeking alternative food sources or feeding in new localities (as with the whales off Newfoundland?), but their capacity to do so will be limited.

Future Requirements for Research and Monitoring

The Workshop identified several gaps in knowledge concerning the incidental take of marine mammals. These include accurate statistics on the extent of incidental take by fisheries, the extent and consequences of injuries suffered by marine mammals that escape or are released from fishing gear, and the effect of losses due to incidental take of small cetaceans and pinnipeds on the populations concerned. Data are also required on the incidence and effects of "ghost" nets, which may entrap marine mammals, and on the numbers and species of marine mammals deliberately killed by fishermen during fishing operations. The Workshop also noted many instances where data on perceived or reported damage to fishing gear or catch, and indeed to the marine mammal, were manifestly incomplete or biased. It was agreed that any opportunities to obtain independent assessments should be taken. In addition, development of techniques for reducing the impact of damage by marine mammals should be given high priority where this approach is feasible.

The limitations in available information to assess ecological interactions between marine mammals and fisheries noted above provide a lengthy list of topics for further research. The need for a better theoretical basis for assessing these interactions and for identifying important avenues for future empirical research bears repeating. Additional energetic studies leading to estimates of energy requirements of marine mammals are also required. And, as a reduction in a marine mammal population may be contemplated to reduce a marine mammal-fishery conflict, alternatives to culling must be explored (see Jewell and Holt, 1981).

Areas of Possible Future Conflict

Changes in fishing techniques or gear may be expected to increase marine mammal-fishery interactions in several locations around the world. For example, a change to gill-netting for certain fish species in the Gulf of Maine would constitute a potential hazard to humpback whales. Increased use of gill-nets on the West Coast of North America for species such as swordfish would affect both resident and migratory populations of marine mammals. Development of trawling for squid in New Zealand waters and off the Kamchatka Peninsula would increase incidental capture of Hooker's *(Phocarctas hookeri)* and Steller's *(Eumetopias jubata)* sea lions respectively.

Anticipating future conflicts of an ecological nature is more difficult. As noted in the Workshop report, for most of the many cases considered, there is hardly any unequivocal evidence of this form of interaction being the dominant factor in determining the long-term abundance, and possibly even the distribution, of either a marine mammal predator or its prey. One notable exception is the sea otter interaction with benthic invertebrates in coastal waters of the eastern Pacific. Unrestricted sea-otter populations and clam fisheries are, it would appear, incompatible in the same locality, and this could easily lead to further conflicts in the near future (Estes 1981).

Concern has also been raised about the current size of the Pacific walrus *(Odobenus rosmarus)* population, the status of its food supply in certain parts of its range, and the possibility that man may exploit this food supply in the near future. There can be little doubt that the development of a clam fishery would be detrimental to the walrus population (Harwood and Lavigne 1981). On the other hand there is little evidence to support claims that the walrus population is having serious impacts on its food supply (e.g., Fay et al. 1977); in fact, recent evidence suggests that it ranges over a considerable area without causing obvious local depletion of its food supply (Anon. 1981a).

More generally, there are situations that might be expected to lead to increased conflicts between marine mammals and fisheries. There are instances where marine mammal populations were reduced to low levels, and hunting ceased, either because of economics or protective legislation. Now they are increasing in numbers, and this will no doubt lead to further conflicts with existing or proposed fisheries for their prey species. Conversely, if a fishery is restricted in an attempt to arrest the decline in a marine mammal population, the reaction of fishermen is obvious. There is also the possibility that a marine mammal will change its feeding habits from noncommercial species to commercial species, bringing it into conflict with fisheries. And finally, as further fish stocks become depleted, man will develop new fisheries, probably at lower trophic levels, if the current global pattern is followed. Such development may well bring fisheries into conflict with marine mammals whose existence had previously gone largely unnoticed. Potential conflicts of this nature may be anticipated in shellfish fisheries in Alaska and British Columbia, involving sea otters; in squid fisheries in the eastern tropical Pacific, involving open ocean cetaceans; in krill fisheries in the Antarctic, involving baleen whales, crabeater seals, and fur seals; and in coastal fisheries for herring and capelin in Alaska, involving sea lions and a number of hair seals.

Similar, and probably more serious, problems are likely to arise if commercially-exploited prey species become depleted by fishing. Any competitive influence of a marine mammal predator may then actually increase if it is better able to search out remaining concentrations of fish than is the industry. Again, under these circumstances fishermen will demand remedial action to reduce the influence of the marine mammal.

Remarks

It is clear from the foregoing that some interactions between marine mammals and fisheries represent serious management problems. Yet, because of the frequent lack of scientific evidence, many of the Workshop discussions were inconclusive. This is not surprising since research on the subject is in its infancy, and this is a time when funding for such research is limited.

The Workshop Report ended on a philosophical note concerning the role of scientists in the assessment of marine mammal-fishery interactions. The juxtaposition of a perceived threat, on the one hand, to a food resource and dependent livelihoods, and on the other, to the protection of a highly-valued wildlife population and possibly other dependent livelihoods, is a conflict that science cannot resolve (Anon. 1981a). Furthermore, it is a conflict that can only be ameliorated through some form of compromise between concerned parties with conflicting views or objectives. Scientists can, within certain limits, provide answers to certain questions, in this case about the nature of interactions between marine mammals and their commercially-exploited prey. They can reject some hypotheses as being inconsistent with available information and outline the "facts" that are consistent with current knowledge. These "facts" are themselves open to subsequent evaluation and possible rejection in the face of new data or analyses. It is the job of the scientist then, to offer the best possible impartial guidance and advice to interested parties, including those ultimately responsible for management decisions (Anon. 1981a). Recognizing that management decisions are frequently based on non-biological considerations, scientists can only trust that their advice will be considered, and that it will not be subsequently misinterpreted, misrepresented, or misquoted to justify decisions or positions that are not scientifically-based.

Epilogue

In the annual discussion of the harp and hooded *(Cystophora cristata)* seal hunts off eastern Canada, "science" is frequently used to justify or support both management decisions and the claims of various groups opposing the hunt. One example relevant to the present discussion is described below.

Subsequent to the IUCN Workshop, scientists participating in the annual Northwest Atlantic Fisheries Organization (NAFO) meeting on seals were asked by Canada and the European Economic Community (EEC) to answer six questions related specifically to harp seal-fishery interactions. Questions and answers particularly relevant to the present discussion are summarized below (Northwest Atlantic Fisheries Organization 1981).

Q1. What quantities of commercially exploited fish and invertebrates are estimated to be consumed annually by Northwest Atlantic harp seals? What is the size, age, and species-stock composition of this consumed food?

A. There is as yet little information to produce reasonable estimates of the quantities of food items eaten because of variability in species composition of the food by season, location, age of seals, and biased sampling (i.e. during whelping periods when seals do not feed regularly).

Q2. What direct or indirect (e.g., through competition for food) effects would increasing or decreasing the Northwest Atlantic harp seal population to 25 percent above or below its current abundance be expected to have on exploited fish and invertebrate stocks and yields from them?

A. The effects are unknown for the reasons given in the answer to (1).

Q3. To what extent, when, and where do Northwest Atlantic harp seals compete directly with fishermen by taking commercially exploited fish species near, in or from fishing gear?

A. The information available indicates that such competition is rare.

Q4. To what extent does such competition damage gear or fish or disturb the functioning of gear?

A. Much damage is known to occur occasionally to gillnets in the cod fishery of northern Norway, but there is no evidence of such damage in the Northwest Atlantic.

These questions were also addressed generally at the IUCN Workshop. Clearly, the responses of the NAFO scientific advisors were totally consistent with the conclusions of the IUCN Workshop and indeed some of the NAFO scientists participated in both meetings. What has not been consistent, however, is how this scientific advice has been used, both by the Canadian Department of Fisheries and Oceans, and by Canadian Members of the Parliament (Holt and Lavigne 1982).

During the first two months of 1982, the annual debate over the harp seal hunt off eastern Canada (Lavigne 1978) became the subject of international political discussion because of a proposal before the European Parliament to ban the importation of products derived from young harp and hooded seals (Maij-Weggen 1982). The proposal itself was not without errors, but in defending the hunt, both at home and abroad, Members of Parliament, and indeed a written response to the proposal (Anon. 1982) submitted to Members of the European Parliament by the Canadian Government, portrayed the harp seal (and other seals) as predators of commercial fisheries whose population size must be controlled to reduce competition between seals and man for limited marine resources (Anon. 1982). In other words, statements of Canadian Government officials blatantly neglect, or contradict, the advice of their own scientific advisors. Such tactics are used to justify a policy that is aimed primarily at achieving economic, social, or political objectives, and has very little to do with biological considerations. Such actions demean the role of scientists who provide advice to management authorities; they also further cloud the issues in what is already a complex and poorly understood management problem.

Acknowledgements

This paper is based to a large extent on the "Report of the IUCN Workshop on Marine Mammal/Fishery Interactions" (Anon. 1981a). The various contributions of all workshop participants is acknowledged. In particular, I must single out the other members of the steering committee: J.R. Beddington, R. Brownell, and S.J. Holt; and R.J.H. Beverton, who kindly agreed to act as rapporteur, and graciously accepted the responsibility of bringing the final report to completion. Timely discussions with S. Holt contributed to the final form of the manuscript.

The Workshop was generously hosted by the Southwest Fisheries Center, U.S. National Marine Fisheries Service, La Jolla, California. Financial support was provided by The International Union for the Conservation of Nature and Natural Resources, The People's Trust for Endangered Species, and The International Fund for Animal Welfare.

I hasten to add that the present paper represents my interpretation of the workshop report and its implications. Consequently, views expressed in the paper should not be interpreted necessarily to represent those of any other persons or organizations acknowledged herein.

Literature Cited

Allen, R.L. 1981. Dolphins and the purse seine fishery for yellowfin tuna. IUCN Workshop on Marine Mammal/Fishery Interactions, La Jolla, Ca. 30 March–2 April 1981. Working Paper No. 9.

Anon, 1981a. Report of IUCN workshop on marine mammal/fishery interactions. La Jolla, CA, 30 March– 2 April 1981. International Union for the Conservation of Nature and Natural Resources, Gland, Switzerland. 68pp.

Anon. 1981b. Draft Report. Workshop on marine mammal-fisheries interactions. 26–28 October 1981, Vancouver, Washington. U.S. Marine Mammal Commission, Washington, D.C.

Anon. 1982. (Canadian Government comments on) Proposal of Committee on the Environment, Public Health, and Consumer Protection for a ban on trade in sealskins. 7pp + appendix.

Estes, J.A. 1981. The case of the sea otter. Pages 167–180 *in* P.A. Jewell and S.J. Holt, eds. Problems in management of locally abundant wild mammals. Academic Press Inc., New York. 361pp.

Fay, F.H., H.W. Feder, and S. Stoker. 1977. An estimation of the impact of the Pacific walrus population on its food resources in the Bering Sea. Report MMC–75/06 and MMC–74/03. Marine Mammal Commission, Washington, D.C.

Gallivan, G.J. In press. Metabolic rate. *In* D.M. Lavigne, K. Ronald, and R.E.A. Stewart, eds. The harp seal. Dr. W. Junk bv Publishers, The Hague, The Netherlands.

Harwood J., and D.M. Lavigne, 1981. Locally abundant marine mammals—problems and attempted solutions Pages 151–166 *in* P.A. Jewell and S.J. Holt, eds. Problems in management of locally abundant wild mammals. Academic Press Inc., New York. 361 pp.

Holt, S., and D. Lavigne. 1982. Seals slaughtered—science abused. New Scientist 93:636–639.

Innes, S., R.E.A. Stewart, and D.M. Lavigne. 1978. Growth in Northwest Atlantic harp seals, *Pagophilus groenlandicus*; density-dependence and recent changes in energy availability. Can. Atl. Fish. Sci. Advisory Comm. Working Paper 78/46.

Jewell, P.A., and S.J. Holt, eds. 1981. Problems in management of locally abundant wild mammals. Academic Press Inc., New York. 361 pp

Lavigne, D.M. 1978. The harp seal controversy reconsidered. Queen's Quarterly 85:377–388.

_____. 1979. Management of seals in the Northwest Atlantic Ocean. Trans. N. Amer. Wildl. and Natural Resourc. Conf. 44:488–497.

_____, W.W. Barchard, S. Innes, and N.A. Øritsland. In press. Pinniped bioenergetics. ACMMR/MM/SC/112. Scientific Consultation on Marine Mammals. 31 August–10 September, 1976, Bergen, Norway.

Lien, J., and B. Merdsoy. 1979. The humpback is not over the hump. Natural Hist. 88:46–49.

Lien, J., and S. Gray. 1980. Net Loss. Nat. Can. 9:4–9.

Lien. J., and P. McLoed. 1980. Humpback collisions with fishing gear in Newfoundland: arbitration and education in a whale fishermen dispute. Paper submitted to the Northeast Endangered Species Workshop, 7–11 May 1980, Provincetown, Mass. 33 pp.

Maij-Weggen, J.R.H. (Rapporteur). 1982. Second Report on Community trade in seal products, etc. Working Documents 1981–1982. European Communities, European Parliament, Committee on the Environment, Public Health and Consumer Protection, Doc. 1-984/81. 22 pp + 3 Annexes.

Mate, B.R. 1980. Workshop on marine mammal-fisheries interactions in the northeastern Pacific. Report No. MMC- 78/09. Nat. Tech. Info. Serv., U.S. Dep. of Commerce, Springfield, Va.

Matkin, G.O., and F.H. Fay. 1980. Marine mammal-fishery interactions on the Copper River and in Prince William Sound, Alaska, 1978. Report No. MMC-78/07, Nat. Tech. Info. Serv., U.S. Dep. of Commerce, Springfield, Va.

Northwest Atlantic Fisheries Organization. 1981. Report on Special Meetings of Scientific Council, Dartmouth, Canada, 23-26 November, 1981. NAFO SCS Doc. 81/XI/29. Pp 14-15.

Parrish, B.B. 1979. Notes on the scientific basis of the fisheries case. Appendix 5 *in* J. Lister-Kaye, Seal cull, the grey seal controversy. Penguin Books Ltd., Harmondsworth, Middlesex, England.

Williams, H.A. 1981. The grey seal and British fisheries. Background paper IUCN/CMM/WG3/10. IUCN Workshop on Marine Mammal/Fishery Interactions, 30 March–2 April, La Jolla, Ca. 22 pp.

Forest-Wildlife Management in the Pacific Northwest

Chairman:
E. CHARLES MESLOW
Leader
Oregon Cooperative Wildlife Research Unit
Oregon State University
Corvallis
Cochairman:
FRED BUNNELL
Professor
Faculty of Forestry
University of British Columbia
Vancouver

Spotted Owl Research and Management in the Pacific Northwest

Eric D. Forsman
Cooperative Wildlife Research Unit
Oregon State University
Corvallis

Kirk M. Horn
USDA Forest Service
Pacific Northwest Region
Portland, Oregon

William A. Neitro
USDI Bureau of Land Management
Portland, Oregon

Introduction

In recent years, a rapidly expanding body of research has made wildlife biologists and land managers increasingly aware that old-growth forests are critical wildlife habitat. This has come at a time when old-growth forests are rapidly being eliminated in order to meet human demands for wood products. In Oregon, for example, it is anticipated that virtually all remaining old-growth forests on commercial forest lands will be harvested by the year 2020 (Beuter et al. 1976). Thereafter, regenerating forests on cutover areas will be intensively managed and harvested every 60–80 years on most sites. If history is a good example, it is extremely unlikely that old-growth forests will ever again be regenerated on these cutover areas. Because of the overwhelming economic pressures mandating the harvest of the remaining stands of old-growth, we believe that the single most difficult issue facing wildlife biologists and land managers in the Pacific Northwest is how to retain viable populations of wildlife that find their optimum habitat in old-growth forests.

One species associated with old-growth forests in the Pacific Northwest is the spotted owl (*Strix occidentalis*). During the last 10 years we have been closely involved with studies and management of this species in Oregon. The purpose of this report is to briefly summarize the research that has been conducted on the spotted owl and to describe a management plan that has been proposed for the species in Oregon.

A Summary of Research Efforts

The spotted owl was first discovered in the Pacific Northwest in 1893 (Rhoads 1893), but because of its retiring nature, remained essentially unknown until the early 1970s. As interest in nongame forest wildlife increased during the early 1970s, studies were initiated in Oregon and California to determine the distribution and abundance of the spotted owl and to determine which habitats the species occurred in (Gould 1974, 1977, 1979, Forsman 1976, Forsman et al. 1977). These studies stimulated considerable interest in the spotted owl and led the USDA Forest Service (USFS) and USDI Bureau of Land Management (BLM) to initiate inventories of spotted owls on federal lands in Oregon, Washington and California. Private timber companies also became involved in the effort, in two instances conducting inventories of spotted owls on private timber lands (Postovit 1979, J. Wickham pers. comm. 1982). In many instances, private and state forest lands were also inventoried by USFS and BLM biologists in areas where federal, state, and private lands were adjacent.

As a result of the combined efforts of biologists from the federal, state and private sectors, large areas of Oregon, Washington and California were inventoried for spotted owls between 1972 and 1981. In Oregon, where the inventory effort was most intensive, we estimate that over 50 percent of the potential spotted owl habitat was searched for spotted owls. The results were surprising. Between 1972 and 1981 spotted owls were located at over 600 sites in Oregon, 400 sites in California and 200 sites in Washington (Gould 1979, Forsman unpubl. data). Considering that there were only 24 historical records of the spotted owl in Oregon prior to 1970, the location of so many pairs in a period of only 10 years seems almost unbelievable. However, considering that the number of man hours spent searching for spotted owls each year before and after 1972 went from practically none to many thousands, the results are not really that remarkable. What is remarkable is that a large predator like the spotted owl, which has turned out to be fairly widespread in forests of the Pacific Northwest, could have remained unknown for so long.

Another particularly interesting result of the spotted owl inventories conducted between 1972 and 1981 was that the vast majority of owls were found in older forests (Gould 1974, 1977, 1979, Forsman 1976, Forsman et al. 1977, Postovit 1979, Garcia 1979, Marcot and Gardetto 1980). This was not an entirely unexpected result, since most of the spotted owls reported by early ornithologists in the Pacific Northwest were observed in dense old forests (Dawson 1923, Brooks and Swarth 1925, Gabrielson and Jewett 1940, Marshall 1942, Jewett et al. 1953). However, the large volumes of data collected between 1972 and 1981 served to conclusively document the strong preference of the spotted owl for old forests. In Oregon, for example, over 90 percent of the spotted owls located between 1970 and 1978 were found in old-growth forests or in forests of mixed old-growth and mature timber (Forsman 1976, unpubl. data). Of 47 nests located in Oregon between 1970 and 1980, all were in forests over 70 years old and most (89%) were in forests over 200 years old (Forsman 1976, unpubl. data). This is not to say, however, that spotted owls do not occur in heavily cutover areas. In Oregon, for example, some spotted owls have been found in areas where as much as 70 percent of the forest had been harvested in the previous 50 years (Forsman 1981). However, when spotted owls are found in such areas, they are usually found in the remaining patches of old-growth and mature forest (Figure 1).

The apparent preference of spotted owls for old-growth forests, which was suggested by the inventory data, has been confirmed in two recent radiotelemetry studies in Oregon during which 14 radio-tagged adult spotted owls were observed for periods ranging from 3–13 months (Forsman 1980, 1981). Radio-tagged individuals spent 63–98 percent of their foraging time in old-growth forests, even though some occupied heavily cutover areas where less than 21 percent of the land area was covered by old-growth. Recent clear-cuts and young second-growth forests were generally avoided by the owls (Figure 2). On both study areas, radio-tagged owls roosted in old-growth stands over 90 percent of the time, indicating a strong preference for old-growth forests as roost areas. Preliminary results of an ongoing radiotelemetry study in northern California also indicate that spotted owls prefer older forests for foraging and roosting in that region (D. Solis, pers. comm. 1982).

The overwhelming preference of spotted owls for older forests is undoubtedly related to their requirements for nests, food, and protective roosts. In the Pacific Northwest, spotted owls most commonly nest in large cavities in old-growth trees or in deformed clumps of limbs in mature or old-growth trees (Forsman 1976). These types of nesting sites are usually absent in young forests. The principal prey of spotted owls in Oregon and northern California are flying squirrels (*Glaucomys sabrinus*) and dusky-footed woodrats (*Neotoma fuscipes*) (Marshall 1942, Forsman 1976, Beebe and Schonewald 1977, K. Balderston, pers. comm. 1976, D. Solis, pers. comm. 1982). Although quantitative data on populations of these arboreal mammals are not available, it has been suggested that flying squirrels, at least, are most abundant in older forests where there are numerous cavities and large volumes of lichens and fungi. Lichens and fungi constitute a major source of food for flying squirrels in the Pacific Northwest (McKeever 1960, Maser et al. 1978, Forsman unpubl. observations). Forsman (1976, 1980, 1981) noted that spotted owls frequently roosted in large old-growth trees during inclement weather, apparently because such trees provided greater protection from rain and snow than did second-growth trees. It is also possible that the multi-layered canopies that characterize old-growth stands provide greater protection from high temperatures during the summer than do single-layered second-growth stands. The preference of spotted owls for cool roost sites during warm weather was noted by a number of early ornithologists (e.g., Bent 1938, Marshall 1957) and has since been documented by Forsman (1976, 1980, 1981), Barrows and Barrows (1978), and Barrows (1981).

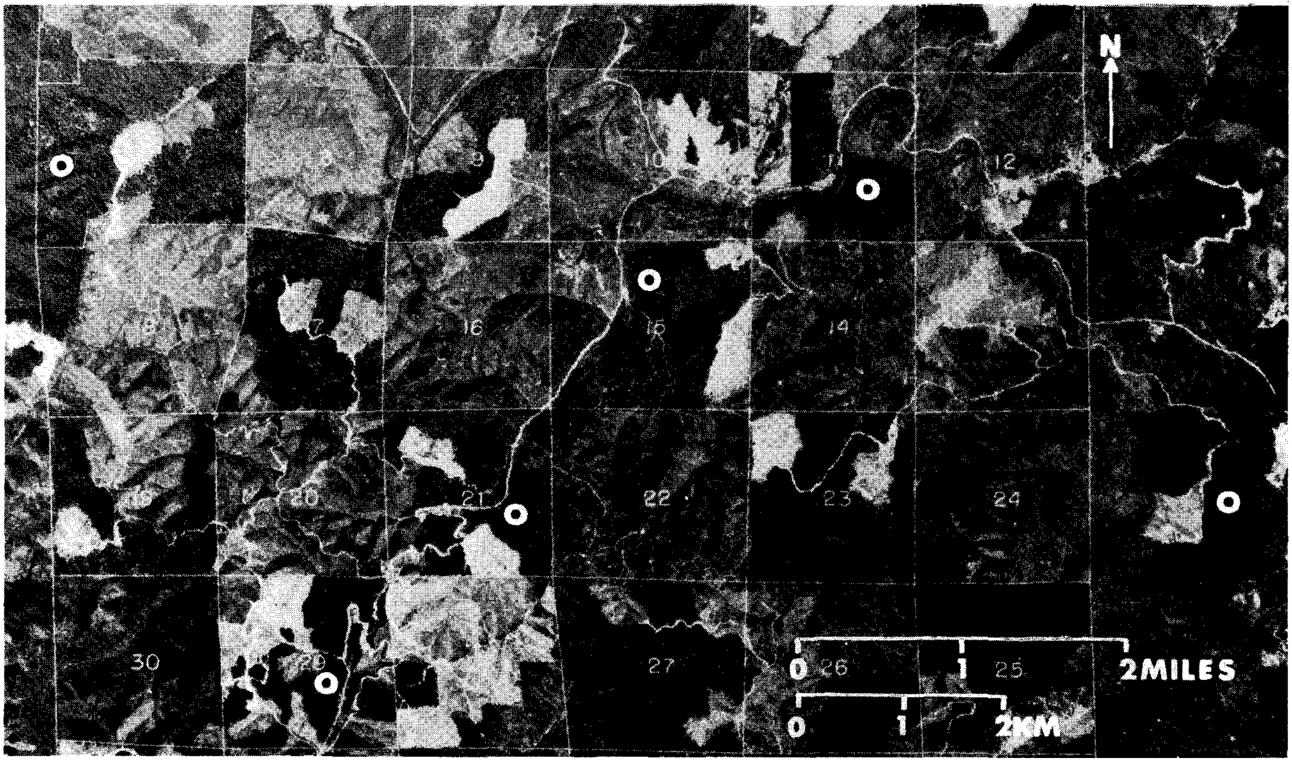


Figure 1. Distribution of pairs of spotted owls in a heavily cutover area in the Oregon Coast Range near Lorane, Lane County. Note that pair locations (indicated by circular white symbols) correspond with the remaining uncut areas of old-growth and mature forest. Of the six pairs indicated on the photo, four disappeared between 1972 and 1978 after additional clear-cutting was conducted in the areas they occupied.

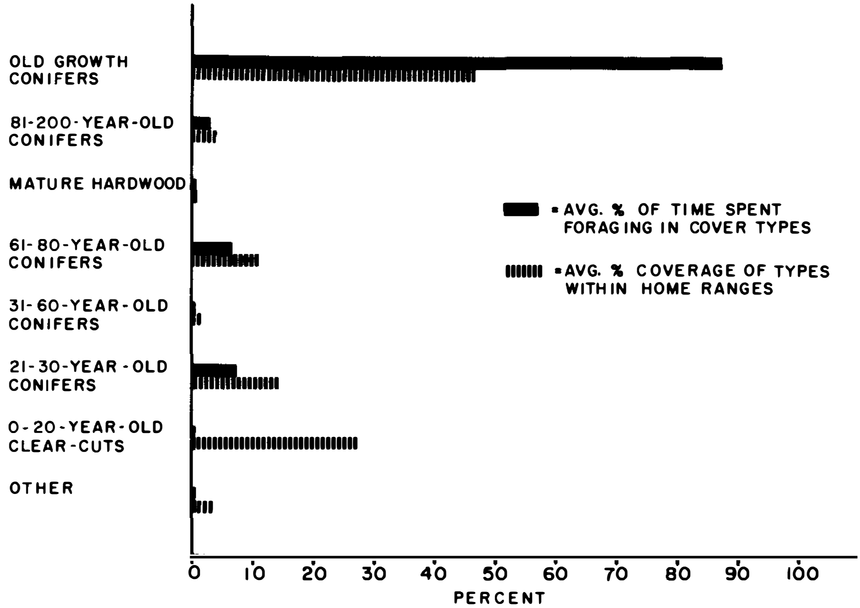


Figure 2. Use of different cover types for foraging by radio-tagged spotted owls in Oregon relative to cover type availability. The data were averaged for 14 owls studied in western Oregon. Data summarized from Forsman (1980, 1981).

Population Trends

Each year in the Pacific Northwest many old-growth stands occupied by spotted owls are harvested. When this occurs, some pairs react by simply shifting their activities into adjacent areas that have not been cutover. Other pairs, apparently confronted with insufficient habitat, simply disappear (Forsman 1976). The net result is that spotted owl populations in the Pacific Northwest and parts of California are declining (Gould 1974, 1977, 1979, Forsman 1976, 1981, Forsman et al. 1977, Postovit 1979, J. Mires, pers. comm. 1981). If present timber harvest trends continue, and there is every reason to believe that they will, it is likely that spotted owls will become very uncommon on commercial forest lands in the Pacific Northwest by the middle of the twenty-first century. Confronted with this set of circumstances, the federal land management agencies in Oregon, California, and Washington are attempting to initiate management programs that will provide habitat for spotted owls and for other wildlife that prefer old forests. One such program is described in the next section.

A Proposed Management Plan

The first attempt to develop a management plan for the spotted owl was launched in Oregon in 1973 by an interagency committee made up of biologists from the USFS, BLM, U.S. Fish and Wildlife Service, Oregon Department of Fish and

Wildlife, and Oregon State University. In recent years, the scope of the management effort has expanded to include representatives of the Washington Department of Game.

Two major issues were addressed in the management plan proposed by the above committee: (1) the number and distribution of spotted owl pairs to be managed for in Oregon; and (2) specific recommendations for habitat management. At the outset the committee agreed that the most appropriate management goal would be to maintain pairs of spotted owls distributed as uniformly as possible throughout the known range of the species. It was recommended, therefore, that a system of spotted owl management areas should be established on federal forest lands in Oregon that would provide suitable areas of spotted owl habitat spaced at intervals of 3–12 miles (4.8–19.3 km). Wider spacing between areas of suitable habitat was deemed undesirable because the available inventory data indicated that pairs of spotted owls were rarely isolated by more than a few miles from other pairs of spotted owls (Marshall 1942, Forsman 1976, unpubl. data). The management plan was restricted to federal forest lands because there was no way to control or predict management activities on private lands, and because the Oregon State Department of Forestry declined to commit state-owned commercial forest lands for management of old-growth ecosystems.

The spotted owl management committee estimated that approximately 400 pairs of owls would be required to obtain a uniform spacing of 3–12 miles (4.8–19.3 km) between pairs on federal forest lands within the range of the owl in Oregon. It was decided, therefore, that the goal for management should be to maintain enough habitat to support 400 pairs of spotted owls in Oregon. It was assumed that a population of 400 pairs (800 individuals) would insure an adequately heterozygous gene pool to maintain a healthy population, especially since that population was continuous into Washington and California (Franklin 1980, Soule 1980).

To insure that areas selected for management would be suitable for spotted owls, the committee agreed that the 400 management areas should be selected on the basis of occupancy by spotted owls. The committee did not discourage the placement of some spotted owl management areas in Wilderness Areas and other restricted use areas, but emphasized that the main objective should be to maintain a uniformly distributed population regardless of land classifications; the emphasis was added to avoid a scenario in which spotted owl management areas were crammed into special use areas (e.g., Wilderness and Roadless Areas), thereby creating a series of island populations rather than a uniformly distributed population.

In the first draft of the Oregon Spotted Owl Management Plan the interagency wildlife committee recommended that a core area of at least 300 acres (121.5 ha) of old-growth forest should be retained around the nest area of each pair of owls selected for management. In 1977 this plan was accepted as the guideline for spotted owl management by the USFS Pacific Northwest Region and the Oregon State office of the BLM.

In a recent revision of the 1977 spotted owl management plan, the interagency wildlife committee recommended that the amount of old-growth retained per pair of spotted owls be increased to 1,000 acres (405 ha), including a 300 acre (121.5 ha) old-growth core area around the nest and an additional 700 acres (283.5 ha) of old-growth distributed in patches of variable size within a 1.5 mile (2.4 km) radius of the nest. This amounts to the retention of 19 percent of the land area in an old-growth condition within a 1.5 mile (2.4 km) radius of the nest. The recommendation to increase the amount of old-growth managed for each pair of owls was prompted by radiotelemetry studies (Forsman 1980, 1981) in which all radio-tagged pairs of owls utilized more than 1,000 acres (405 ha) of old-growth for foraging. The recommendation to confine the management of old-growth to areas within a 1.5-mile radius of the nest was prompted by the observation that spotted owls rarely foraged more than 1.5 miles from their nests while they were nesting (Forsman 1980).

Although not formally stated in the spotted owl management plan, it was presumed that all old-growth forests on commercial forest lands in the Pacific Northwest will be periodically harvested. If this is to occur on spotted owl management areas, then land managers must initiate a cycle of old-growth management in which spotted owl management areas are harvested and replaced at intervals of about 300 years. This is the most intransigent aspect of the proposed spotted owl management plan and of old-growth management in general. We use the word intransigent because the establishment of an old-growth rotation requires that the area committed to the rotation be several times larger than the amount of old-growth that is to be periodically replaced. This would mean that on a typical spotted owl management area several thousand acres would have to be involved in an old-growth rotation to perpetuate a standing crop of 1,000 acres with old-growth characteristics. Obviously, therefore, a large amount of land area would have to be managed on an old-growth rotation in order to maintain 1,000 acres of old-growth at each of 400 sites in western Oregon. How this aspect of the spotted owl management plan will be reconciled with economic reality is unclear.

The position of the federal land management agencies with respect to spotted owl management and old-growth management in Oregon is clear. Without exception these agencies are truly concerned and are trying to initiate management programs to protect species like the spotted owl. The objective of both the USFS and BLM is to maintain viable populations of all native wildlife. At the present time, the USFS and the BLM in Oregon and Washington are in the process of selecting spotted owl management areas to meet the recommendations of the spotted owl management committee. However, the USFS has declined to manage for more than 300 acres of old-growth per pair of spotted owls until it is conclusively proven that the recommendation to increase the amount to 1,000 acres is justified. The latter position is not completely unreasonable considering that only a few studies on habitat use by spotted owls have been completed. Additional studies will undoubtedly permit a refined estimate of the amount of old-growth needed. Along these lines, a study of habitat use by spotted owls that is just being completed in northern California indicates that, on the average, spotted owls in that area utilize smaller home ranges and smaller areas of old-growth than spotted owls in northwestern Oregon (D. Solis, pers. comm. 1982). It is entirely possible, therefore, that the amount of old-growth and mature forest required by spotted owls may vary on a regional basis.

Economic Realities and Research Needs

Understandably, people whose incomes depend either directly or indirectly on the forest products industry are concerned that retention of old-growth forests for spotted owls and other wildlife will reduce timber revenues. Such concerns are not unfounded. The hard facts are that the timber industry in the Pacific Northwest long ago became dependent on the systematic liquidation of old-growth and *will* suffer economic setbacks if this liquidation program is curtailed.

Given the above set of economic conditions, the most optimistic prognosis is that the amount of old-growth maintained for spotted owls and other old-growth dependent wildlife will be near the bare minimum necessary to maintain viable populations. It is imperative, therefore, that further studies be initiated to more accurately determine how much old-growth is needed to sustain pairs of spotted owls and to determine what constitutes a minimum viable population of spotted owls. Hopefully, the necessary research will be initiated soon, as the options for old-growth management are rapidly disappearing; the remaining old-growth forests in many areas of the Oregon Coast Range will be liquidated within the next 15–20 years.

In conclusion, we would like to emphasize that the decline of the spotted owl population in the Pacific Northwest is just one symptom of a more general problem. The elimination of old-growth forests on commercial forest lands in the Pacific Northwest will undoubtedly have a negative influence on populations of many plants and animals that find their optimum habitat in old forests. Unfortunately, so little is known about many of these species that it is difficult to develop specific management recommendations for them. Hopefully, therefore, the management of old-growth areas for spotted owls will also provide habitat for a wide range of other species that find their optimum habitat in older forests.

Acknowledgments

The list of biologists who helped to locate spotted owls in Oregon would fill a page; their efforts and dedication are greatly appreciated. We are especially grateful to Jack Ward Thomas of the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, La Grande, Oregon, and Charlie Thomas of the USDI Bureau of Land Management, Eugene, Oregon, who arranged for funding of several studies of the spotted owl in Oregon through their respective agencies. This is a contribution of the Oregon Cooperative Wildlife Research Unit and the cooperators shared in funding: Oregon Department of Fish and Wildlife, Oregon State University, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating. This is Oregon Agricultural Experiment Station Technical Paper 6501.

Literature Cited

Barrows, C. 1981. Roost selection by spotted owls: an adaptation to heat stress. Condor 83:302–309.

______, and K. Barrows. 1978. Roost characteristics and behavioral thermoregulation in the spotted owl. Western Birds 9:1–8.

Beebe, G. D., and J. Schonewald. 1977. Spotted owls near Palomarin. Point Reyes Bird Observatory Newsletter 43:6–7.

Bent, A. C. 1938. Life histories of North American birds of prey. Part 2: Orders Falconiformes and Strigiformes. Bull. 170. U.S. National Museum and Smithsonian Institution, Washington, D.C. 482 pp.

Beuter, J. H., K. N. Johnson, and H. L. Scheurman. 1976. Timber for Oregon's tomorrow: an analysis of reasonably possible occurrences. Res. Bull. 19. Forest Research Laboratory, School of Forestry, Oregon State Univ. 111 pp.

Brooks, A., and H. S. Swarth. 1925. A distributional list of the birds of British Columbia. Pac. Coast. Avif. No. 17:59.

Dawson, W. L. 1923. The birds of California. Vol. 3. South Moulton Co., San Diego, Los Angeles and San Francisco. Pp. 1090–1096.

Forsman, E. D. 1976. A preliminary investigation of the spotted owl in Oregon. M. S. Thesis. Oregon State Univ., Corvallis. 127 pp.

———. 1980. Habitat utilization by spotted owls in the west-central Cascades of Oregon. Ph.D. Thesis. Oregon State Univ., Corvallis. 95 pp.

———. 1981. Habitat utilization by spotted owls on the Eugene District of the Bureau of Land Management. Unpubl. Tech. Rep., Bureau of Land Management, Portland, Oregon. 63 pp.

———, E. C. Meslow, and M. J. Strub. 1977. Spotted owl abundance in young versus old-growth forests, Oregon. Wildl. Soc. Bull. 5:43–47.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135–149 *in* M. E. Soule and B. A. Wilcox, eds. Conservation biology: an evolutionary-ecological perspective. Sinauer Assoc., Inc., Sunderland, Mass.

Gabrielson, I. N., and S. G. Jewett. 1940. Birds of Oregon. Oregon State College, Corvallis. 650 pp.

Garcia, E. R. 1979. A survey of the spotted owl (*Strix occidentalis*) in Washington. Pages 18–28 *in* P. Schaffer and S. Ehlers, eds. Owls of the west: their ecology and conservation. Proc. of a Nat. Audubon Soc. Symposium at Calif. Acad. Sciences, San Francisco.

Gould, G. I., Jr. 1974. The status of the spotted owl in California. Unpubl. Rep., Calif. Dep. of Fish and Game, Sacramento. 36 + 20 appendix pp.

———. 1977. Distribution of the spotted owl in California. Western Birds 8:131–146.

———. 1979. Status and management of elf and spotted owls in California. Pages 86–97 *in* P. Schaeffer and S. Ehlers, eds. Owls of the west: their ecology and conservation. Proc. of a Nat. Audubon Soc. Symposium at Calif. Acad. Sciences, San Francisco.

Jewett, S. G., W. P. Taylor, W. T. Shaw, and J. W. Aldrich. 1953. Birds of Washington State. Univ. of Washington Press, Seattle. 767 pp.

Marcot, B. G., and J. Gardetto. 1980. Status of the spotted owl in Six Rivers National Forest, California. Western Birds 11:79–87.

Marshall, J. T., Jr. 1942. Food and habitat of the spotted owl. Condor 44:66–67.

———. 1957. Birds of pine-oak woodland in southern Arizona and adjacent Mexico. Pacific Coast Avifauna No. 32:78–79.

Maser, C., J. M. Trappe, and R. A. Nussbaum. 1978. Fungal-small mammal interrelationships with emphasis on Oregon coniferous forests. Ecology 59:799–809.

McKeever, S. 1960. Food of the northern flying squirrel in northeastern California. J. Mammal. 41:270–271.

Postovit, H. 1979. A survey of the spotted owl (*Strix occidentalis*) in northwestern Washington. Nat. Forest Products Assoc., Washington, D.C. 15 pp.

Rhoads, S. N. 1893. Notes on certain Washington and British Columbia birds. Auk 10:16–24.

Soule, M. E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151–169 *in* M. E. Soule and B. A. Wilcox, eds. Conservation biology: an evolutionary-ecological perspective. Sinauer Assoc., Inc., Sunderland, Mass.

Habitat Use by Nesting and Roosting Bald Eagles In the Pacific Northwest

Robert G. Anthony
Oregon Cooperative Wildlife Research Unit
Oregon State University
Corvallis

Richard L. Knight[1] and George T. Allen[2]
Nongame Wildlife Program
Washington Department of Game
Olympia, Washington

B. Riley McClelland
USDI National Park Service
Glacier National Park
West Glacier, Montana

John I. Hodges
USDI Fish and Wildlife Service
Juneau, Alaska

Introduction

The American bald eagle (*Haliaeetus leucocephalus*) was designated our national symbol in 1782. Since that time, populations of the species have declined due to a combination of factors including habitat loss, shooting, and environmental pollutants. As a result, in 1978 the U.S. Department of Interior officially listed the species as endangered in 43 of the 48 contiguous states and threatened in Oregon, Washington, Michigan, Wisconsin, and Minnesota. The bald eagle is protected under the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Protection Act. These pieces of legislation protect the species from direct persecution, harassment, and destruction of nests, and the Endangered Species Act provides for the identification of "critical habitat" for preservation and enhancement of populations. Five regional recovery teams appointed by the U.S. Fish and Wildlife Service are presently developing management plans to increase populations and secure habitat. The goal of these efforts is the removal of the species from the threatened and endangered list.

Meslow et al. (1981) list the bald eagle as a species that "finds optimum habitat for breeding . . . in old-growth Douglas-fir forests in western Oregon and Washington." They further state that old-growth forests are rapidly being liquidated on lands managed by USDA Forest Service and USDI Bureau of Land Management, and little old-growth timber remains on private lands in the Pacific Northwest. In view of the threatened and endangered status of the bald eagle and its apparent dependency on old-growth forests, a better understanding of its habitat require-

[1]Present address: Department of Wildlife Ecology, University of Wisconsin, Madison, WI 53706.
[2]Present address: Department of Zoology, North Dakota State University, Fargo,ND 58105.

ments is of paramount importance. In this paper we describe habitat use by nesting and roosting bald eagles in six forest types in the Pacific Northwest and provide recommendations for habitat management for the species. Hopefully, this information will aid state and federal agencies, private companies, and recovery teams in preparing management plans for the species.

Nesting Habitat

In the Pacific Northwest, bald eagles nest primarily in the ponderosa pine (*Pinus ponderosa*), mixed-conifer, Douglas-fir (*Pseudotsuga menziesii*), and sitka spruce (*Picea sitchensis*)/western hemlock (*Tsuga heterophylla*) forest types.[1] In addition, some nesting occurs along the large river systems in riparian communities where nests are often found in black cottonwood (*Populus trichocarpa*). Most nests are located within 1 mile (1.6 km) of large bodies of water, usually lakes, reservoirs, large rivers, or coastal estuaries.

Nest Tree Species

Species of trees used for nesting change on a north-south gradient depending on the forest types (Table 1). In California, ponderosa pine (71%) and sugar pine (16%) are the most frequently used species for nesting (Lehmann 1979). In Oregon, east of the crest of the Cascade Mountains, ponderosa pine (81%) is most often used, with Douglas-fir (13%) replacing sugar pine. In both of these areas the ponderosa pine and mixed-conifer forest types are used for nesting, and ponderosa pine is the most highly preferred nest tree species even when forest stands are dominated by Douglas-fir or other species. In Oregon and Washington, west of the crest of the Cascades, Douglas-fir (74 and 70%, respectively) is most frequently used for nesting with sitka spruce (23 and 17%, respectively) also being used. In

Table 1. Species of tree used for nesting by bald eagles in four states in the Pacific Northwest.

	State				
		Oregon (N = 155)			
Tree species	California (N = 87)[a] (%)	East of the Cascades (%)	West of the Cascades (%)	Washington (N = 218)[b] (%)	Alaska (N = 4455) (%)
Ponderosa pine	71	81			
Sugar pine	16	4			
Douglas-fir	2	13	74	70	
Sitka spruce			23	17	75
Western hemlock			3	4	19
Other species	11	3	0	9	6

[a]From Lehmann (1979)
[b]From Grubb (1976)

[1]Classification of forest types follows Franklin and Dyrness (1973).

Alaska (southeast, Prince William Sound, and Afognak Island), sitka spruce (75%) and western hemlock (19%) are the most important nest tree species in the sitka spruce/western hemlock forest types (Hodges and Robards 1981).

The important nest tree species are also important timber producing species. Consequently, there is a conflict between timber management and habitat management for nesting bald eagles. The severity of this conflict depends on the size of nest trees used by bald eagles and the size of trees available at maximum timber rotation age under current intensive forest management practices.

Nest Tree Characteristics

Height and diameter at breast height (DBH) of nest trees vary from northern California to southeast Alaska (Table 2) due to the use of different tree species in different forest types over a broad geographic area. Considering this variability and the different species of trees used for nesting in other parts of North America,

Table 2. Characteristics of bald eagle nest trees and specifications for old-growth management for four forest types in the Pacific Northwest.

Forest type/ Geographic area	Height[c] (ft.)	DBH[c] (in.)	Minimum DBH[b] specifications for old-growth management (in.)	Percentage of nest trees > minimum specifications
Ponderosa pine				
California[a]	131 75–205	43 25–82	21	100
Oregon	134 95–176	46 33–76	21	100
Mixed conifer				
Oregon	124 68–176	41 21–64	32	81
Douglas-fir				
Oregon	191 90–285	69 29–107	32	97
Washington	116 82–197	50 24–90	32	94
Sitka spruce/western hemlock				
Washington	145 82–197	75 41–109	32	100
Alaska, Southeast	97 25–200	43 12–110		
Alaska, Prince William Sound	77 25–200	36 12–75		

[a]From Lehmann (1979).
[b]From Pacific Northwest Regional Plan (U.S. Forest Service 1981).
[c]Values are mean and range.

some degree of plasticity in tree size and species for nesting is apparent. Structure of the platform on which to build a nest is what is most highly selected for.

In the Pacific Northwest, bald eagles select large old-growth trees for nesting (Table 2). In the ponderosa pine forest type there is a high degree of similarity in the range and mean values for height and DBH of nest trees in California and Oregon. Nest trees average approximately 44 inches (112 cm) DBH and some are larger than 72 inches (183 cm) DBH and attain heights of 200 feet (61 m). Nest tree characteristics in the mixed conifer forest type of Oregon are similar in size to those in the ponderosa pine type with average DBHs of 41 inches (104 cm) and heights up to 175 feet (53.3 m). In the Douglas-fir forest type, there are considerable differences in the range and means for height and DBH of nest trees in Oregon and Washington. Nest trees are larger in western Oregon than in the Puget Sound area in Washington, where there are shallower soils and more xeric conditions. These differences stress the importance of recognizing geographic areas as well as forest types in managing for nesting bald eagles. Nest trees in this forest type average 50 inches (127 cm) (Washington) and 69 inches (175 cm) (Oregon) DBH and some are as large as 107 inches (272 cm) DBH. Heights of nest trees may be greater than 275 feet (83.8 m).

In the sitka spruce/western hemlock forest type, there are also considerable differences in the range and means for height and DBH of nest trees in Washington, southeast Alaska, and Prince William Sound, Alaska. Nest trees are smaller at the more northern latitudes. These geographic differences in nest tree characteristics in the sitka spruce/western hemlock forest type are similar to geographic differences in other forest types. Nest trees in this forest type in western Washington are some of the largest on record with average DBHs of 75 inches (190 cm) and some as large as 109 inches (277 cm) DBH.

The U.S. Forest Service has established "minimum specifications" for old-growth timber management (Table 2) in the Pacific Northwest Regional Plan (U.S. Forest Service 1981:62), which establish criteria for old-growth inventory. All nest trees in the ponderosa pine type and the sitka spruce/western hemlock type (Washington) are larger than these minimum specifications. For the Douglas-fir type, 97 and 94 percent of the nest trees in Oregon and Washington, respectively, are larger than these specifications. In fact, most nest trees are considerably larger than the specifications. Minimum DBH specifications for the mixed-conifer type are well below the mean and at the lower end of the range in size of nest trees in that type. Eighty-one percent of the nest trees in the mixed-conifer type are larger than the minimum specifications. Average DBH of old-growth trees in southeast Alaska is 24 inches (61 cm) and 91 percent of the nest trees are larger than this value. The above comparisons indicate that most of the forest stands classified as old-growth on National Forests are not adequate for bald eagle nesting habitat.

In summary, bald eagles build their nests in old-growth coniferous trees regardless of forest type or geographic area. Sizes of nest trees depend on the tree species, forest type, and geographic area. Data from California (Lehmann 1979), Washington (Grubb 1976), and Oregon indicate that nest trees are usually (>95% of the time) the dominant or co-dominant member of the forest canopy. Nest trees are generally larger (81 to 100%) than the minimum DBH specifications for inventory of old-growth forests as suggested by the Pacific Northwest Regional Plan (U.S. Forest Service 1981:62).

Forest Stand Characteristics

Nest trees tend to be larger than surrounding trees (Tables 2 and 3). Data in Table 3 are means of mean forest stand characteristics around individual nest trees for a geographic area, so extremes in height and DBH are masked. The range and means in height and DBH are variable due to the occurrence of nesting in different forest types and geographic areas and variation in individual stand structure. Forest stands around eagle nest trees are generally multi-layered with considerable variation in height and DBH. Most forest stands surrounding eagle nests include old-growth trees with mean DBHs close to and maximum DBHs usually above the minimum DBH specifications for old-growth management (Table 2). Consistent with differences in nest tree characteristics, forest stands in the Douglas-fir type for Oregon have larger trees than stands in the Puget Sound area of Washington. However, mean stand characteristics for the Douglas-fir type in western Oregon are similar to those for the sitka spruce/western hemlock type on the Olympic Peninsula of western Washington.

Density of forest stands around eagle nest trees also varies (Table 3), because of alteration of forest stands by logging activities. Mean densities range from 36 to 67 stems/acre (89 to 165 stems/ha). We suggest a range of 45 to 70 trees/acre (111 to 173 stems/ha) for management of nest sites. Densities in the ponderosa pine and mixed-conifer types could be at the lower (45 to 60 trees/acre [111 to 148

Table 3. Characteristics of forest stands surrounding bald eagle nests in four forest types in the Pacific Northwest.

Forest type/ geographic area	Height (ft)	DBH (in)	Density[c] (stems/acre)
Ponderosa pine			
California[a]	101	29	44
	26–220	9–46	6–129
Oregon	75	20	49[b]
	38–176	14–28	5–136
Mixed conifer			
Oregon	65	19	36[b]
	38–176	14–29	4–123
Douglas-fir			
Oregon	98	28	59[b]
	38–285	17–45	4–125
Washington	74	21	64[b]
	56–105	15–31	4–126
Sitka spruce/western hemlock			
Washington	86	27	67[b]
	56–118	19–33	31–146

[a]From Lehmann (1979).
[b]Density of trees larger than 10.5 in DBH.
[c]Values are mean and range.

trees/ha]) end of this range, while densities for the Douglas-fir and sitka spruce/western hemlock types should be at the upper (60 to 70 trees/acre [148 to 173 trees/ha]) part of the range. Human disturbance around nest sites during the nesting season can negatively influence nesting success (Broley 1947, Murphy 1965, Gerrard et al. 1975, Grubb 1976). A dense forest stand around nests will provide a visual barrier to human intrusion into the nest site and mitigate disturbance. Stand integrity and susceptibility to windthrow, disease, and other causes of tree mortality should also be considered in establishing density requirements.

Communal Roosting Habitat

In the Pacific Northwest, bald eagles roost communally in the ponderosa pine, mixed-conifer, Douglas-fir, black cottonwood, and western larch (*Larix occidentalis*) forest types. Roosts receive low to high levels of use, with as many as 400 individuals observed in a roost on a given night. The adaptive significance of communal roosting is not well understood; however, a number of hypotheses have been proposed: (1) aids in food finding, (2) enhances thermoregulation, by the selection of favorable microclimates, and (3) aids in the establishment of a social hierarchy or other social functions. Stalmaster (1981) and Keister (1981) have demonstrated that communal roosts have more favorable microclimates than surrounding areas and thereby require lower energy expenditures.

Forest Stand Characteristics

Mean DBHs (20–24 inches [51–61 cm]) and heights (81–91 feet [24.7–27.7 m]) of trees are similar in forest stands of communal roosts in the ponderosa pine, Douglas-fir (eastern Washington), and mixed-conifer forest types (Table 4). The Eagle Island roost in eastern Washington in the black cottonwood type has a mean DBH and height that are also comparable to these values. In addition, the black cottonwood roost sites in western Washington (Barnaby) and Montana are similar in characteristics. This similarity in stand characteristics within and between forest types suggests that bald eagles are selective for communal roost sites. The large ranges in height and DBH of individual trees within roosts indicate a high degree of variability in size, suggesting a high degree of stratification (multilayering) in the forest stands. Mean values of DBH for roosts in the ponderosa pine, mixed conifer, and Douglas-fir types are similar to the minimum DBH specifications (U.S. Forest Service 1981:62); however, all of the roosts in these types possess old-growth trees that are considerably larger than these specifications. Minimum specifications are not available for the black cottonwood or western larch types.

Roost Tree Characteristics

Roost trees in the ponderosa pine type are larger than the surrounding trees in the forest stands (Tables 4 and 5). Mean DBH and height for roost trees in the Mt. Dome, Three Sisters, and Caldwell roosts of northern California are only slightly larger than mean DBH and height of forest stands in the respective areas. Mean values for roost trees in the Cougar roost are considerably larger than those for the forest stand. Average age of roost trees varies from 131 to 311 years in the ponderosa pine type and is indicative of old-growth forests. The communal roosts

Table 4. Characteristics of forest stands used for communal roosting by bald eagles in 11 communal roosts in the Pacific Northwest.

Forest type/ geographic area	Height[c] (ft.)	DBH[c] (in.)
Ponderosa pine		
California (Mt. Dome)[b]	88	24
	50–125	13–46
California (Three Sisters)[b]	84	21
	50–125	13–34
California (Caldwell)[b]	81	20
	50–125	13–37
California (Cougar)[b]	91	22
	50–150	13–38
Mixed conifer[a]		
Oregon (Bear Valley)[b]	91	20
	50–125	13–40
Eastern Washington (Azwell)	89	23
	50–132	12–34
Douglas-fir		
Eastern Washington (Brewster)	79	24
	50–116	11–48
Black cottonwood		
Washington (Barnaby)	93	21
	66–132	12–52
Washington (Eagle Island)	91	23
	66–149	12–64
Montana (Glacier National Park)	125	38
	108–135	32–41
Western larch		
Montana (Glacier National Park)	82	15
	10–138	3–28

[a]Weighted means of measurements on ponderosa pine and Douglas-fir.
[b]From Keister (1981).
[c]Values are mean and range.

in the mixed-conifer type have similar roost tree characteristics, and roost trees are significantly larger than forest stands, indicating a selection for larger trees and/or associated factors (i.e. openness, visibility, canopy cover) for roosting. Average age of roost trees in the Bear Valley roost (Oregon) is 199 years. Roost trees in the Douglas-fir type are larger than the general forest stand characteristics. Hansen et al. (1980) indicate that roost trees in two communal roosts (Table 5) in western Washington averaged 63 and 60 feet (19.2 and 18.3 m) taller than surrounding trees. Roost trees in the Douglas-fir type of western Washington (Van Zandt, Slide Mt.) are the tallest thus far measured.

Table 5. Characteristics of roost trees used by bald eagles in 13 communal roosts in the Pacific Northwest.

Forest type/ geographic area	Height[e] (ft.)	DBH[e] (ft.)	Average Age (yrs.)
Ponderosa pine			
California (Mt. Dome)[b]	89 51–110	25 20–32	250
California (Three Sisters)[b]	82 69–100	22 17–26	131
California (Caldwell)[b]	81 70–88	30 24–41	289
California (Cougar)[b]	101 86–121	31 24–40	311
Mixed conifer[a]			
Oregon (Bear Valley)[b]	111 69–138	29 17–42	199
Eastern Washington (Azwell)	104 67–160	29 20–44	ND[d]
Douglas-fir			
Eastern Washington (Brewster)	83 72–93	43 38–52	ND[d]
Western Washington (Van Zandt)[c]	190	33	ND[d]
Western Washington (Slide Mt.)[c]	174	32	ND[d]
Black cottonwood			
Washington (Barnaby)	123 59–191	36 19–79	ND[d]
Washington (Eagle Island)	140 73–182	43 30–74	
Montana (Glacier National Park)	124 108–135	38 32–42	ND[d]
Western larch			
Montana (Glacier National Park)	112 85–138	22 16–28	300+

[a]Weighted means of measurements on ponderosa pine and Douglas-fir.
[b]From Keister (1981).
[c]From Hansen et al. (1980).
[d]ND = Age not determined for roost trees in these roosts.
[e]Values are mean and range.

Roost trees in the black cottonwood type are significantly larger than forest stands for the Washington (Barnaby) site, but this is not the case for the Montana site. Mean characteristics of roost trees are similar for the two sites. Both sites are old-growth stands of black cottonwood. Roost trees in the western larch type are larger than forest stands, and individual old-growth trees are present in the stand. Most roost trees are probably at least 300 years old.

Means and ranges of DBH of roost trees in 3 of the 4 ponderosa pine types and all of the Douglas-fir types are larger than the minimum DBH specifications (Table 2) for old-growth forest management (U.S. Forest Service 1981). Many roost trees in the mixed-conifer type are old-growth (200 years old) and are larger than the minimum specifications of 32 inches (81.3 cm) DBH for this type. No specifications (definitions) are available for the black cottonwood or western larch types. Again, these comparisons show the inadequacy of the minimum specifications for old-growth inventory for bald eagle roosting habitat.

In summary, the communal roosts analyzed have old-growth trees (averaging 131 to 311 years) that are larger than the minimum DBH specifications for the ponderosa pine, mixed conifer, and Douglas-fir types. Many of the forest stands have similar mean DBH and heights, suggesting some degree of selectivity of roosting sites. The large range in height and DBH within each roost indicates a high degree of stratification in communal roosts. Bald eagles select roost trees that are larger than the average size of trees in the stand, and these trees are usually old-growth. In addition, Keister (1981) documented use of snags (9%) and spike-topped (7%) trees for roosting by bald eagles in the Klamath Basin; this use was greater than expected based on availability.

Discussion and Management Implications

The nesting ecology of bald eagles has been studied throughout the range of the species in North America. Bald eagles use a wide variety of tree species for nesting, which indicates they select for structure of the tree rather than species (Gerrard et al. 1975:173). In the Pacific Northwest, old-growth ponderosa pine, Douglas-fir, sitka spruce, and western hemlock provide the desirable structure for nesting, and small trees (<30 inches [76 cm] DBH) are rarely used. Nest trees are usually dominant or co-dominant individuals in the forest stand. Forest stands surrounding nest trees vary from open areas (generally clearcuts) to pristine old-growth. Where forest stands are undisturbed, a component of old-growth is invariably present. Crucial questions in habitat management for nesting bald eagles include: (1) at what level does habitat alteration change a site from being optimal (preferred) to sub-optimal habitat that a pair of eagles continues to use because of nest site tenacity and/or pair bonding, (2) will an altered site be used once one or both members of a nesting pair die, and (3) is there a difference in productivity of eagles nesting in optimal versus sub-optimal habitat? The amount of habitat alteration a pair of nesting bald eagles will tolerate on a short time frame is probably more than what the species can tolerate in general. Until we know how much habitat alteration the species will tolerate we should manage for preferred (optimal) nesting habitat.

The Pacific Northwest appears to differ slightly from other parts of the contiguous 48 states with respect to roosting behavior of bald eagles in that larger numbers (200–400+) of these birds use night communal roosts during fall and winter. These communal roosts are invariably located near a rich food resource (i.e., runs of anadromous fish, high concentrations of waterfowl) and in forest stands that have at least a remnant of the old-growth component. These stands are variable in species composition, size, and tree size (i.e., not entirely old-growth), but the old-growth component provides the roost trees. Keister (1981) found that bald eagles roosted in the old-growth forest stands closest to a rich food resource in the

Klamath Basin even though closer stands of juniper and young-aged ponderosa pine were available.

Special management considerations are needed for communal roosts that have been shaped by natural disturbances such as floods (cottonwood roosts) and fire (larch roosts). Water impoundment projects often eliminate habitat or natural processes that maintain roosting habitat or destroy anadromous fish runs; such projects must be carefully scrutinized. Natural or prescribed fires should be accommodated in any management scheme designed to perpetuate the characteristics of forest communities shaped by fire.

The immediate problem is that old-growth forests are rapidly being removed on lands administered by the U.S. Forest Service and Bureau of Land Management (Meslow et al. 1981). At the current rate of timber harvest, old-growth stands will be eliminated on Bureau of Land Management districts in Oregon within the next 10 to 30 years (Luman and Neitro 1980). In addition, little old-growth timber exists on private and state forest lands in the Pacific Northwest, and there is little incentive or willingness to manage for older forests. Most forest lands in the Pacific Northwest are programmed for a 40- to 80-year stand rotation, which will eliminate nesting and roosting habitat for bald eagles in the Pacific Northwest.

The current strategy of short rotation and even-aged management of forest stands clearly will not provide the necessary requirements (large sized trees and multi-layered forests) for nesting and communal roosting by bald eagles. In addition, the U.S. Forest Service's definitions (minimum specifications) of old-growth (U.S. Forest Service 1981:62) are inadequate for preservation of nesting and roosting habitat for bald eagles in the Pacific Northwest. The solution to this problem is the preservation and management of existing and potential nesting and roosting areas as old growth (200 to 400+ years). We recommend the following steps to insure the continued existence of nesting and roosting habitat for bald eagles:

1. Identify all existing and potential nest and communal roost sites (not all of these areas are currently known and areas used by bald eagles may change annually),
2. Remove all existing and potential nest sites and communal roosts from forest rotation systems and establish special management areas (or zones in the case of dense nesting concentrations), and
3. Develop management plans for individual nest sites and communal roosts, if necessary, to identify and accommodate special management problems.

In addition, modified silvicultural systems that avoid clearcutting should be designed to create the desired habitat, and these systems should be tested.

Some of the above steps have already been initiated in local areas of the Pacific Northwest. Management plans for nesting bald eagles on national forests have been developed (Goold 1981, Isaacs and Silovsky 1981) and represent positive steps. We emphasize the need for similar steps to be accomplished throughout the region. The designation and preservation of *potential* nesting and roosting areas are important to (1) insure adequate habitat in the future when some existing sites are no longer viable and (2) encourage increase in bald eagle populations. This is important for population recovery.

Acknowledgments

We are indebted to numerous individuals and agencies who helped in data collection, particularly F. Isaacs, S. Knight, J. Crenshaw, A. Bruce, G. Keister, L. Young, and R.

Anderson. EARTHWATCH and the Center for Field Research of Belmont, Massachusetts supported field activities in Washington. The U.S. Fish and Wildlife Service, U.S. National Park Service, U.S. Forest Service, Washington Department of Game, Oregon Department of Fish and Wildlife, Crown Zellerbach Corporation, Weyerhaeuser Company, The Nature Conservancy, and Oregon State University funded much of the work. E. Meslow, W. Neitro, T. Grubb, G. Keister, R. Pedersen, R. Anderson, A. Twomby, M. Stalmaster, J. Grier, F. Cassel, and F. Isaacs reviewed drafts of this paper. This is a contribution of the Oregon Cooperative Wildlife Research Unit: Oregon Department of Fish and Wildlife, Oregon State University, U.S. Fish and Wildlife Service, and the Wildlife Management Institute cooperating. Oregon State University Agricultural Experiment Station Technical Paper 6271.

Literature Cited

Broley, C. L. 1947. Migration and nesting of Florida bald eagles. Wilson Bull. 59:3–20.

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. Gen. Tech. Rep. PNW-8. USDA Forest Service, Portland, Ore. 417 pp.

Gerrard, J. M., P. Gerrard, W. J. Maher, and D. W. A. Whitfield. 1975. Factors influencing nest site selection of bald eagles in northern Saskatchewan and Manitoba. Blue Jay 33:169–176.

Goold, J. W. 1981. Klamath Bald Eagle Habitat Management Area, Winema National Forest. USDA Forest Service, Pacific Northwest Region. 99 pp.

Grubb, T. G. 1976. A survey and analysis of bald eagle nesting in western Washington. M.S. Thesis. University of Washington, Seattle. 87 pp.

Hansen, A. J., M. V. Stalmaster, and J. R. Newman. 1980. Habitat characteristics, functions, and destruction of bald eagle communal roosts in western Washington. Pages 221–229 *in* R. L. Knight et al., eds. Proc. Washington Bald Eagle Symposium, Seattle.

Hodges, J. I., and F. C. Robards. 1981. Observations on 3,850 bald eagle nests in southeast Alaska. *In* Proc. Symp. Raptor Management, Anchorage, Alaska.

Isaacs, F. B., and G. Silovsky. 1981. Bald Eagle Management Plan, Fremont National Forest. USDA Forest Service, Pacific Northwest Region. 87 pp. + appendices.

Keister, G. P., Jr. 1981. Characteristics of winter roosts and populations of bald eagles in the Klamath Basin. M.S. Thesis. Oregon State University, Corvallis. 82 pp.

Lehmann, R. N. 1979. A survey of selected habitat features of 95 bald eagle nest sites in California. Admin. Report 79-1. Calif. Dep. Fish and Game, Sacramento. 23 pp.

Luman, I. D., and W. A. Neitro. 1980. Preservation of mature forest stages to provide wildlife habitat diversity. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:271–277.

Meslow, E. C., C. Maser, and J. Verner. 1981. Old-growth forests as wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:329–355.

Murphy, J. R. 1965. Nest site selection by the bald eagle in Yellowstone National Park. Proc. Utah Acad. Sci. 42:261–264.

Stalmaster, M. V. 1981. Ecological energetics and foraging behavior of wintering bald eagles. Ph.D. Dissertation. Utah State Univ., Logan. 157 pp.

U.S. Forest Service. 1981. Pacific Northwest Regional Plan. USDA Forest Service, Portland, Ore. (Draft). 98 pp. + appendices.

Old-Growth Forests and Black-Tailed Deer on Vancouver Island

A. S. Harestad
Department of Biological Sciences, Simon Fraser University
Burnaby, British Columbia, Canada

James A. Rochelle
Environmental Sciences Research, Weyerhaeuser Company
Centralia, Washington

Fred L. Bunnell
Faculty of Forestry, University of British Columbia, Vancouver

Introduction

Published information on relationships between forestry practices and black-tailed deer for the Pacific Northwest comes primarily from more southerly regions. Early studies reported that few black-tailed deer inhabited coastal old-growth forests (Einarsen 1946, Cowan 1945, 1956, Brown 1961). Recently it has become apparent that deer in more northerly areas of the Pacific Northwest are often abundant in old-growth forests. These latter observations have originated in British Columbia (Jones 1974, Bunnell and Eastman 1976, Bunnell et al. 1978, Bunnell 1979, Hebert 1979) and Alaska (Schoen and Wallmo 1979, Schoen et al. 1981, Wallmo and Schoen 1980).

On northern Vancouver Island, black-tailed deer show modest increases when some types of old-growth forests are cut, but population declines may occur when old-growth forests used as winter range are cut. The different responses to forest harvesting derive from ecological differences between northern and southern regions.

We propose a simple model of habitat selection based on trade-offs between energy expended for locomotion and energy acquired from forage. The ecological relationships of black-tailed deer in a region of deep snowfall are summarized. Using these relationships and the model, we discuss the role of old-growth forests and forestry practices in the management of black-tailed deer in regions of deep snowfall.

Study Area

The study area is located on north central Vancouver Island, British Columbia in the Nimpkish Valley. The valley is mountainous with many peaks reaching higher than 4,000 feet (1,220 m). Biogeoclimatic zones (*sensu* Krajina 1965) found within the study area include the Coastal Western Hemlock Zone at lower elevations 650–3,000 feet (200–900 m), the Subalpine-Mountain Hemlock Zone at upper elevations 2,600–5,200 feet (800–1,600 m), and the Alpine Zone near the mountain tops (above 4,900 feet [1,500 m]). Even-aged stands of *Pseudotsuga menziesii* resulting from past wildfires occurred in large blocks at lower elevations, prior to forest harvesting.

Forest harvesting began in the study area in 1948 along the flat valley bottom.

By 1975, 39 percent of forests below 2,667 feet (800 m) were logged, while only 7 percent of forests above 2,667 feet (800 m) were logged. The pattern of forest harvesting was predominantly progressive clearcutting, while in more recent years patch-cutting of blocks less than 200 acres (81 ha) has occurred. Logged areas were usually slashburned. Immature seral stages in the study area ranged up to 27 years old.

The Nimpkish Valley has moderate temperatures but high precipitation. No month has an average temperature that is below freezing. Annual precipitation at Woss Camp (333 feet [100 m] above mean sea level) averaged 90 inches (229 cm) over a 15-year period.

Snow falls every year at elevations above 1,000 feet (300 m). Snowfall may begin as early as November above 1,500 feet (450 m) and accumulates to varying depths until late March. With the exception of steep north slopes, the snow line usually recedes to 2,667 feet (800 m) by the end of April. On steep north slopes at high elevations, snow remains until mid-summer. Snow depths may be substantial in some years, particularly at high elevations. At Woss Camp, average annual snowfall for the period 1954 to 1973 was 3.2 inches (8 cm) in November, 15.4 inches (39 cm) in January, and 1.2 inches (3 cm) in April. During the severe winter of 1971–1972, 53.9 inches (137 cm) of snow fell in December. Snow depths in forests and cutover areas over a range of elevations within the study area were reported by Jones (1975), Harestad (1979), and Rochelle (1980).

Habitat Selection Model

The model incorporates the energy trade-offs faced by deer living in different habitats and snow conditions (Figure 1). It has two functions: the relationship between energy (food) availability and snow depth and the relationship between energy expenditure for movement and snow depth. The criterion for selection of habitats is the relative net energy available to deer.

In a given habitat, most types of ground-rooted forage become buried by snow during winter. Because the proportion of food decreases with height above the ground, energy available to deer decreases with increasing snow depths (Jones 1974, Harestad 1979, Rochelle 1980). Because litterfall in the form of lichens and conifer boughs occurs, some food may always be available even when all herbs, ferns, and shrubs are buried by snow. Snow depth also influences deer sinking depths. Jacobsen (1973) reported energy expenditures by deer increased with increased sinking depth in the snow. By adding snow density and hardness, a third axis, the utility of the model is enhanced but its general nature is unchanged (Harestad and Bunnell 1979).

For shallow snow conditions, more energy is obtained from the available food than is expended to acquire the food. The converse is true in deep snow. The utility of a given habitat to black-tailed deer is a function of its ability to provide energy and modify snow cover (Figure 1).

Results and Discussion

Food Habits and Availability

Jones (1975) and Rochelle (1980) present detailed treatments of food habits. Here we consider the differences between deer foraging in cutovers and in old-

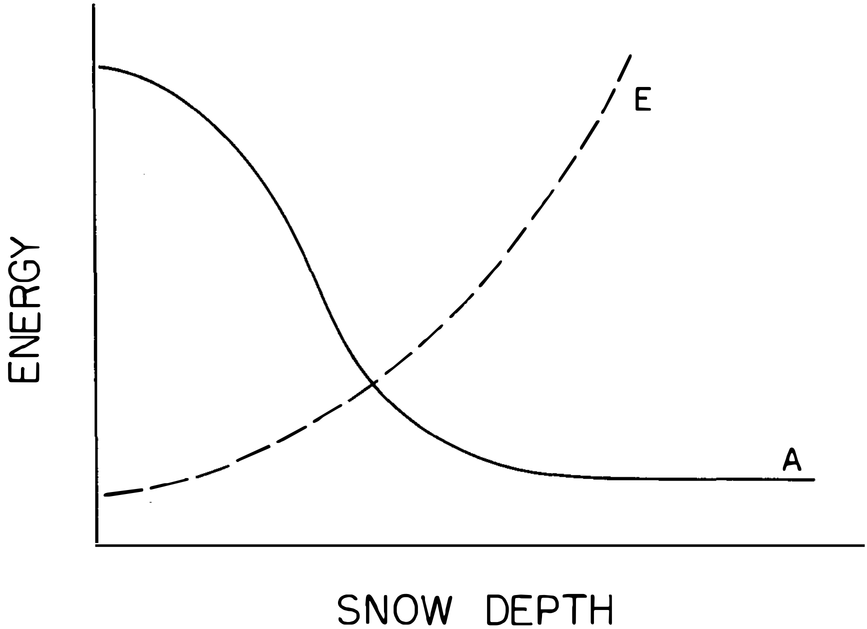


Figure 1. Simple model of the influences of snow depth upon energy expenditure (E) and energy acquisition (A).

growth forested areas. Deer collected from forested areas were tracked for several hours to ensure that at least their most recent feeding occurred in the forest. The differences were striking. In the spring, rumens from animals foraging in cutovers contained about 65 percent forbs while those from animals in the forests contained about 70 percent shrubs. In the fall-winter period, forbs still represented about 35 percent of the diet of deer from cutovers, but constituted less than 5 percent of the diet of animals in forested areas. Arboreal lichens dominated the diet of deer collected from forests. It is noteworthy that lichens also contributed about 12 percent of the diet of deer from cutovers, suggesting that these animals spent some time foraging in forests.

Estimates of the amounts of food available to deer are provided by Jones (1975), Stevenson (1978), Harestad (1979), and Rochelle (1980). Here we summarize only the general pattern. Residual conifers and shrubs remaining after logging provide most of the available food in newly logged seral stages. After the cutover is burned, herbs, primarily *Epilobium angustifolium,* are the most abundant food type. Later, shrubs, primarily *Gaultheria shallon, Vaccinium parvifolium,* and *Vaccinium alaskaense,* increase on the site, and herbs decrease in abundance. As succession progresses in the cutover, shrubs become taller and more abundant while herbs become a minor portion of the available food. Conifer regeneration increases and eventually dominates the site after 15–20 years.

Food abundance in old-growth forests differs between plant associations. Some plant associations have little available food at any time of the year; other associations have abundant food, comparable if not surpassing that available in cutovers (Figure 2). Forested plant associations differ from young seral stages in that generally the greatest proportion of food is in the form of shrubs. Conifer boughs and arboreal lichens may fall from the canopy and provide additional forage.

Forage quality, as measured by digestible dry matter, protein, and digestible energy, was greatest in spring, decreased slightly during summer, and decreased further in winter (Rochelle 1980). Although quality of food exhibited seasonal patterns, consistently higher nutrient contents in forage plants from cutover or forested areas were not observed for any season. However, if the nutrient contents of the principal forages consumed by black-tailed deer are considered, cutovers have consistently higher quality food than do forests (Table 1).

Although forested habitats are generally lower in forage quality than are cutover habitats, forests provide arboreal lichens that are not present in cutovers. *Alectoria sarmentosa* is highly digestible, but low in nitrogen and energy. It appears to enhance the digestibility of other forage species when present in a mixed diet (Rochelle 1980).

Snow-Food Interactions

During winter, black-tailed deer in the Nimpkish Valley feed primarily on shrubs, conifers, and arboreal lichens (Jones 1975, Rochelle 1980). The amount of food available to deer during winter depends on the height of shrubs and the depth of snow (Figure 2). The vertical distribution of browse differs between habitats and depends on the species, height, and growth form of the shrubs (Harestad 1979, Rochelle 1980). Besides direct burial, snow can also collect on the branches and weigh the shrubs down allowing burial at shallow snow depths. Assuming no shrub displacement by snowpack, a snow depth of 19.7 inches (50 cm) would bury about 80 percent of shrub forage in immature seral stages, but only 50 percent of the shrub forage in old-growth forests.

Snow also can increase the availability of some forage. Snow accumulated on branches in the forest canopy can be sufficient to break off conifer boughs or strip arboreal lichens from high branches, especially during storms (Stevenson 1978). This material tumbles to the forest floor as litterfall and can be as abundant as rooted forage in some forest types (Rochelle 1980). Relationships established for white-tailed deer movement through snow (Jacobsen 1973) were adapted to account for differences in leg length and footloading of black-tailed deer (Harestad and Bunnell 1979). These estimates were used to simulate the energy costs encountered by black-tailed deer in different snow conditions. Initial predictions indicate that these additional energy expenditures could be a substantial and deciding factor in winter-habitat selection.

Snow depth decreases with increasing canopy cover (Harestad and Bunnell 1981) and may be the principal factor determining deer use in cutovers and forests during winter. In periods of deep snowfall, most forage in cutovers is buried and unavailable to deer. Acquisition of that forage available above the snowpack is

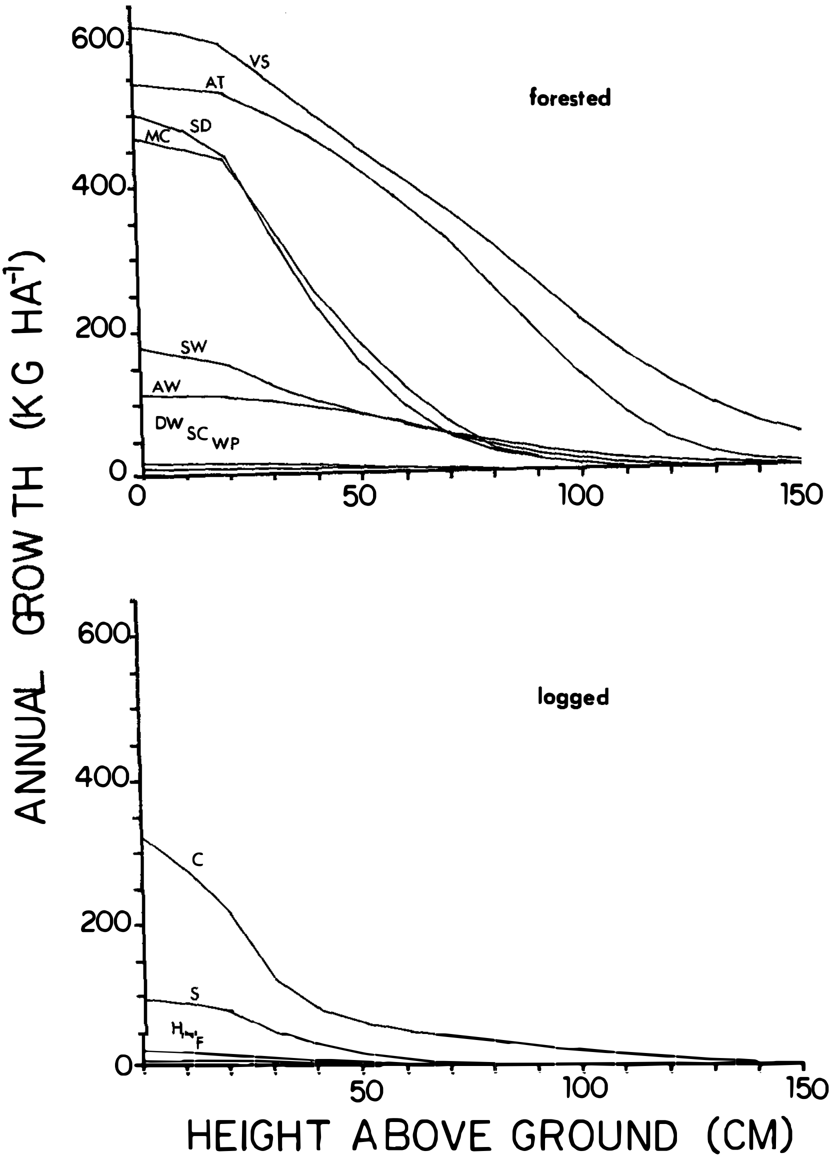


Figure 2. Vertical distribution of shrub annual growth in different habitats (VS = *Vaccinium* - Skunk cabbage; AT = Amabilis fir-twisted stalk; SD = Salal - Douglas fir; MC = Mountain hemlock - Copperbush; SW = Salal - Western hemlock; AW = Amabilis fir - Western hemlock; DW = Deer fern - Western hemlock; SC = Sword fern - Western red cedar; WP = Western hemlock - Plagiothecium; C = Conifer; S = Shrub; H = Herb; N = Newly-logged; F = Fern.

Table 1. Seasonal characteristics (energy, crude protein, and digestible dry matter content) of primary forages consumed by black-tailed deer in forested and cutover areas.

	Spring		Summer		Fall-Winter		Annual	
Forage characteristic	Forested	Cutover	Forested	Cutover	Forested	Cutover	Forested	Cutover
Energy content (kcal/0.8 g)	3.3	3.7	3.2	4.8	1.4	1.9	2.1	2.9
Crude protein (%)	18.8	20.9	8.1	13.3	7.2	10.2	9.4	12.7
Digestible dry matter (%)	50.5	65.2	40.7	70.2	49.6	61.6	47.5	64.3

energy expensive because of the sinking depths encountered by deer. In forested areas, snow depths are less and, depending on the plant association, there may be more food available to deer (Figure 2). Furthermore, litterfall provides forage that is available in forests under all snow conditions, but nonexistent in cutovers. Energy costs for movement are also less.

Habitat Use

The population of black-tailed deer inhabiting the study area is comprised of individuals exhibiting one of three types of seasonal movements: residents, altitudinal migrators, or horizontal migrators. Resident deer inhabited low elevations throughout the year and made relatively small shifts in their home ranges between seasons. Altitudinal migrators moved down in elevation at the beginning of winter and occupied winter home ranges below 2,167 feet (650 m). Their spring home ranges were usually in valley bottoms adjacent to their winter home ranges. During summer these deer moved to high elevations. Where local climate changed substantially over a horizontal distance, such as between a narrow tributary valley and the wide main valley, deer made horizontal migrations. They attained differences in local climate similar to those experienced by altitudinal migrators.

Deer use of cutover and forested areas was determined from proportions of locations of radio-tagged deer occurring in each habitat. Use varied with season and with weather conditions, particularly during winter (Figure 3). Deer spent spring in low elevation cutovers and nearby old-growth forests. Use of snowfree cutovers increased with an accompanying decrease in use of old-growth forests. About 80 percent of nighttime locations and 60 percent of daytime locations were in cutovers.

During summer, patterns of use of cutover and forest changed. Nighttime use of cutovers decreased by about 10 percent as old-growth forests were used more. Daytime use of old-growth forest in summer doubled from that observed during spring. These trends were observed for both resident and migratory deer, indicating changes in habitat preference and not changes due to differences in habitat availability. Daytime was spent primarily in forested habitats while nighttime was spent primarily in cutover habitats.

During winter, daytime use of cutovers increased from 12 to 28 percent, but was still much less than use observed in spring; nighttime use of cutovers decreased and was less than that in both spring and summer. Most use in winter was observed in forested habitats. These observations integrate the entire winter season; more extreme differences are evident if specific periods in winter are considered. During periods with deep snow, deer used old-growth forests during both night and day. They ventured into cutovers when there was shallow snow or when the snowpack could support them (Jones 1974). When snowfall was sufficiently deep, use of cutovers and some forest habitats decreased with accompanying increases in use of other forest types.

Factors such as slope and aspect play a greater role in winter-habitat selection than during other seasons. Forested winter ranges used during periods of deep snow are typically at low elevations on steep, south-facing sidehills. Here the canopy is sufficiently closed to provide adequate shelter and interception of snow yet open enough to allow an abundant understory of shrubs (Rochelle 1980).

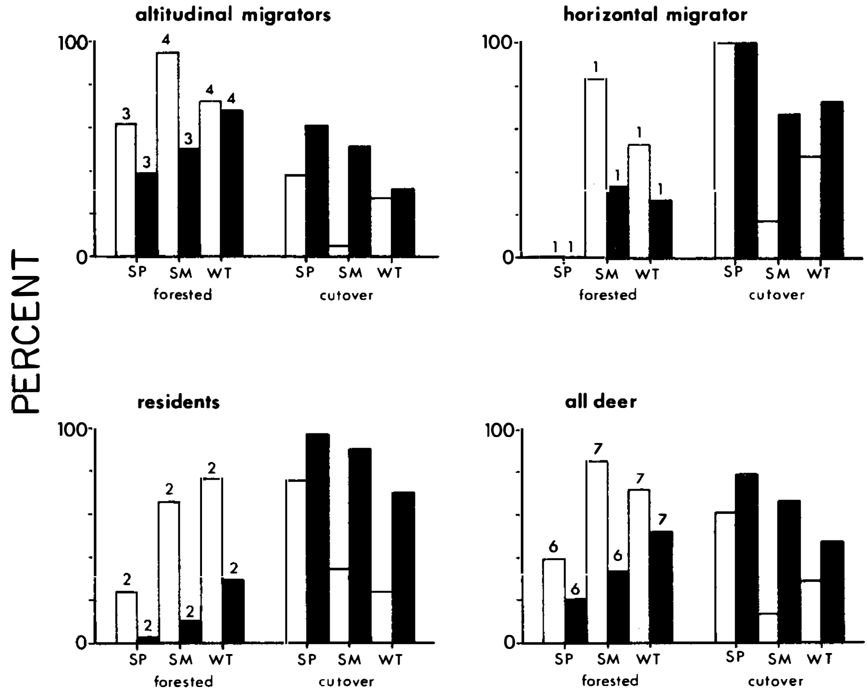


Figure 3 Percentage use of forested and cutover habitats during each season (SP = spring, SM = summer, WT = winter). Unshaded histograms are daytime use, shaded histograms are nighttime use. Number of deer from which the percentage use of forested and cutover habitats in each season was calculated are indicated above the histograms for forested habitats.

The patterns of habitat selection described (Figure 3) are consistent with the model (Figure 1). Within the limits of these proceedings we can note only the general patterns. Harestad (1979) provides a more detailed evaluation of the model for specific cases.

Management Implications and the Role of Old Growth

The effect of forestry practices on deer in northern regions with deep snowfalls differs from the same practices in southern regions. Canopy removal alters the quality and quantity of forage. Most available energy is packaged in the form of herbs, shrubs, and conifers in cutovers and in the form of shrubs, conifers and lichens in old-growth forests. These differences determine the availability of food during winter. Food availability is further altered by the effect of canopy cover on snow depth. Deep snow in cutovers buries greater amounts of food than does shallow snow in forests. Although quality of food in cutovers is greater than in forests, burial of food by snow counteracts this difference and results in forests having greater amounts of available energy than cutovers.

In deep snowfall areas on Vancouver Island, old-growth forests play an important role in satisfying the habitat requirements of black-tailed deer. Quality and quantity of forage in cutovers is of little consequence because food is inaccessible, while litterfall and rooted plants continue to supply deer with forage in old-growth forests.

With continued harvesting of old-growth forests at low and mid elevations, the capability of the area to support substantial deer populations during severe winters is reduced. Options under the control of forest and wildlife managers include the temporary reservations of selected mature stands until adjacent second-growth stands develop an approximate structure. As second-growth stands develop, specific forest management prescriptions, including the use of thinnings and fertilization, can be employed to manipulate stand structure. These silvicultural techniques may produce the canopy structure desired for effective interception of snow as well as permit the growth of forage plants in the understory. With harvest rotations of 100 years or less, it appears unlikely that significant biomass of arboreal lichens will develop in second-growth forests (Bunnell and Eastman 1976).

Vancouver Island contains watersheds in various stages of forest development, from all second-growth to all old-growth forest. This range of conditions presents an opportunity to examine the response of deer to conversion of old-growth into second-growth forest. Determination of habitat selection patterns of deer in second-growth watersheds should aid in predicting response of deer and suggest management opportunities for less developed watersheds. The challenge is one of managing second-growth stands to provide both forage and reduced snow depths necessary for deer survival during severe winters.

Acknowledgements

Research was supported by grants from Canadian Forest Products Ltd., British Columbia Fish and Wildlife Branch, Natural Sciences and Engineering Research Council of Canada, the University of British Columbia, and Weyerhaeuser Company to F. L. Bunnell.

Literature Cited

Brown, E. R. 1961. The black-tailed deer of western Washington. Washington State Game Dep. Biol. Bull. 13:1–124.

Bunnell, F. L. 1979. Deer-forest relationships on northern Vancouver Island. Pages 86–101 *in* O. C. Wallmo and J. Schoen, eds. Proc. Sitka Black-tailed Deer Conf. USDA Forest Service, Reg. 10, Juneau, Alaska.

——, and D. S. Eastman. 1976. Effects of forest management practices on wildlife in the forests of British Columbia. Pages 631–689 *in* Proc. Div. I, XVI IUFRO World Congress, Oslo, Norway.

Bunnell, F. L., R. M. Ellis, S. K. Stevenson, and D. S. Eastman. 1978. Evaluating ungulate populations and range in British Columbia. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43:311–322.

Cowan, I. McT. 1945. The ecological relationships of the food of the Columbian black-tailed deer, *Odocoileus hemionus columbianus* (Richardson), in the coast forest region of southern Vancouver Island, British Columbia. Ecol. Mongr. 15:110–139.

——. 1956. Life and times of coast black-tailed deer. Pages 523–617 *in* W. P. Taylor, ed. The deer of North America. Stackpole Co., Harrisburg, Pa. 668 pp.

Einarsen, A. S. 1946. Management of black-tailed deer. J. Wildl. Manage. 10:54–59.

Harestad, A. S. 1979. Seasonal movements of black-tailed deer on northern Vancouver Island. Fish and Wildlife Rep. No. R-3. Ministry of Environment, Victoria, British Columbia. 98 pp.

———, and F. L. Bunnell. 1979. Snow and its relationship to deer and elk in coastal forests. Report to Council of Forest Industries, Vancouver, Canada. 53 pp.
Harestad, A. S., and F. L. Bunnell. 1981. Prediction of snow water equivalents in coniferous forests. Canad. J. For. Res. 11:854–857.
Hebert, D. 1979. Wildlife-forestry planning in the coastal forests of Vancouver Island. Pages 133–158 *in* O. C. Wallmo and J. Schoen, eds. Proc. Sitka Black-tailed Deer Conf. USDA Forest Service, Reg. 10, Juneau, Alaska.
Jacobsen, N. L. K. 1973. Physiology, behaviour, and thermal transactions of white-tailed deer. Ph.D. Thesis. Cornell University, Ithaca. 245 pp.
Jones, G. W. 1974. Influence of forest development on black-tailed deer winter range on Vancouver Island. Pages 139–148 *in* H. C. Black, ed. Proc. Symp. Wildlife and Forest Management in the Pacific Northwest. Oregon State Univ., Corvallis. 236 pp.
Jones, G. W. 1975. Aspects of the winter ecology of black-tailed deer (*Odocoileus hemionus columbianus* Richardson) on northern Vancouver Island. M.Sc. Thesis. University of British Columbia, Vancouver. 78 pp.
Krajina, V. J. 1965. Biogeoclimatic zones and classification of British Columbia. Ecol. W. North America 1:1–17.
Rochelle, J. A. 1980. The role of mature conifer forests in the winter nutrition of black-tailed deer. Ph.D. Thesis. University of British Columbia, Vancouver. 285 pp.
Schoen, J. W., and O. C. Wallmo. 1979. Timber management and deer in southeast Alaska: current problems and research direction. Pages 69–85 *in* O. C. Wallmo and J. Schoen, eds. Proc. Sitka Black-tailed Deer Conf. USDA Forest Service, Reg. 10. Juneau, Alaska.
Schoen, J. W., O. C. Wallmo, and M. D. Kirchhoff. 1981. Wildlife-forest relationships: is a reevaluation of old growth necessary? Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:531–544.
Stevenson, S. K. 1978. Distribution and abundance of arboreal lichens and their use as forage by black-tailed deer. M.Sc. Thesis. University of British Columbia, Vancouver. 148 pp.
Wallmo, O. C., and J. W. Schoen. 1980. Response of deer to secondary forest succession in southeast Alaska. Forest Sci. 26:448–462.

Management of Roosevelt Elk Habitat and Harvest

E. E. Starkey
USDI National Park Service
Oregon Cooperative Park Studies Unit
Oregon State University, Corvallis

D. S. deCalesta
Department of Fisheries and Wildlife
Oregon State University, Corvallis

G. W. Witmer
Department of Forest Science
Oregon State University, Corvallis

Introduction

Historically, Roosevelt elk (*Cervus elaphus roosevelti*) were distributed from northern California to southern British Columbia in the coastal Pacific Northwest. During the Pleistocene, the subspecies was isolated reproductively from the Rocky Mountain elk (*C. e. nelsoni*) to the east by the Cascade Mountain Range and by glaciation (Guthrie 1966). Thus Roosevelt elk have adapted to relatively moist forest habitats with maritime climates, while Rocky Mountain elk evolved under the continental climate of the interior.

Unfortunately, less is known of Roosevelt elk biology than of the closely related Rocky Mountain elk east of the Cascades. This has frequently resulted in generalization of Rocky Mountain elk research findings to management of Roosevelt elk. However, differing evolutionary histories may have resulted in significant differences in the two subspecies' behavior, physiology, and habitat requirements. It may be improper to manage Roosevelt elk as if they are Rocky Mountain elk.

Wood products production is one of the most important industries within the range of the Roosevelt elk; opportunities for conflict between elk and forest management are numerous. Our objectives are to postulate probable primeval Roosevelt elk-habitat relationships, to describe contemporary elk habitats and impacts of forest management on elk, and to discuss areas of compromise and cooperation between wildlife and forest managers.

Primeval Habitat

Prior to human settlement, Roosevelt elk inhabited forests of Douglas-fir (*Pseudotsuga menziesii*) and western hemlock (*Tsuga heterophylla*) 200 to 750 years old, commonly referred to as old-growth. However, in spite of the relatively great ages of many of these forests, they were not structurally uniform. Rather, there was considerable variation in tree size and age, and understories were relatively diverse. Numerous small openings, with early seral communities were scattered throughout the forests. Grasses, forbs and deciduous shrubs provided forage in these areas, as well as in the understory of the mature forest. Wind storms, insects, diseases, and landslides created openings that resulted in a high degree of patchiness (Franklin et al. 1981).

Infrequent fires occurred at intervals of several hundred years. Such fires were often extremely large and catastrophic. This fire regime is distinctly different from that typical of much Rocky Mountain elk habitat where fires are smaller, more frequent, and burn with relatively less intensity because of less fuel.

There were also alluvial areas dominated by grasses and deciduous forest. Some were relatively large, such as the Willamette Valley, but many were associated with smaller streams and rivers. Periodic flooding maintained these areas in early seral stages.

Except for large and rare wildfires, most disturbances were relatively small scale, and habitats were generally stable. For large areas, many generations of elk probably were not displaced nor affected by major forest perturbations. Subsequent to the retreat of glaciers, the climate of the coastal northwest has been characterized by mild temperatures and by a consistent pattern of high winter precipitation, and warm, dry summers. Thus, Roosevelt elk evolved within an environment characterized by stable habitat and mild climate.

Historic Abundance and Distribution

Although historic abundance is difficult to determine, Roosevelt elk were found by Lewis and Clark to be plentiful along the lower Columbia River in 1805. During settlement, elk were reported from nearly all areas of western Oregon and Washington. They were particularly abundant on the Olympic Peninsula; Skinner (1936) suggested that 25–40,000 elk were present in the 1850s.

Roosevelt elk mainly occurred in lowland areas that contained a mixture of open and forested communities. These habitats provided many sources of both forage and cover, including old-growth forests containing a diversity of understory communities. Ecotones were probably preferred by elk as today (Witmer 1982). Use patterns undoubtedly changed seasonally as elk matched physiological and behavioral needs to availability of forage and cover.

Apparently, these elk populations coexisted primevally with various predators, including wolves (*Canis lupus*), cougars (*Felis concolor*), grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), and man. Human predation may have influenced population structures somewhat, but had relatively little effect on distribution or density (Raedeke and Taber, in press).

In sharp contrast to patterns of primeval coexistence with humans, Roosevelt elk were impacted significantly by both hunting and habitat modification following settlement by European man. Elk were a source of meat and hides for settlers, and they were heavily hunted throughout the Northwest. Market hunting was especially damaging to elk populations and many animals were slaughtered for their canine teeth or "tusks." Roosevelt elk populations were greatly reduced, and actually extirpated, in many areas by the early 1900s. As few as 2,000 elk remained on the Olympic Peninsula by 1905 (Morganroth 1909). This population apparently declined by over 90 percent in approximately 50 years.

Such dramatic decreases stimulated considerable public outcry, and soon after the turn of the century protective legislation was enacted by states and provinces. In addition, Mt. Olympus National Monument was established in 1909 (later to become Olympic National Park) with a primary objective of protecting Roosevelt elk. Intensive predator control also began at this time.

Subsequently, Roosevelt elk populations have recovered in many areas and have even become locally abundant. Approximately 60,000 Roosevelt elk presently inhabit western Washington (with 15,000 on the Olympic Peninsula) and 40,000 in western Oregon (Thomas and Toweill 1982). Presently, Roosevelt elk provide abundant and increasing sport-hunting recreation in these states. In addition, many elk herds have become local "tourist attractions," providing considerable non-consumptive recreation.

Key Biological Characteristics

The stability of primeval Roosevelt elk habitat likely resulted in stable elk populations that were characterized by low reproductive rates. For example, Trainer (1971) found that about 50 percent of female Roosevelt elk became pregnant annually while nearly 90 percent of female Rocky Mountain elk conceived each year. In addition, recruitment rates of 30–40 percent have been reported for Roosevelt elk calves (Witmer 1982, Schwartz and Mitchell 1945), whereas 70–90 percent recruitment rates were reported for Rocky Mountain elk calves (Kimball and Wolfe 1979, Knight 1970).

A potential cause of the low reproductive rate in Roosevelt elk populations is forage quality (Trainer 1971, Mereszczak et al. 1981). Apparently, lactating Roosevelt elk cows may not be able to regain a level of physical condition that would permit ovulation in the same year. Reduced milk production associated with a low plane of nutrition could also be significantly related to calf mortality.

Deficiencies of micronutrients such as selenium could be involved in lowered reproductive performance. The entire coastal Pacific Northwest is deficient in selenium, and domestic livestock require selenium supplementation. Symptoms of selenium deficiency include high mortality of young and reduced fertility of adults (Church and Pond 1978).

Whether density independent factors such as forage quality limited primeval Roosevelt elk populations is impossible to determine. If habitats preferred primevally contained higher quality forage resources, populations may have been regulated by density dependent factors such as forage quantity (Caughley 1979). However, recent displacement from preferred habitats could have forced elk to areas that are nutritionally inferior and therefore cause reduced fecundity.

Franklin and Lieb (1979) suggested that stable habitats favor long-term social bonding and cohesiveness of elk. Unhunted Roosevelt elk in unmanaged forests of Prairie Creek Redwoods State Park, California, and Olympic National Park, Washington, form stable and long-lasting associations (Franklin and Lieb 1979, Jenkins and Starkey 1982). On the other hand, hunted populations of Roosevelt elk inhabiting silviculturally managed forests in southwestern Oregon form relatively smaller bands with greater interchange of individuals (Harper 1964, Witmer 1982). The tendency to form stable social groups is apparently not shared by Rocky Mountain elk (Knight 1970, Shoesmith 1979). This difference in social organization could be a result of differing evolutionary histories, with Roosevelt elk occupying relatively more stable habitats.

The two subspecies may also have different cover requirements, with Roosevelt elk requiring more cover than Rocky Mountain elk (Peek et al. 1982). In southwestern Oregon, Roosevelt elk spent as much as 80 percent of their time in cover in some seasons (Witmer 1982). Consequently, the 60 percent forage/40 percent cover recommendation for Rocky Mountain elk habitat in the Blue Mountains of Oregon (Thomas 1979) may not be appropriate.

Managed Forest Habitat

Although protection and regulation of hunting resulted in partial recovery of many elk populations, impacts of habitat modifications remained. By the mid-1800s pioneers had settled in many areas of the Pacific Northwest. Their pattern of settlement was not random and the most productive Roosevelt elk habitats were the first occupied by settlers. These were the valleys and floodplains of the larger river systems. Areas such as the Willamette Valley contained rich soils for agricultural use, and the associated rivers provided water, fish, and a transportation system. Many of these valleys were maintained as grasslands by Indians who burned the areas to enhance game habitat. These same areas supported abundant Roosevelt elk populations. With settlement, elk were forced into densely forested areas at higher elevations (Bailey 1936). A similar pattern occurred with the closely related red deer (*C. elaphus*) in Eurasia (Flerov 1952).

Soon after settlement, harvest of timber began in the lowlands and progressively moved to higher elevations. Because logging residues were not treated or disposed of, fire was frequently associated with logging. Many sites were repeatedly burned, resulting in an increased abundance of herbaceous species. Today, forest fires are controlled and slash is usually managed to reduce fire hazard.

Most historic Roosevelt elk habitat has been altered by clearcut logging and only federal lands contain significant areas of primeval forest. At forest harvest rates typical of the last decade, even these lands will be logged in the next 20–40 years (Franklin et al. 1981, Meslow et al. 1981). Roosevelt elk will be required to exist in a managed landscape dominated by second-growth forest and clearcuts.

Early forestry was different from that practiced today. Individual areas logged and burned were of greater acreage. Reforestation efforts were minimal. Areas remained brushy or hardwood-dominated, often for decades. These areas provided good elk habitat, but only after adequate cover became re-established. Accessibility of these lands to the public was generally limited.

A rapid rate of harvest occurred on private lands in the early days of logging and still occurs in areas of public lands dominated by large acreages of old-growth forest. With "progressive clearcutting," large, adjacent tracts were clearcut one after the other. On private lands, size of clearcuts was often determined by property lines so that whole sections or half-sections were clearcut. These practices led to large acreages devoid of cover other than occasional residual patches. Only edges provided Roosevelt elk with foraging places close to thermal and escape cover. Clearcuts then became brushy and provided good elk habitat until the canopy closed with subsequent decline in forage levels. The vast area of dense, young conifers was then poor elk habitat until the canopy opened either naturally or through human activities.

During the last half of this century intensive forest management became the dominant practice on forestlands. Silvicultural prescriptions common to intensive forest management are: clearcut logging of relatively smaller-sized parcels followed by burning; planting nursery-grown seedlings; controlling competing brush with herbicides or mechanical means; using fertilizers and thinning stands; protecting young trees from damaging mammals and insects; and suppressing, to a high degree, post-planting fire. The potential for conflicts between wood fiber production and elk production increased as these practices significantly altered elk habitat.

Managed second-growth stands are much different in structure and composition than old-growth forest (Edmonds 1979). The former are of less value to elk populations during periodic severe winters because they have less forage and, in some cases, a lower ability to intercept snow than old-growth stands. Recent studies also suggest that old-growth stands provide better summer thermal cover than younger stands (M. Zahn, pers. comm.). Because old-growth forests provide all cover needs of elk as well as forage and because Roosevelt elk evolved in an old-growth dominated setting, it is not surprising that elk prefer old-growth over younger stands throughout much of the year (Janz 1980, Witmer 1982).

The liquidation of old-growth forest, followed by rapid regeneration, thinning, and shortened rotations truncates natural succession, thus reducing the diversity of age and structure of forest stands. This also introduces instability in the pattern and duration of the forest openings. The acreage of old-growth forest in western Oregon and Washington has declined from about 75 percent of forestlands in the mid-1800s to less than 30 percent currently (Meslow et al. 1981).

Diversity is further reduced when hardwood stands (of low commercial value) are converted to vigorous conifer stands—a common practice in the intensively managed forest. The mature mixed forests bordering perennial streams are important to Roosevelt elk for foraging, loafing, and travel (Jenkins 1980, Witmer 1982). These areas are being harvested completely, or more commonly, only a narrow band of 1–2 tree widths is left on each side of the stream. Such a band may protect water temperature and quality, but does not provide a corridor for elk use.

Conifer stocking densities and thinning regimes often resulted in a reduced quality of forest cover for elk. In the past, clearcut areas were densely planted with seedlings, resulting in stands difficult to traverse and containing little forage. Pre-commercial thinning results in more elk forage, but the slash generated may be a travel barrier. Commercial thinning increases forage for elk, but decreases thermal cover and a stand's ability to intercept snow.

Forest practices can have dramatic impacts on the quantity and quality of forage available to elk. These may be direct, as with actual changes in forage production, or indirect with behavioral and physiological characteristics of Roosevelt elk greatly restricting their use of forage beyond a relatively short distance from cover.

Removal of the forest canopy allows light penetration to the understory, leading to increased forage production. Burning and fertilization further improve the quality of the forage. These benefits are short-lived because other common practices, such as the planting of large conifer seedlings and the use of herbicides to reduce brush competition, hasten succession. The result is less forage and shorter periods of availability.

Roads facilitate implementation of silvicultural practices as well as make forestland accessible to the public for recreational purposes or travel. Some intensively managed forests have 6 miles of roads per square mile (9.7 km per 260 ha) of forestland. This density of roads is often associated with moderate to high levels of harassment of elk. Roosevelt elk, like Rocky Mountain elk, have shown a sensitivity to human harassment by significantly lowered levels of use of areas near roads (Witmer 1982).

High road densities also lead to higher elk harvest rates, both legal and illegal. This is especially important for Roosevelt elk, which have a significantly lower reproductive rate than Rocky Mountain elk. Roosevelt elk are faithful to traditional home range areas and do not readily colonize new habitat. They generally have a smaller home range size and are less prone to migrate than Rocky Mountain elk. Locally extirpated Roosevelt elk bands are not soon replaced by animals from surrounding areas.

The ability to maintain adequate amounts of forage and cover with appropriate juxtaposition as well as old-growth stands may be lessened in other ways. For example, portions of the forested acreage in management units are withdrawn from harvest for various reasons without a forest district's allowable cut volume being reduced. Thus, forest harvest must be concentrated in other basins or diverted to areas that had been set aside earlier for retention as elk habitat. Within the next few decades, large areas of public and private forestlands in western Oregon and Washington will consist of 15–40 year old second-growth Douglas-fir. Forage for elk would be severely limited in these areas.

Thus, forest management has greatly changed primeval Roosevelt elk habitat, and its stability has inadvertently exposed elk to much higher than normal mortality (legal and illegal harvest via roads). What have been the consequences, and what does the future hold for Roosevelt elk in the coastal Pacific Northwest?

Roosevelt Elk Management—Past, Present, Future

With the removal of vast stands of old-growth from the coastal forests, areas were created that initially were of high value to elk—openings with associated forage, surrounded by uncut forest that provided thermal and escape cover. It is probable that more habitat suitable for Roosevelt elk was created than previously existed in the absence of logging. With increased numbers of elk came increased demand from sportsmen to again harvest elk.

Hunting for Roosevelt elk resumed in the 1930s; harvests were restricted to bulls during fairly short hunting seasons. Harvest of elk grew quickly. Oregon records indicate that, in 1940, 198 Roosevelt elk were harvested by 1,343 hunters. The counts soared to 1,955 elk harvested by 14,765 hunters in 1960 and, in 1970, the levels reached 3,340 elk killed by 21,370 hunters.

By 1977, low bull escapement from hunting and the resultant public comment prompted wildlife commissioners to restrict bull harvest in Oregon to 3-point-or-better bulls in management units exhibiting low escapement. This restriction on bull harvest was designed to prevent suboptimal reproduction by cows that were bred primarily by yearling bulls (Hines and Lemos 1979). This tactic had little effect on overall harvest of Roosevelt elk in Oregon, however, as more liberal cow seasons compensated for reduced bull harvests and hunter numbers grew: 4,482 elk were harvested by 37,550 hunters in 1975, and 5,692 were harvested by 34,083 hunters in 1980 (Oregon Department Fish and Wildlife 1980).

Harvest of Roosevelt elk in Oregon increased by 292 percent from 1950 to 1980, and the number of elk hunters increased by 561 percent. Success rate dropped from a high of 32 percent in 1950 to 19 percent in 1980. From 1976–80 in Washington, harvest of Roosevelt elk increased by only 2 percent while number of hunters increased by 23 percent; success rate declined from 12.5 to 10.4 percent (Washington Game Department 1980). Number of elk counted per mile of census route in Oregon increased from 2.8 (1.7 per km) elk in 1950 to a high of 4.8 elk (3.0 per km) in 1960 and then declined continuously to 2.1 elk per mile (1.3 per km) in 1980. The continuing high number of elk harvested may relate to increased hunter pressure and access to the elk. National forest road mileage in the Pacific Northwest increased from approximately 20,000 miles (32,200 km) in 1953 to 85,000 miles (136,850 km) in 1981 (J. Hughes, pers. comm.). The trend over the last 30 years was for more hunters, with greater access, to collectively shoot more and more elk. The decline in success rates and census trend counts over this period suggests that elk populations may be declining, or at least will not be able to meet the increasing demand placed on them for a sustained yield.

Fall ratios of calves per 100 cows recorded in Oregon do not indicate increased productivity in response to increasing harvest: 31 calves:100 cows in 1950 increased to 36 calves:100 cows in 1960, and remained unchanged through 1980 (Oregon Department of Fish and Wildlife 1950, 1960, 1980). Similarly, exploited elk populations adjacent to Olympic National Park did not have significantly higher calf:cow ratios than unexploited populations within the Park (Smith 1980). Rocky Mountain elk reproductive rates were substantially greater in exploited populations (Knight 1970, Houston 1982). Until the difference in reproductive performance between the subspecies is understood, harvest of Roosevelt elk should be more conservative than that of Rocky Mountain elk.

Efforts in Oregon to transplant Roosevelt elk into suitable habitat have increased. However, Roosevelt elk damage Douglas-fir seedlings as well as forage and crops intended for domestic use. Complaints of elk damage, primarily from small, private ranchers have increased. Elk were identified as the second most significant pest of reforestation efforts in coastal Oregon and Washington (Black et al. 1979). The very areas essential to elk for procuring forage are contested by man for timber and crop production. As forest management and agriculture replace the small forest openings and alluvial plains with clearcuts and cultivated lands, the potential for conflict will grow as elk are forced onto these areas for forage.

The future of Roosevelt elk populations in the coastal Pacific Northwest is clouded. There will be increased harassment and harvest pressures as more logging roads are built. Hunters from highly populated areas of western Oregon and Washington will increasingly favor hunting nearby Roosevelt elk as transportation costs increase. In Oregon, 27 percent of elk hunters hunted Roosevelt elk in 1950, but by 1980 the figure was 37 percent. For Washington, Roosevelt elk hunters comprised 41 percent of elk hunters in 1976; this figure increased to 50 percent in 1980. Demands to reduce damages by elk to forestry and agriculture will increase; already, special post-season hunts exist to reduce local populations of depredating elk. Habitat instability, habitat loss, overharvest of forest cover, and truncation of succession will result in acreages less optimum for elk production.

Essentially, the problem faced by elk managers consists of producing enough elk to satisfy hunter demand on habitats managed primarily for other purposes. Current and future forest management will, in all probability, continue to expose elk to harassment, including poaching and hunting via increased logging road construction, reduce thermal and escape cover with favorable juxtaposition to foraging areas, and reduce the period of forage availability on regeneration sites. This management will serve to depress rather than maintain or increase elk numbers.

Short-term solutions exist for some of these problems. Road construction and logging activity in an area are short-term. Elk may leave the area, but return after disturbance ceases. To minimize this disturbance, forest managers can condense roading and logging activities in time and space, especially during peak elk breeding and calving periods.

The long-term harassment of elk continues, and may even increase after roading and logging cease. Harassment and hunting pressures can be reduced by road closures. A road closure program may provide additional benefits because elk utilize old, non-paved, logging roads as travel lanes and forage on the abundant grass and forb growth along sides (Witmer 1982).

Numbers of hunters, and subsequent harvest, can be controlled by limiting number of hunters via a permit system. Such a system, which would deny the opportunity to hunt elk to some hunters, is a politically and economically sensitive issue and may not be implemented until state wildlife agencies are confident of damage to elk herds by overharvest and can replace funds that would be lost through reduced sales of elk tags.

Providing good forage areas for elk would not be so frustrating for the forest manager if elk did not damage conifer seedlings. Forest managers often resort to the physical protection of seedlings. Seeding and fertilizing preferred elk forage on clearcuts may provide a less expensive answer; elk obtain abundant and nutritious forage while damage is reduced. Additionally, enhanced forage quality may support better reproductive performance by elk (Mereszczak et al. 1981).

The real challenge to managers and agencies is to plan for managing the animal and its habitat cooperatively and concurrently. Management objectives related to elk numbers must be related to management of habitats needed to produce the elk and to management objectives related to other outputs (i.e. timber) from those habitats. Deliberations between elk managers and managers of public and private forestlands are necessary so that optimal outputs of sport hunting, nonconsumptive use, and wood products are achieved. Special interest groups must be prepared to compromise. If not, the day will soon come when supply of elk is outstripped by demand. It will be too late then to determine whether harvest levels are realistic or habitat adequate, for battle lines will be drawn, rigid positions taken, and management options foregone.

Acknowledgments

The authors thank Bruce Coblentz, Jerry Franklin, David Leslie, Jr., Charles Meslow, and Harold Sturgis for reviewing the manuscript. Research support was provided, in part, by USDA Forest Service Grant No. FW-PNW-18 and by USDI National Park Service, Pacific Northwest Region Contract No. CX-9000-7-0085.

Literature Cited

Bailey, V. 1936. The mammals and life zones of Oregon. North American Fauna No. 55. USDA Bureau of Biol. Survey, Washington, D.C. 416 pp.

Black, H. C., E. J. Dimock II, J. Evans, and J. A. Rochelle. 1979. Animal damage to coniferous plantations in Oregon and Washington. Part 1. A Survey, 1963–73. School of Forestry Research Bull. 25. Oregon State Univ., Corvallis. 44 pp.

Caughley, G. 1979. What is this thing called carrying capacity? Pages 2–8 *in* M. S. Boyce and L. D. Hayden-Wing, eds. North American Elk: ecology, behavior and management. Univ. Wyoming Press, Laramie. 294 pp.

Church, D. C. and W. G. Pond. 1978. Basic animal nutrition and feeding. O and B Books, Corvallis, Ore. 300 pp.

Edmonds, R. L. 1979. Western coniferous forests: how forest management has changed them. Biology Digest 5(8):12–23.

Flerov, C. C. 1952. Muskdeer and deer. New Series No. 55. Acad. Sci., Moscow, USSR. 257 pp.

Franklin, J. F., K. Cromack, W. Dennison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. Gen Tech. Rep. PNW-118. USDA For. Serv., Pac. NW Forest and Range Exp. Sta., Portland, Ore. 48 pp.

Franklin, W. L., and J. W. Lieb. 1979. The social organization of a sedentary population of North American elk: A model for understanding other populations. Pages 185–198 *in* M. S. Boyce and L. D. Hayden-Wing, eds. North American Elk: ecology, behavior and management. Univ. of Wyoming Press, Laramie. 294 pp.

Guthrie, R. D. 1966. The extinct wapiti of Alaska and Yukon Territory. Can. J. Zool. 44(1):47–57.

Harper, J. A. 1964. Movement and associated behavior of Roosevelt elk in southwestern Oregon. Proc. West. Assoc. State Game Comm. 44:139–141.

Hines, W. W., and J. C. Lemos. 1979. Reproductive performance by two age-classes of male Roosevelt elk in southwestern Oregon. Wildlife Research Report No. 8. Oregon Department of Fish and Wildlife, Portland. 54 pp.

Houston, D. 1982. The northern Yellowstone elk: ecology and management. MacMillan, New York, N.Y. In press.

Janz, D. W. 1980. Preliminary observations on seasonal movements and habitat used by Vancouver Island Roosevelt elk. Pages 115–142 *in* W. Macgregor, ed. Proc. of western states elk workshop, Cranbrook, B.C. British Columbia Fish and Wildlife Branch, Victoria. 174 pp.

Jenkins, K. J. 1980. Home range and habitat use by Roosevelt elk in Olympic National Park, Washington. M.S. Thesis. Oregon State Univ., Corvallis. 84 pp.

______, and E. E. Starkey. 1982. Social organization of Roosevelt elk in an old-growth forest, Olympic National Park, Washington. J. Mammal. 63:331–334.

Kimball, J. F., Jr., and M. L. Wolfe, Jr. 1979. Continuing studies of the demographics of a northern Utah elk population. Pages 20–28 *in* M. S. Boyce and L. D. Hayden-Wing, eds. North American Elk: ecology, behavior and management. Univ. Wyoming Press, Laramie. 294 pp.

Knight, R. R. 1970. The Sun River elk herd. Wildl. Monograph No. 23. The Wildlife Society, Washington, D.C. 66 pp.

Mereszczak, I. M., W. C. Krueger, and M. Vavra. 1981. Effects of range improvement on Roosevelt elk winter nutrition. J. Range Manage. 34(3):184–187.

Meslow, E. C., C. Maser, and J. Verner. 1981. Old-growth forests as wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:329–335.

Morganroth, C. 1909. Management of the Roosevelt elk. Unpubl. manuscript. USDA For. Serv., Olympia, Wash.

Oregon Department of Fish and Wildlife. 1950–80. Annual reports, wildlife division. Portland.

Peek, J., M. Scott, L. Nelson, J. Pierce, and L. Irwin. 1982. Role of cover in habitat management for big game in northwestern United States. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 47:363–373.

Raedeke, K. J., and R. D. Taber. In press. Mechanisms of population regulation in western Washington forests for *Cervus* and *Odocoileus*. *In* Intern. Union of Game Biologists Congress, Oct. 1979. Dublin, Ireland.

Schwartz, J. E., and G. E. Mitchell. 1945. The Roosevelt elk on the Olympic Peninsula, Washington. J. Wildl. Manage. 9(4):295–319.

Shoesmith, M. W. 1979. Seasonal movements and social behavior of elk on Mirror Plateau, Yellowstone National Park. Pages 166–176 *in* M. S. Boyce and L. D. Hayden-Wing,

eds. North American Elk: ecology, behavior and management. Univ. Wyoming Press, Laramie. 294 pp.
Skinner, M. P. 1936. Browsing of the Olympic Peninsula by elk in early winter. J. Mammal. 17(3):253–256.
Smith, J. L. 1980. Reproductive rates, age structure and management of Roosevelt elk in Washington's Olympic Peninsula. Pages 67–111 *in* W. Macgregor, ed. Proc. of western states elk workshop, Cranbrook, B.C. British Columbia Fish and Wildlife Branch, Victoria. 174 pp.
Thomas, J. W., ed. 1979. Wildlife habitats in managed forests. Agriculture Handbook No. 553. USDA For. Serv., Washington, DC. 512 pp.
———, and D. E. Toweill, eds. 1982. Elk of North America: ecology and management. Stackpole Books, Harrisburg, Pa. 698 pp.
Trainer, C. E. 1971. An investigation concerning the fertility of female Roosevelt elk in Oregon: A progress report. Proc. West. Assoc. State Game Comm. 51:378–385.
Washington Game Department. 1980. Big game status report 1979–80. Olympia, Wash. 293 pp.
Witmer, G. W. 1982. Roosevelt elk habitat use in the Oregon Coast Range. Ph.D. Thesis. Oregon State Univ., Corvallis. 104 pp.

Role of Cover in Habitat Management for Big Game in Northwestern United States[1]

James M. Peek, Michael D. Scott, Louis J. Nelson, and D. John Pierce
Department of Wildlife Resources
University of Idaho, Moscow

Larry L. Irwin
Department of Zoology and Physiology
University of Wyoming, Laramie

Introduction

Conifer and deciduous overstories, or cover, are a significant component of the habitat of big game in the northwestern United States. The spatial and temporal distribution of cover is affected by natural processes such as plant growth, plant succession, disease, pests and fire. Big game animals have evolved under this regime and are presumed to be well adapted for existence under these conditions. Man is now significantly influencing the dynamics of cover in the northwestern United States. Logging, fire control, and pest control are radically altering the distribution of cover within the ranges of big game in this area. The impact of these changes on big game populations depends on their ability to adapt to rapid changes in habitat.

Six distinct groups of antlered game occupy the northwestern United States: Shiras moose (*Alces alces shirasi*), Roosevelt elk (*Cervus elaphus roosevelti*), Rocky Mountain elk (*C. e. nelsoni*), white-tailed deer (*Odocoileus virginianus*), black-tailed deer (*Odocoileus hemionus columbianus, O. h. sitkensis*) and mule deer (*O. h. hemionus*). These species occupy extremely diverse habitats, from sagebrush/grassland to coastal rain forest. The role of cover in the habitat of each species will obviously vary among areas. Generalizations must be based on the requirements of the individual and the type of cover that serves to meet these needs in each area.

Black et al. (1976) distinguished between thermal and hiding (security) cover, the former being overstories that protect from weather and sun, and the latter being used for escape and protection against predators and humans. However, the distinction between the two types of cover is not absolute. Moen (1973) reported that a white-tailed deer could receive protection from wind, the major source of energy loss, by laying down in a shrub field. Conversely, dense thermal cover can provide security from hunters.

The home range of an individual is comprised of a mosaic of different types of habitat. The specific pattern of habitat use is the result of a series of tradeoffs among costs and benefits from each of the available types of habitat. The critical factor to the individual is the total net benefit it obtains from all habitat available to it. Cover provides a certain combination of costs and benefits (e.g., low forage

[1]Contribution No. 230, Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow, ID 83843.

availability, high security, and low thermoregulatory costs) that differ from non-cover types (e.g., high forage availability, low security, and high thermoregulatory costs). Either of these combinations may result in similar levels of fitness.

The importance of cover to big game can be evaluated by examining the unique characteristics of cover that result in large net benefits under various environmental conditions. First, cover moderates the extremes of weather. Individuals can find lower ambient temperatures under cover in hot weather and warmer temperatures during cold weather. Wind velocity is greatly reduced in cover compared to other types of habitat. Snow depth and condition are more favorable to animal movement in cover versus no-cover areas. Second, forage abundance may be low in cover areas, but forage availability is sometimes relatively high compared to non-cover areas. Snow depths may preclude access to forage in open areas at times when forage under cover is available. Third, cover obstructs the visibility of individuals, thereby providing security from disturbance by man or other agents.

The objectives of this paper are: (1) to review and evaluate studies of cover use patterns of big game, and (2) to discuss the relationship between cover preference and requirement.

Cover Use Patterns of Big Game

White-tailed Deer

Pengelly (1963) recognized that logging grand fir timber types in northern Idaho had only limited potential for improving white-tailed deer winter range. Within wintering areas, small clearcuts that open up the forest canopy could be used by white-tailed deer when available, but usually not in midwinter in areas of persistent snow cover. The preference for closed canopy stands in winter in northern Idaho and northwestern Montana has been noted by many, including Owens (1981) and Mundinger (1979). Heavy use of Sitka spruce park forest for resting, and more open types for feeding, by Columbian white-tailed deer was observed by Suring and Vohs (1979), in the mild, wet coastal climate where forage could grow throughout the year.

In northern climates, white-tailed deer exhibit reduced activity in winter, consistent with a reduced metabolic rate, an adaptation to naturally deteriorating forage supplies (Moen 1978). During periods of low metabolic rates, deer may be considered to be in an energy conservation mode, as compared to other periods when they are in an energy production mode. Thus, high quality thermal cover that helps maintain energy reserves in winter by reducing thermoregulatory costs may be interspersed with areas containing forage that can be used when accessible in winter and, more importantly, in early spring.

Habitat use patterns of white-tailed deer at other times of the year suggest that quality forage sources are the predominant influence, but mature conifer cover is still preferred habitat (Suring and Vohs 1979, Owens 1981).

Information on the role of security cover in maintaining deer populations is lacking. In terms of predation by wolves, overstory cover as it affects snow characteristics is important (Mech et al. 1971). Cover characteristics, however, may not be an important influence on wolf/deer interactions (Rogers et al. 1980). The interactions among cover, white-tailed deer, and cougars, coyotes, and bobcats may be important in the northwest. Further, the effects of snowmobiles and other human activity are affected by security cover. More detailed work on the role of security cover for white-tailed deer is needed.

Mule Deer/Black-tailed Deer

In winter, the value of forest cover to mule deer varies among areas. Leckenby (1977) felt that since winter forage is poorly digestible, the primary value of winter cover is the reduction of energy losses. However, in the central and northern Rocky Mountains, mule deer migrate to foothill or basin shrub/grass ranges that seldom remain snow covered more than 1–2 days (Wilkins 1957, Lovaas 1958, Loveless 1964, Mackie 1970). During periods of harsh weather conditions they may move into dense cover such as juniper (Mackie 1970, Julander 1966, Richens 1967) or lodgepole stands, lee sides of rock outcrops, or drainage channels (Loveless 1964). Mule deer winter in dense timber in northern Washington (Ziegler 1978) and in Douglas fir stands, with 75 percent canopy closure, in northern Idaho (Keay and Peek 1980).

Cover is important to mule deer wintering in deep snow (Loveless 1964, Jones 1974, Bunnell 1979, Geist 1981). This is especially true for Columbian black-tailed deer on northern Vancouver Island (Taber and Hanley 1979, Jones 1974, Bunnell 1979) and for Sitka black-tailed deer (Wallmo and Schoen 1980, Schoen and Wallmo 1979, Bloom 1978). Lichen rain and downfall can be significant forage sources in old-growth stands. Thus, Barrett (1979) found a consistent browse-timber interaction influencing Sitka black-tailed deer track distributions, and could not separate the individual effects of cover from forage availability. Barrett (1979) concluded that winter deer distributions were determined primarily by availability of preferred browse, which is strongly influenced by snow depth and its relationship to overstory closure.

Heavy precipitation that leaches nutrients from forage species can be critical (Einarsen 1946, Laycock and Price 1970). Overstory canopies that intercept rainfall can reduce the effect of the leaching process on forage. This may be especially critical in coastal rain forests, but is noted elsewhere as well.

Thermal cover can be provided by shrubs such as dense chamise (Linsdale and Tomich 1953) or juniper woodlands, or by physical objects providing shade, such as boulders and ledges. Security cover influences mule deer distributions in some areas. Wilkins (1957), Lovaas (1958), and Mackie (1970) reported use of security cover on north slopes during hunting season. Black et al. (1976) suggested security cover was required even in the absence of humans and predators, implying a psychological need. The presence of security cover on at least two sides of openings facilitates their use by mule deer (Short et al. 1977). Security cover can also be provided by scattered boulders, breaks, and irregular topography (Dasmann 1971), and even logging slash (Black et al. 1976). These authors recognized a cover preference during fawning, presumably to reduce insect attack, predation, and to protect from weather extremes.

While the structure of coniferous forests undoubtedly influences habitat selection, data do not support the hypothesis that deer actually require forests to survive (Wallmo and Schoen 1981). Mule and black-tailed deer may have the thermoregulatory capacity to make minor microclimate modifications provided by forest cover insignificant as long as adequate forage exists and activity is not a factor (Swift et al. 1980).

Elk

Use of thermal cover in winter by elk varies greatly between areas. Beall (1974) observed elk bedding areas could be predicted given the wind, ambient temperature, and solar radiation in winter in the Bitterroot River, Montana, area. Elk did not frequent open areas during high winds and very low temperatures. Conversely, elk in the Sun River, Montana, area used timber in winter only when ice crusts prevented them from using the grasslands (Knight 1970). Beall (1974) noted that elk on the Sun River, an area of frequent high winds, tolerated higher winds than the elk on the Bitterroot area.

Elk will use cover in summer when available, but it is apparently not necessary. Habitat selection strategies appear to be based primarily on the availability of succulent vegetation and the absence of human disturbance (Franklin and Lieb 1979, Irwin 1978, Marcum 1975, Schoen 1977). Dense canopies are generally not preferred, but rather, more open timber on relatively moist areas receive most use (Irwin 1978, Marcum 1975, Pederson et al. 1980, Schoen 1977). Elk achieve very high summer densities where little or no thermal cover occurs, e.g. as in Jackson Hole (Martinka 1969), Wind Cave National Park (Varland et al. 1978), and portions of southern Idaho (Will 1979, Yeo 1981). A small but growing population of elk now exists on sagebrush-grassland in southern Washington (Richard et al. 1977). Red deer in Scotland exist in areas devoid of cover (Staines 1976). Historical evidence of elk on prairies where little or no thermal cover existed also indicates that summer cover is not needed for thermoregulatory processes by this species (Burpee 1907, Koch, 1941, Murie 1951).

Further, simulations indicate that thermoregulatory costs are probably insignificant for wintering elk (Swift et al. 1980). We conclude that the use of thermal cover by elk is required only during extreme winter conditions involving high winds. At other times cover is probably preferred but is not required for maintenance of homeothermy. At most, the absence of thermal cover appears to create only an insignificant increase in thermoregulatory costs for elk.

However, security cover does appear to be a requirement for elk in the presence of human disturbance. The large herds of the great plains vanished quickly in the face of white exploitation. Security cover affects responses of elk to hunting and activities along roads (Basile and Lonner 1979, Irwin and Peek 1979, Lyon 1979, Perry and Overly 1976). The size of the security area and the density of the cover affects the degree to which elk are affected by disturbance.

Shiras Moose

The physical attributes of moose allow them to tolerate deeper snows than deer (Kelsall 1969), but moose are usually restricted to areas where snows are less than 90 cm (Formozov 1946). Cover plays a key role in mountainous regions by providing habitat that meets this snow depth criteria, allowing moose to occupy otherwise unsuitable winter range. Where snow depths average less than 90 cm, cover may be less critical. The snow depths in areas where willow communities are important Shiras moose winter range (Houston 1968, Stevens 1965, Dorn 1970) are characteristically less than in areas where moose winter in mature conifer stands (Ritchie 1978).

Selection within local areas for more open communities occurs during late fall, early winter, and again in the spring when snow depths are not inhibiting (Irwin 1974, Phillips et al. 1973, Peek et al. 1976). Moose use of cover types also vary between years, reflecting differences in winter severity (Peterson 1977).

Moose in northcentral Idaho select for old-growth grand fir stands during the winter months. The variable canopy coverage within these stands provides abundant forage, which is available throughout the winter, as well as cover. In this case, the interaction of cover and forage may be the governing force of habitat selection. Information on the amount of mature conifer cover needed to retain a population, and the degree to which spring/fall forage can substitute for winter cover by increasing the health and condition of individual moose, are critical in assessing the impacts of cover removal in areas of deep snows.

The Shiras moose may be restricted at the southern boundary of its range by excessive summer heat, absence of shade, water and suitable foods (Kelsall and Telfer 1974). Cover may be important during the summer by relieving stress due to accumulation of body heat (Belovsky 1981). Moose can respond to heat stress by moving to higher elevations, utilizing aquatic environments, and/or seeking shade during mid-day. Areas with temperatures exceeding 27°C for extended periods without adequate cover or access to lakes or rivers do not support moose (Kelsall and Telfer 1974).

The occurrence of feeding activities during the summer has been associated with cooler times of the day, and the amount of time spent feeding has been related to average daily temperature (Belovsky and Jordan 1978). Use of more open communities, including clearcuts and burns, is associated with selection of cooler micro-environments (Irwin 1974), cooler times of the day (personal observation), and at cooler times of the year (Houston 1968, Ritchie 1978).

One other role of cover that may have a pronounced effect on Shiras moose is protection from humans. Shiras moose are less wary of humans than deer and elk. This lack of wariness can significantly increase extra-legal losses in some areas (Ritchie 1978).

Discussion

The importance of cover in maintaining big game in the northwestern United States is highly variable (Table 1). The interaction of forage quality and quantity with precipitation and snow depth, and the effect that cover has on the interaction, confounds attempts to isolate the need for cover solely from field observation. This appears to be especially true for white-tailed deer and black-tailed deer, but is less apparent for the other species. Thermal cover does not seem especially necessary to maintain high populations of elk and mule deer. Topographical variations and lower vegetation may function as thermal cover in many areas.

Habitat preference or selection and habitat requirement may not be equivalent. Field evaluations of habitat use patterns versus availability can give indications of requirements but are not definitive in differentiating between preferences and requirements. An animal may show preference for a habitat that may or may not be required to assure survival and ability to reproduce. Conversely, an animal

Table 1. Summary of environmental conditions that cause cover to become important to big game in the northwestern United States.

	White-tailed deer	Mule deer	Black-tailed deer	Elk	Roosevelt elk	Moose
Winter						
Deep snow	+ +	+	+ +	+	+	+ +
High winds[a]	+ +	+	+	+	+	–
Heavy precipitation	+	+	+	–	+	–
Cold	–	–	–	–	–	–
Summer						
Heat	+	+	+	+	+	+ +
Dessicated forage	+	+	+	+	+	+
Human Activity[b]	+	+ +	+	+ +	+ +	–

KEY: + = preferred
+ + = required
– = not important

[a]Topography, lower vegetation can substitute for thermal cover.
[b]This specifies populations not conditioned to tolerating human activity.

may not exhibit a preference for a habitat requirement that is in oversupply. A knowledge of individual response in terms of reproduction and survival are needed to determine a habitat requirement. If the removal of a habitat component causes a decline in production/survival, then that component is a requirement. Experimental investigations that evaluate energy expenditures in relation to environmental change offer promise of defining habitat requirement more precisely (Moen 1973).

Johnson (1980) described the habitat selection process as a series of hierarchical questions. The first three levels are appropriate to this discussion; the geographic range of the species, the home range within the geographic range, and the usage of habitats within the home range. Many habitat use studies compare the habitat use patterns of an individual with availability in a large study area. However, the individual's activities are confined to its home range, not the entire study area. The third level of selection emphasizes that availability within the home range should be used for comparisons with habitat use. The examination of the habitat use patterns of individuals is assumed to represent the best tradeoffs for the particular set of conditions each individual experiences. Comparisons among home ranges with different amounts of the same habitat can be used to determine a requirement. This implies that determination of a requirement should be carried out at the second level of selection. If a measure of home range quality varies in relation to the level of a given habitat, then that habitat could be classified as required.

Habitat use patterns may vary with different population densities, as Fretwell and Lucas (1970) indicate. Thus, investigations of a population at high density may well yield habitat use information that would not be the same if the population was at low density. Also, a habitat that may promote high life expectancies of adults may not be equivalent to the habitat that promotes high productivity and survival of young through the first year. Interpretation of habitat preference must include an evaluation of characteristics of the population inhabiting the area in consideration. Management of habitat for high productivity of a big game population may be different than management for maximum survival of adults. The comparative studies by Klein (1965) and Ransom (1965) imply that these relationships are subject to management.

While a better understanding of the relationship of habitat preference and requirements is needed, an animal will be expected to seek out preferred habitats within its home range even if it could survive elsewhere. If this is true, then extensive habitat change that diminishes preferred habitats, even though still containing required habitats, will alter animal distribution by concentrating them in preferred habitats. At extremes, abandonment of traditional home range and occupation of new areas may result.

Frequently, predicted effects of habitat manipulation practices are offered in terms of changes in animal numbers. Aside from the considerable difficulty in measuring such changes, these predictions are virtually useless unless knowledge of limiting factors and factors affecting distribution are incorporated into the predictions. The population response integrates all the factors that affect the population. Many of these factors are significantly influenced by the habitats individual animals occupy. However, any source of mortality may limit the response; for example, severe weather conditions causing large overwinter mortality may prevent a population from increasing in even the best habitat. Where seasonal ranges are involved, the population response may be limited by the most restrictive seasonal habitat, which may or may not be the one under consideration. The response of populations in two identical areas or in the same area at different times could be significantly different if the major mortality factors differ. Because population size involves factors such as hunter harvest and weather patterns not controlled by the land manager, predictions of habitat use patterns relative to change in habitat offer a more realistic and useful approach than predictions of changes in population size.

A population responds to the combination of habitats within its range. In certain cases it may be possible to show a correlation between one component of the habitat, e.g. cover, and the population response. A more likely situation is that the effect of one habitat component is dramatically affected by the availability of other components. The costs and benefits associated with each component must be evaluated to arrive at some indication of the importance of a given component to the population.

As cover reductions occur from logging, increases in forage can be expected. In cases where forage has previously been limiting, populations may be expected to respond by increasing production and survival. However, if animals do not utilize the increased forage because of a lack of adjacent security cover, then production and survival may decline. Moreover, forage availability can be reduced during drought or deep snow in open areas more dramatically than underneath cover. If the population is limited by forage, fluctuations will be smaller if cover is readily available to moderate climatic extremes.

Fundamental theories concerning natural regulation of native cervidae center on the role of food, predators, and weather/climate interactions in maintenance of numbers. However, cover in its various forms is a fundamental influence on all three of these factors. Overstory characteristics influence animal visibility, snow depth and density, understory microclimate, and forage quality and quantity; all of which affect predator/prey relationships. Leopold (1933) and Elton (1939) recognized these various factors and uses of cover long ago. Elton's (1939) suggestion that finer analysis of the components of cover was needed has certainly been elaborated upon, but his comment that we lack methods of describing the way cover influences population density is still applicable to big game.

Literature Cited

Barrett, R. H. 1979. Admiralty Island deer study and the Juneau unit timber sale. Pages 114–132 *in* O. C. Wallmo and J. W. Schoen, eds. Sitka black-tailed deer. Proc. of Conf. USDA For. Serv., Alaska Reg., Juneau.

Basile, J. V., and T. N. Lonner. 1979. Vehicle restrictions influence elk and hunter distribution. Montana J. Forestry 77:155–159.

Beall, R. C. 1974. Winter habitat selection and use by a western Montana elk herd. Ph. D. Diss. Univ. of Montana, Missoula. 197 pp.

Belovsky, G. 1981. Optimal activity times and habitat choice of moose. Oecologia 48:22–30.

———, and P. A. Jordan. 1978. The time-energy budget of a moose. Theoret. Popul. Biol. 14(1):76–104.

Black, H., R. Scherzinger, and J. W. Thomas. 1976. Relationships of Rocky Mountain elk and Rocky Mountain mule deer habitat to timber management in the Blue Mountains of Oregon and Washington Pages 11–31 *in* S. R. Hieb, ed. Proceedings of the Elk-Logging-Roads Symposium, Moscow, Idaho, Dec. 16–17, 1975.

Bloom, A. M. 1978. Sitka black-tailed deer winter range in the Kadashan Bay area, southwest Alaska. J. Wildl. Manage. 42(1):108–112.

Bunnell, F. L. 1979. Deer-Forest relationships on northern Vancouver Island *In* O. C. Wallmo and J. W. Schoen, eds. Sitka black-tailed deer. Proc. of Conf. USDA For. Serv., Alaska Reg., Juneau. 231 pp.

Burpee, J. L., ed. 1907. York Factory to the Blackfoot Country—the journal of Anthony Hendry, 1754–1755. Royal Soc. Can. Ser. 3, Vol. 1, Sect. II, Part V. Pages 307–364.

Dasman, W. 1971. If deer are to survive. Stackpole Books, Harrisburg, Pa. 128 pp.

Dorn, R. O. 1970. Moose and cattle food habits in southwest Montana, J. Wildl. Manage. 34(3):559–564.

Einarsen, A. S. 1946. Crude protein determination of deer food as an applied management technique. Trans. N. Amer. Wildl. Conf. 11:309–312.

Elton, C. 1939. On the nature of cover. J. Wildl. Manage. 3:332–338.

Franklin, W. L., and J. W. Lieb. 1979. The social organization of a sedentary population of North American elk: A model for understanding other populations. Pages 185–198 *in* M. S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior and management. Univ. of Wyoming, Laramie. 294 pp.

Fretwell, S. D., and H. L. Lucas. 1970. On territorial behavior and other factors influencing distribution in birds. Acta. Biotheoretica 19:16–36.

Formozov, A. N. 1946. Snow cover as an integral factor of the environment and its importance to the ecology of mammals and birds (English ed.) Occasional Paper No. 1. Boreal Inst., Univ. of Alaska, College. 176 pp.

Geist, V. 1981. Behavior: adaptive strategies in mule deer. Pages 157–224 *in* O. C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. of Nebraska Press, Lincoln. 605 pp.

Houston, D. B. 1968. The shiras moose in Jackson Hole, Wyoming. Tech. Bull. No. 1. Grand Teton Nat. Hist. Assoc. 110 pp.

Irwin, L. L. 1974. Relationships between deer and moose on a burn in northeastern Minnesota. M. S. Thesis. Univ. of Idaho, Moscow. 51 pp.

———. 1978. Relationships between extensive timber culture, big game habitats, and elk habitat use patterns in northern Idaho. Ph. D. Diss. Univ. of Idaho, Moscow. 282 pp.

———, and J. M. Peek. 1979. Relationship between road closures and elk behavior in northern Idaho. Pages 199–204 *in* M. S. Boyce and L. D. Hayden-Wing eds. North American elk: ecology, behavior and management. Univ. Wyoming, Laramie. 294 pp.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Jones, G. 1974. Influence of forest development on black-tailed deer winter range on Vancouver Island. Pages 139–148 *in* H. C. Black, ed. Proceedings: Wildlife and forest management in the Pacific Northwest Symposium. Oregon State University, Corvallis. 236 pp.

Julander, O. 1966. How mule deer use mountain rangeland in Utah. Utah Acad. Sci. Arts Let. Proc. 43(2):22–28.

Keay, J. A., and J. M. Peek. 1980. Relationships between fires and winter habitat of deer in Idaho. J. Wildl. Manage. 44(2):372–380.

Kelsall, J. P. 1969. Structural adaptations of moose and deer for snow. J. Mammal. 50(2)302–310.

———, and E. S. Telfer. 1974. Biogeography of moose with particular reference to western Canada. Can. Natur. 101(1):117–130.

Klein, D. R. 1965. Ecology for deer range in Alaska. Ecol. Mono. 35:259–284.

Knight, R. R. 1970. The Sun River elk herd. Wildl. Monogr. 23. The Wildlife Society, Washington, D.C. 66 pp.

Koch, E. 1941. Big game in Montana from early historical records. J. Wildl. Manage. 5:357–370.

Laycock, W. A., and D. A. Price. 1970. Environmental influences on nutritional value of forage plants. Pages 37–47 *in* H. A. Paulsen and E. H. Reid, eds. Range and wildlife habitat evaluation. Misc. Publ. 1147. USDA Forest Service, Washington, D.C. 220 pp.

Leckenby, D. A. 1977. Management of mule deer and their habitat: Applying concepts of behavior, physiology, and microclimate. Proc. West.Assoc. State Fish and Game Comm. 57:206–217.

Leopold, A. 1933. Game management. Chas. Scribner & Sons, New York. 481 pp.

Lindsdale, J. M., and P. Q. Tomich. 1953. A herd of mule deer: A record of observations made on the Hastings Natural History Reservation. Univ. of California Press, Berkeley. 567 pp.

Lovaas, A. L. 1958. Mule deer food habits and range use, Little Belt Mtns., Montana. J. Wildl. Manage. 22(3):275–283.

Loveless, C. M. 1964. Some relationships between wintering mule deer and the physical environment. Trans. N. Amer. Wildl. Conf. 29:415–431.

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. J. Forestry 77:658–660.

Mackie, R. J. 1970. Range ecology and relations of mule deer, elk and cattle in the Missouri River breaks, Montana. Wildl. Monogr. No. 20. The Wildlife Society, Washington, D.C. 79 pp.

Marcum, C. L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. Ph. D. Diss. Univ. of Montana, Missoula. 188 pp.

Martinka, C. J. 1969. Population ecology of summer resident elk in Jackson, Wyoming. J. Wildl. Manage. 31: 115–123.

Mech, L. D., L. D. Frenzel, Jr. and P. D. Karns. 1971. The effect of snow conditions on the vulnerability of white-tailed deer to wolf predation. Pages 51–59 *in* L. D. Mech and L. D. Frenzel, Jr., eds. Ecological studies of the timber wolf in northeastern Minnesota. USDA For. Serv. Res. Paper NC-51. North Cent. For. Exp. Sta., St. Paul, Minn. 62 pp.

Moen, A. N. 1978. Seasonal change in heart rates, activity, metabolism and forage intake of white-tailed deer. J. Wildl. Manage. 42:715–738.

———. 1973. Wildlife ecology: An analytical approach. W. H. Freeman and Co., San Francisco. 458 pp.

Mundinger, J. G. 1979. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitat of northwestern Montana *In* R. J. Mackie, ed. Montana deer studies. Fed. Aid Proj. W-120-R Progress Rep. July 1978–June 1979. Montana Dep. of Fish and Game, Missoula.

Murie, O. J. 1951. The elk of North America. Stackpole Co., Harrisburg, Pa. 376 pp.
Owens, T. 1981. Movement patterns and determinants of habitat use of white-tailed deer. M. S. Thesis. Univ. of Idaho, Moscow.
Pedersen, R. J., A. W. Adams, and J. Skovlin. 1980. Elk habitat in an unlogged and logged forest environment. Wildl. Res. Rep. 9. Oregon Dep. of Fish and Wildlife, Portland. 121 pp.
Peek, J. M., D. L. Urich, and R. J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildl. Monogr. No. 48. The Wildlife Society, Washington, D.C. 65 pp.
Pengelly, W. L. 1963. Timberlands and deer in the northern Rockies. J. For. 61:734–740.
Perry, C., and R. Overly. 1976. Impact of roads on big game distribution in portions of the Blue Mountains of Washington. Pages 62–68 *in* Proc. Elk-Logging-Roads Symp. Univ. of Idaho, Moscow, ID.
Peterson, R. O. 1977. Wolf ecology and prey relationships on Isle Royale. Monogr. Ser. No. 11. U.S. Nat. Park Serv., Wash. D.C. 210 pp.
Phillips, R. L., W. E. Berg, and D. B. Siniff. 1973. Moose movement patterns and range use in northwestern Minnesota. J. Wildl. Manage. 37(3):266–278.
Ransom, A. B. 1965. Breeding seasons of white-tailed deer in Manitoba. Can. J. Zool. 44:59–62.
Richens, V. B. 1967. Characteristics of mule deer herds and their range in northeastern Utah. J. Wildl. Manage. 31:651–666.
Rickard, W. H., J. D. Hedlund, and R. E. Fitzger. 1977. Elk in the short-steppe region of Washington: An authentic record. Science 190:1009–1010.
Ritchie, B. W. 1978. Ecology of moose in Fremont County, Idaho. Wildl. Bull. No. 7. Idaho Dep. of Fish and Game, Boise. 33 pp.
Rogers, L. L., L. D. Mech, D. K. Dawson, J. M. Peek, and M. Korb. 1980. Deer distribution in relation to wolf pack territory edges. J. Wildl. Manage. 44(1):253–258.
Schoen, J. W. 1977. The ecological distribution and biology of wapiti (*Cervus elaphus nelsoni*) in the Cedar River watershed, Washington. Ph.D. Diss. Univ. of Washington, Seattle. 405 pp.
Schoen, J. W., and O. C. Wallmo. 1979. Timber management and deer in southeast Alaska: Current problems and research direction. Pages 69–85 *in* O. C. Wallmo and J. W. Schoen, eds. Proceedings: Sitka black-tailed deer Conference. USDA For. Serv., Region 10, Juneau, Alaska. 231 pp.
Short, H. L., W. Evans, and E. L. Boeker. 1977. The use of natural and modified pinyon pine-juniper woodlands by deer and elk. J. Wildl. Manage. 41:543–559.
Staines, B. W. 1976. The use of natural cover by red deer (*Cervus elaphus*) in relation to weather in northeast Scotland. J. Zool. Lond. 180:1–8.
Stevens, D. R. 1965. The recovery of a moose range in southwestern Montana. Proc. West. Assoc. State Game and Fish Comm. 46:76–86.
Suring, L. H., and P. A. Vohs, Jr. 1979. Habitat use by Columbian white-tailed deer. J. Wildl. Manage. 43:610–619.
Swift, D. M., J. E. Ellis, and N. T. Hobbs. 1980. Nitrogen requirements of North American cervids in winter—a simulation study. Pages 244–251 *in* Proc. 2nd Int. Reindeer and Caribou Symp., Roros, Norway.
Taber, R. D., and T. A. Hanley. 1979. The black-tailed deer and forest succession in southeast Alaska. For. Sci. 26(3):448–462.
Varland, K. L., A. L. Lovaas, and R. B. Dahlgren. 1978. Herd organization and movements of elk in Wind Cave National Park, South Dakota. Nat. Resour. Rep. 13. U.S. Dep. Interior, National Park Serv. 28 pp.
Wallmo, O. C., and J. W. Schoen. 1980. Response of deer to secondary forest succession in southeast Alaska. For. Sci. 26(3):448–462.
———. 1981. Forest management for deer. Pages 434–448 *in* O. C. Wallmo, ed. Mule and black-tailed deer of North America. Univ. of Nebraska Press, Lincoln. 605 pp.
Wilkins, B. T. 1957. Range use food habits and agricultural relationships of the mule deer, Bridger Mtns., Montana. J. Wildl. Manage. 21(2):159–169.
Will, G. C. 1979. Elk surveys and inventories. Proj. W-170-R-3, July 1, 1978 to June 30, 1979. Appendix A. Idaho Dep. Fish and Game, Boise.

Yeo, J. J. 1981. The effect of rest-rotation grazing on mule deer and elk populations inhabiting the Herd Creek allotment, East Fork Salmon River, Idaho. M. S. Thesis. Univ. of Idaho, Moscow. 119 pp.

Ziegler, D. L. 1978. The Okanogan mule deer. Biological Bulletin No. 15. Washington Dep. of Game, Olympia. 106 pp.

Patterns of Old Growth Harvest and Implications For Cascades Wildlife

Larry D. Harris
School of Forest Resources and Conservation
University of Florida, Gainesville

Chris Maser
USDI Bureau of Land Management, Forestry Sciences Laboratory, Corvallis, Oregon

Arthur McKee
H. J. Andrews Experimental Ecological Reserve,
Blue River, Oregon

Introduction

Although intensive harvest of the old-growth Douglas-fir (*Pseudotsuga menzeisii*) forests on federal lands west of the Cascade Mountains began in the late 1940s and 1950s, the wildlife habitat implications were not widely perceived until the late 1960s and early 1970s. For example, state agency habitat assessments in western Oregon in 1966 and 1967 (Hutchison et al. 1966, Aney 1967) did not identify old-growth harvest as an issue. As of 1977, the Coniferous Forest Biome research program of the U.S. International Biological Program (IBP) had produced 532 publications, bulletins, theses, and internal reports. Fourteen, or 2.6 percent, of these deal with vertebrate ecology; none deal with impacts of Douglas-fir management on wildlife (Edmonds 1977). It is partly because of this late awareness that the old-growth harvesting issue has surfaced so dramatically. Luman and Neitro (1980), Meslow et al. (1981), and Schoen et al. (1981) have called for national attention in the last two sessions of this conference. This paper describes the harvesting pattern and presents basic ecological information that may be of use in assessing impacts. We suggest habitat conservation strategies derived from island biogeography principles. All statistics and area references refer to Oregon and Washington west of the Cascades crest unless otherwise noted. Because of time and personal background limitations we consider only amphibians, reptiles, and mammals.

Harvesting Trends

For the last 30 years, annual loss and removal of Douglas-fir sawtimber from western Washington and western Oregon has averaged 3 times annual growth (USDA 1978: tables 34, 35, 36). During the 1950s private industry made large gains toward balancing the cut with growth. Small gains were made on public lands in the 1960s, but overall the trend has been toward greater deficit cutting (Figure 1, USDA 1978). While there has been a modest 5 percent reduction in total commercial forest acreage, the reduction in net volume of softwood growing stock has been 18 percent, the reduction in net volume of softwood sawtimber has been 21 percent, and the reduction in large-diameter-class softwood has been 34 percent. This trend may continue in the future, as "public old-growth harvest substitutes

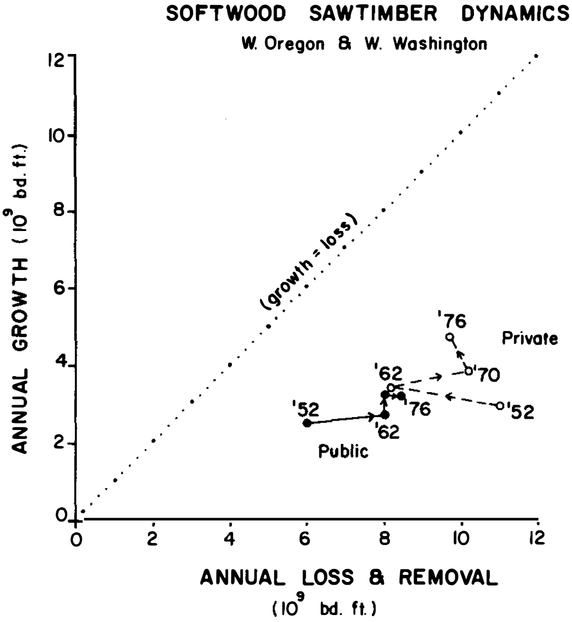


Figure 1. Disparity between annual growth, and annual loss and removal of softwood from private and public lands in western Washington and western Oregon. USDA 1978.

for private young-growth harvest over the next 25 years" (Adams 1977, Brodie et al. 1978). Yet, a different analysis suggests that "only in the north coast timbershed in western Oregon and in the three eastern Oregon timbersheds could harvesting continue at the current level for the next 30 years . . . for western Oregon as a whole, this projection indicates a decline of 22 percent by the year 2000." (Beuter et al. 1976). Only when the recently planted stands reach high levels of mean annual increment will the current annual cut be matched by annual production.

Cutting statistics for the Willamette National Forest in west central Oregon illustrate the trend for the region. Except during the depression of the mid 1930s, the harvest has increased geometrically since the First World War. Between 1935 and 1965 the annual rate of increase in volume of cut was 4.7 percent. This has resulted in a doubling of the cut every 15 years (Figure 2).

The Spatial Cutting Pattern

In 1900, old-growth Douglas-fir forests were distributed from near sea level to over 4,000 feet (1,220 m) elevation. The larger trees and volumes were restricted to the lower elevations and river valleys (Figure 3, Langille et al. 1903). Cutting statistics for the Willamette N.F. indicate the widespread and dramatic shift in cutting from the low elevations in the 1940s to higher elevations during the 1970s (Figure 4). In addition to the high standing volumes, there are logistic and economic

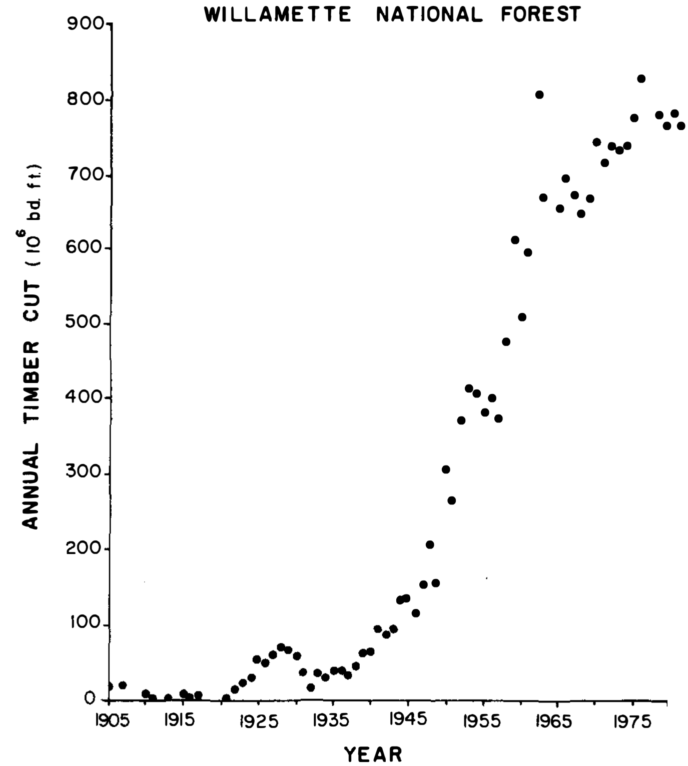


Figure 2. Annual timber cut in million bd. ft. from the Willamette National Forest. Data from historical cutting summary, timber management plan, Willamette N.F. (effective date FY 1977).

advantages to cutting the low elevation and valley bottom sites first. Thus the general pattern has been for clearcutting to begin at low elevations, proceed up the river valleys, and terminate in the steep terrain of the high elevation sites where volumes are low because of extreme environments and frequent fires. Because of lower volumes per acre, and because the average tree is progressively younger and smaller (Tedder 1979), the increase in acreage cut on the Willamette N.F. has been five times greater than the increase in volume cut during the last 40 years (data from Paulson and Leavengood 1977, Acreage cut data from T.R.I. System Forest Supervisor's Office, Eugene, Ore.).

The Situation Today

The temporal and spatial patterns described above have led to conditions as we know them today. A sample of 77 3.9-square-mile (10 km^2) quadrats taken from 1981 Willamette N.F. vegetation type maps suggests that about 25 percent of the Willamette N.F. remains in "old-growth." This is equal to the percentage of National Forest land west of the Cascades summit that is greater than 250 years

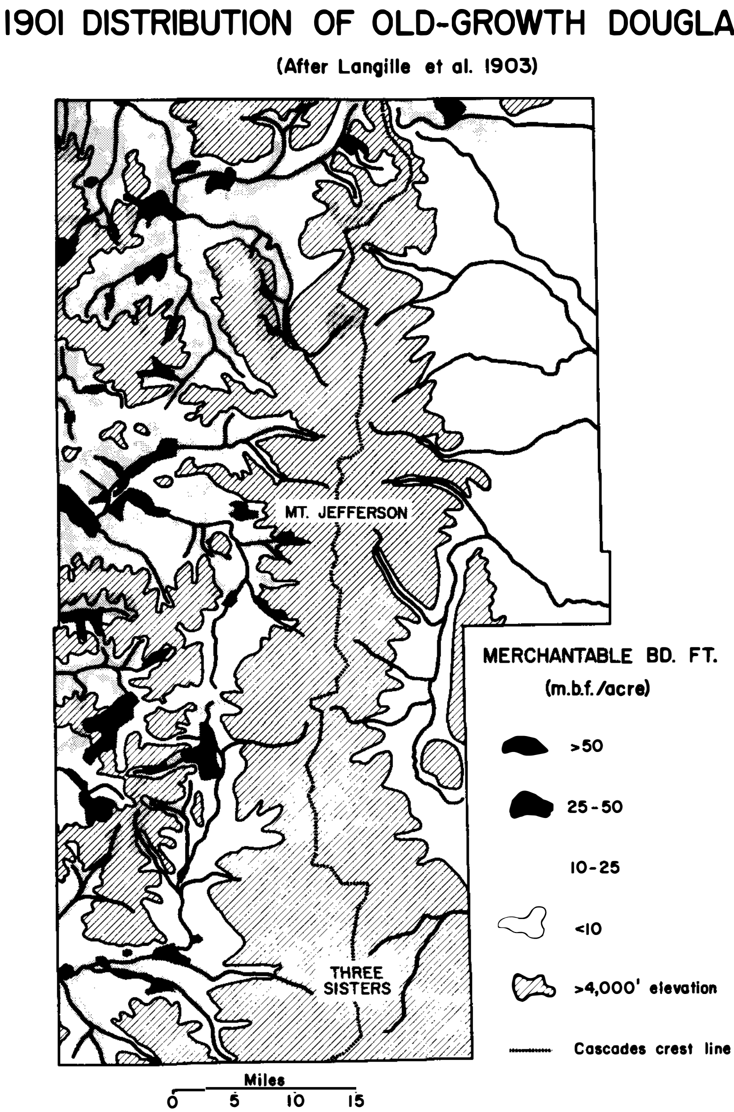


Figure 3. Distribution of Douglas-fir in the Cascade Forest Reserve (now the Willamette N.F.) by volume class and elevation in 1901. (Redrawn from Langille et al. 1903).

old and has had less than 10 percent of the timber removed (Sirmon, in press). Only 3.3 percent of the Siuslaw N.F. remains in old-growth Douglas-fir (TRI System, Forest Supervisor's Office, Corvallis, Ore.). Meslow et al. (1981) note that the situation in southwestern Washington and northwestern Oregon is particularly critical; the Olympic penninsula (including Olympic National Park) is nearly

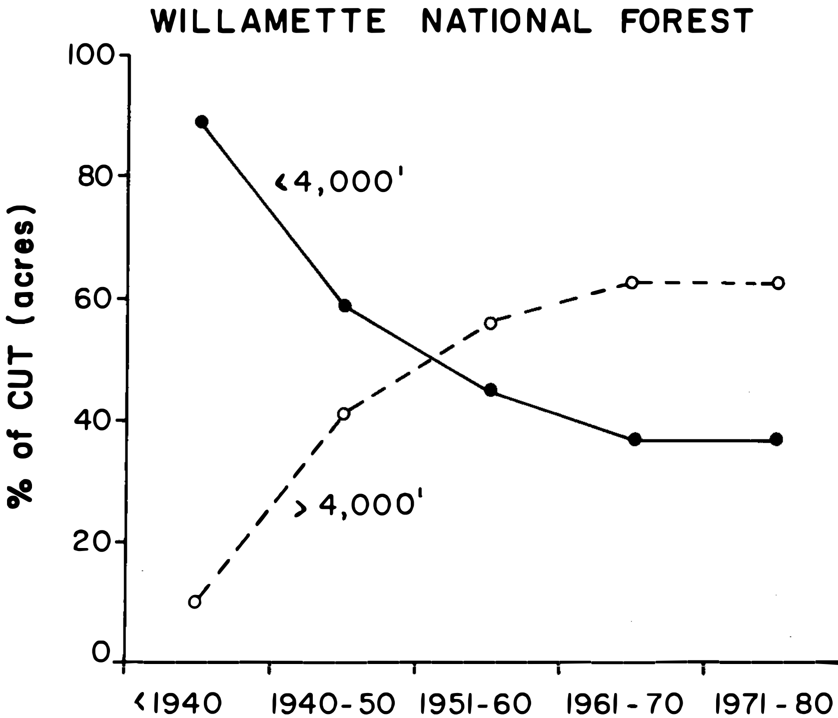


Figure 4. Percentage of total annual cut from two elevation classes in the Willamette N.F. Data extracted from Total Resource Inventory (TRI) system, Forest supervisor's office, Eugene, Ore.

isolated by 60 miles (96 km) of development. Private industry has little old-growth remaining on its lands (Beuter et al. 1976), and it is projected that old-growth will be liquidated from Bureau of Land Management (BLM) Lands within 30 years (Luman and Neitro 1980). Since active regeneration policies have been in effect only 20 years, the distribution of stand age classes on public lands is distinctly bimodal. About 40 percent of BLM acreage is stocked with trees less than 60 years old, about 44 percent has trees over 110 years old, and only 17 percent is between 60 and 110 years of age.

Of equal importance to the reduction in total old-growth acreage and change in age distribution is the reduction in average patch size and the insularization of old-growth habitat islands. In certain areas old-growth remains as the matrix, with clearcuts and young stands appearing as the islands. A gradation of patterns with increasing proportions of clearing leads to the opposite extreme where young growth is clearly the matrix and old-growth occurs only as totally isolated stands (Figure 5). Remaining old-growth stands of the Siuslaw N.F. have a median size of 31 acres (12.6 ha) and a mean of 68.2 acres (27.6 ha). Exact figures for inter-island distances are not yet available but they approach 5 miles (18 km) in three of the four districts of the Siuslaw N.F.

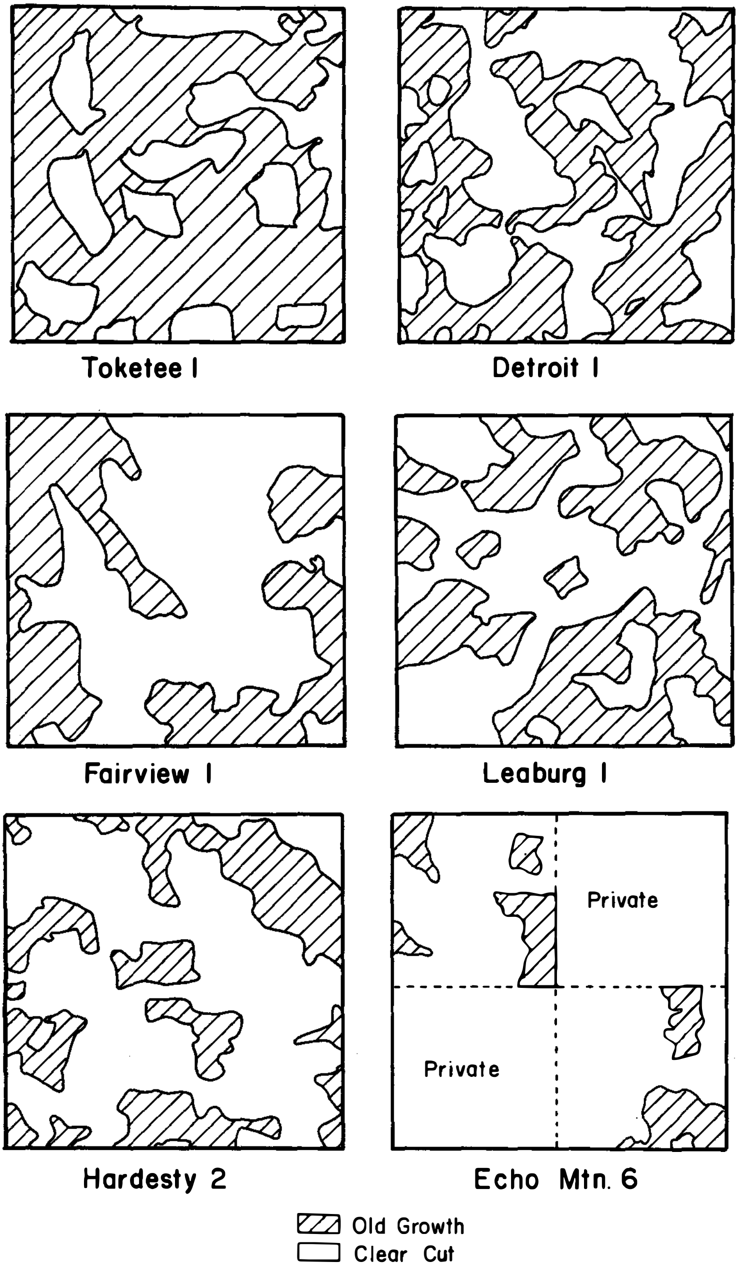


Figure 5. Current distribution of old-growth in 5 representative 3.9-square-mile (10 km^2) quadrat samples taken from 1981 vegetation type maps of the Willamette N.F. Names refer to quadrangle maps programmed into the TRI system. Forest Supervisor's office, Eugene, Ore.

Some Consequences For Wildlife

In an attempt to evaluate the effects of old-growth insularization on wildlife we conducted preliminary faunal surveys in 15 old-growth stands in the Willamette N.F. in the summer of 1981. During the survey we recorded data on 15 site-specific variables such as size of area, elevation, degree of isolation, shape, slope, aspect, and a description of site and stand characteristics such as occurrence of surface water, talus, down logs, snags, and vegetation composition. At each site we proceeded through the list of potential amphibian, reptile, and mammal species and assigned subjective probability values to the presence or absence of each species (Maser et al. 1981).

Despite the small sample size and several confounded variables, it soon became apparent that the variable of greatest importance in governing potential species richness is elevation. We plotted the distributional range of the 108 amphibian, reptile, and mammal species of Western Oregon as a function of elevation (e.g., Figure 6). The 95 species that potentially occur at 1,000 ft (300 m) above sea level is about 40 percent greater than the number of potential species at 4,000 ft (1,200 m) and 2.4 times the number that occur at 6,000 feet (1,800 m) (Table 1). Small mammal trapping data and bird census data from the H. J. Andrews Experimental Ecological Reserve (Unpub. US/IBP data), and small mammal trapping data from Mount Rainier National Park (Schamberger 1970) suggest a slight inverse relation between density of all species combined and elevation.

We recognize that elevation is not a management variable, but the decision to allocate old-growth management areas to low, medium, or high elevation sites is a decision variable of critical importance. To date, old-growth harvesting has been particularly intense at lower elevations. Conversely, wilderness areas, parks, and old-growth set-aside areas occur disproportionately at high elevations (Figure 7). The historical pattern of wildfire (Langille et al. 1903), and thus the probability of future wildfire, is much greater on high elevation sites (Burke 1979). Coupled with the threat of windthrow, landslides, slumps, and other forest protection problems associated with high elevations, these sites make poor choices as old-growth management areas that are expected to persist for centuries. Maintenance of communities intrinsically rich in vertebrate species over long periods of time will require protection of low elevation sites in addition to the present system of high elevation refuges.

A second variable of importance in governing potential species richness is the presence of surface water and wetness of the site. The 96 species that potentially occur on moist sites is about 2.6 times as many as occur on very wet sites and 1.7 times as many as occur on very dry sites. If community richness is the objective, then old-growth management areas should be located on moist sites containing surface water. But, since site potential and standing volume are closely correlated with moisture availability, these sites have been disproportionately logged and replanted. Increased attention needs to be given to moist sites when selecting old-growth habitat islands.

Complexity of habitat corresponds with successional development and may be represented by discrete stand structure types (Figure 8). Ordination of vertebrate species along the successional gradient reveals that the two extremes of age (regeneration stands and old-growth) support notably high vertebrate species rich-

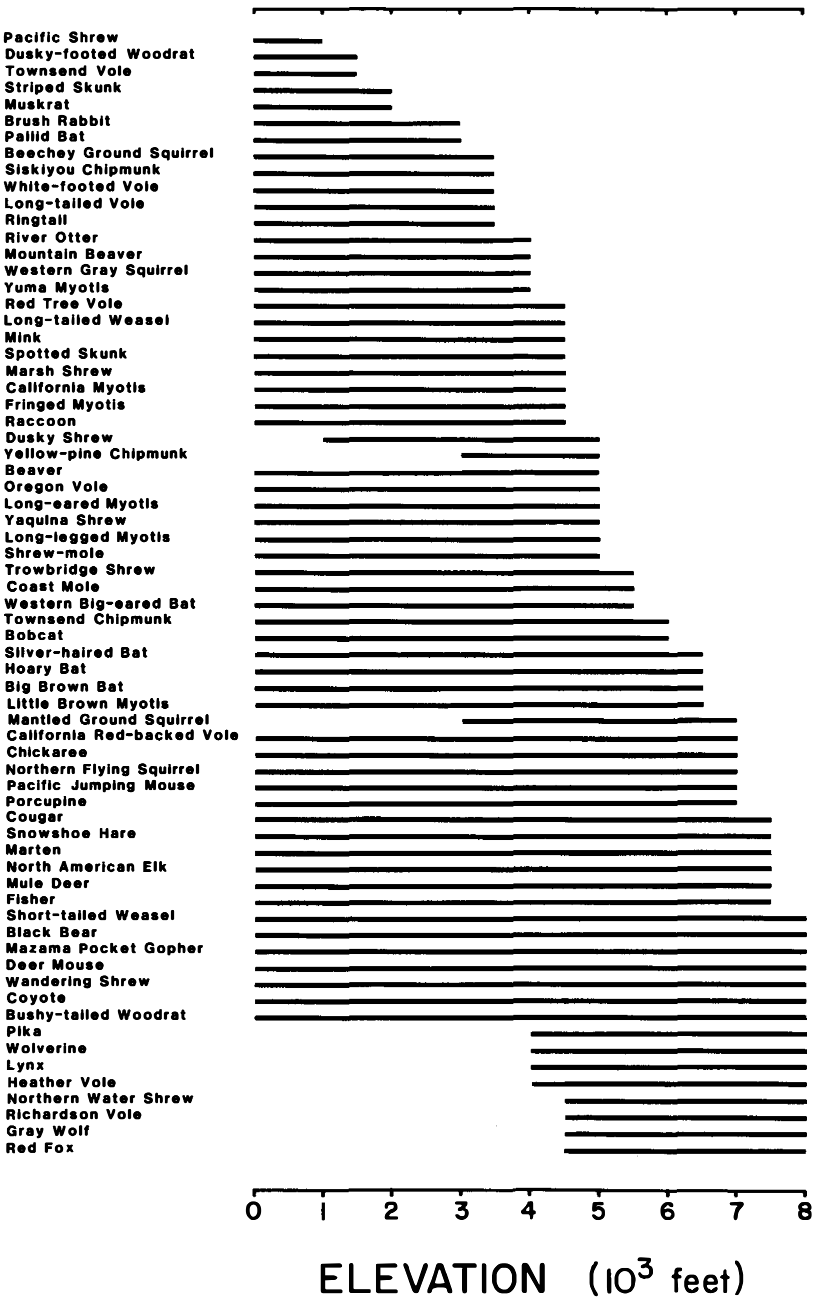


Figure 6. Ordination of western Oregon mammal distributions as a function of elevation.

Table 1. Number of western Oregon amphibian, reptile, and mammal species whose ranges transcend noted elevation points.

Elevation in feet (m)	No. Species
500 (150)	95
1000 (300)	95
2000 (600)	90
3000 (900)	84
4000 (1200)	68
5000 (1500)	60
6000 (1800)	40
7000 (2100)	32
8000 (2400)	17

ness (e.g., Figure 9). This is especially obvious if a distinction is drawn between primary habitat and secondary habitat on the basis of suitability for all natural history functions (e.g., feeding, overwintering, reproducing, escaping). Very early or very late successional stages provide primary habitat for twice as many species as the middle-aged stands (Figure 10). Short rotation forests that do not include the last two successional stages (large sawtimber and old-growth) will not provide primary habitat for 36 species of amphibians, reptiles, and mammals. Although some of these species may use the short rotation forests as secondary habitat, they require that older-aged stands or specific patches of primary habitat be maintained within the short rotation forest. Unfortunately, the two mid-successional stages of least value to wildlife dominate about 60 percent of the standard rotation time (80 years).

Two habitat elements that explain much of the increase in species richness in older stands are standing snags and fallen logs (Thomas et al. 1979, Maser et al. 1979, Franklin et al. 1981). First-generation plantations where residual snags and logs have been retained will provide habitat for species that will not occur in later generation plantations not containing these elements. The tally of species that will occur in short rotation stands without snags is reduced 10 percent below the number occurring in stands with snags (Figure 11). The number of species occurring in short rotation stands that contain neither snags nor fallen logs is reduced about 29 percent below the number occurring in unmanaged old-growth stands. Based on these observations and projections we strongly endorse current recommendations for the inclusion of broken-top trees, snags, and fallen logs in short rotation stands (Thomas 1979).

A final point concerning the changing forest structure centers on the expected shift in age class frequencies in time. At present, about 20 percent of western Oregon and western Washington public forest acreage has trees in the middle classes between age 30 and 80 (only 15 percent of BLM acreage). Over half of the acreage is stocked with trees either less than 30 or greater than 200 years of age (51 percent of BLM acreage). In other words, while only 20 percent occurs in the age classes that have a notably low number of species, over 50 percent occurs in

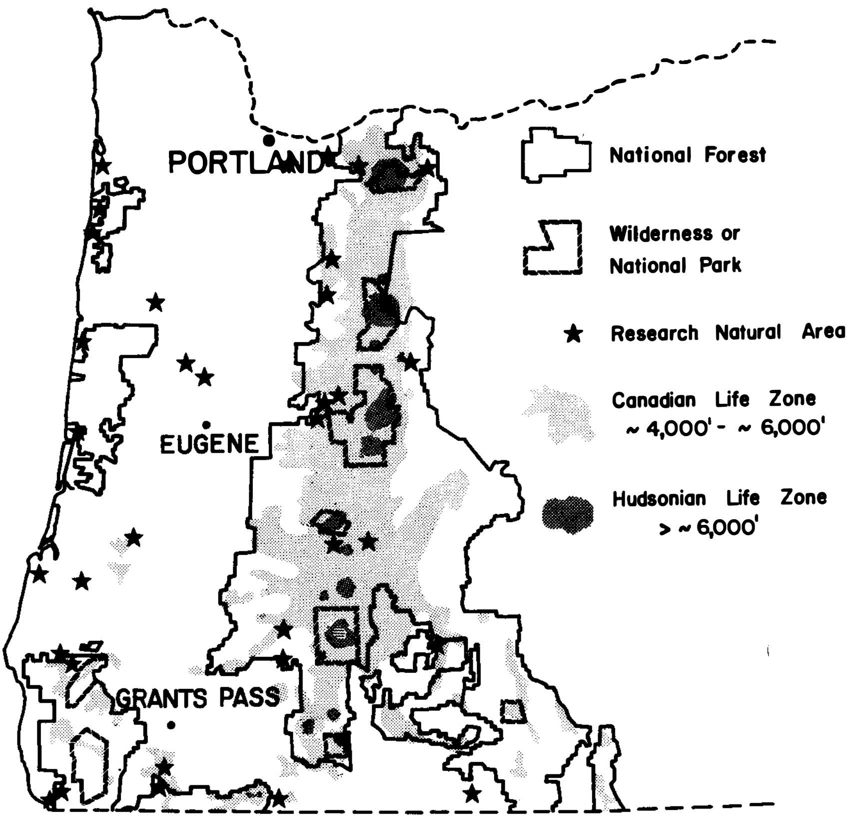


Figure 7. Location of western Oregon national forests, parks, wilderness areas, and research natural areas against the backdrop of the high elevation Canadian and Hudsonian life zones (Bailey 1936). Most protected old growth occurs at elevations above the range of 25 mammal species. Data and location map contributed by Sarah Green and Bob Frenkel.

the age classes supporting the highest number of species. Fifty years from now as much as 65 percent of public land acreage and a higher percentage of total acreage will fall between the ages of 30 and 90. Unless remedial steps are taken, wildlife population declines, similar to the declines in midwestern and eastern areas earlier this century will probably occur.

Habitat Island Design Principles

Island biogeographers recognize two distinct kinds of islands (Darlington 1957). Oceanic islands such as Krakatoa were never associated with a continental land mass and thus the animal community developed from initial colonist species to progressively richer and more complex levels. Islands such as those of the Aleutian chain were formerly points on a continuous land mass. Their origin involves isolation due to rising sea levels. The animal communities of these islands have

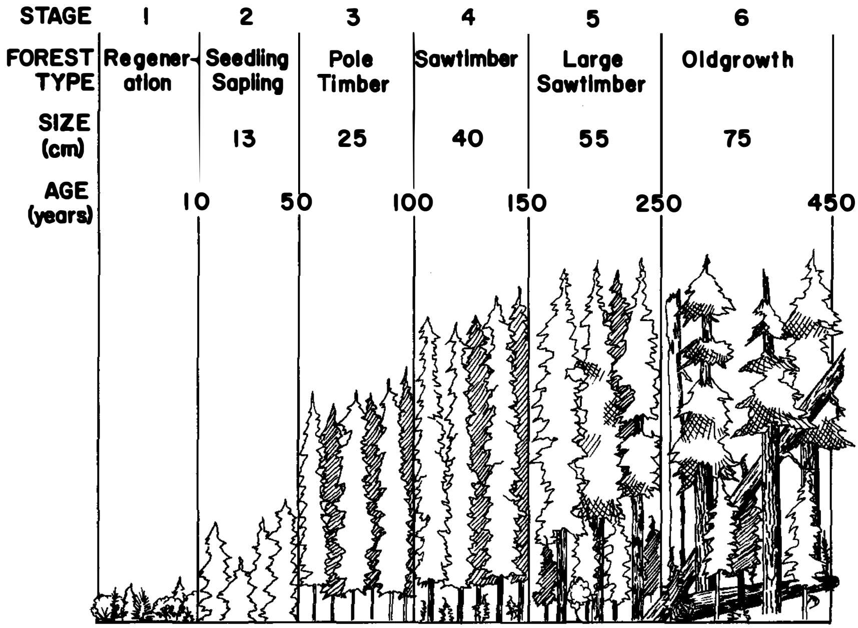


Figure 8. Six discrete stand types representing the development of structural complexity in Douglas-fir-western hemlock (*Tsuga heterophylla*) stands.

regressed from higher levels of species richness characteristic of larger continents to a reduced number of species characteristic of islands. An important principle of island biogeography is that, when standardized for size and degree of isolation, true oceanic islands never develop the same level of species richness as the land bridge islands. Type of origin has considerable influence on species richness.

If the true island analogy applies to old-growth habitat islands and we wish to maintain high levels of species richness, we should identify patches of old-growth that are, or were recently, part of the contiguous natural forest. This proposition begs the question of which patches. It also implies that selection of areas, with some principles in mind, will be, on average, superior to what will result if we make no choice at all (Harris and Kangas 1979, Harris 1980, Harris and Marion 1981). We have assembled data regarding habitat island biogeography and the species depletion process for the Cascades and believe many principles of biogeography derived from true islands apply to old-growth habitats. For example, consider the 375-square-mile (968 km^2) Mt. Rainier National Park an island in the surrounding sea of development. The park presently supports populations of 37 species of mammals. This is 43 percent of the 86 species that occur in western Washington and 54 percent of the species that potentially occur in the park. The 37 present species represent only 74 percent of the species recorded in the park in 1920 by Taylor and Shaw (Weisbrod 1976). The loss of 13 species might be explained on an individual basis, but the fact remains that 26 percent of the mammal species found in 1920 do not presently occur in the park.

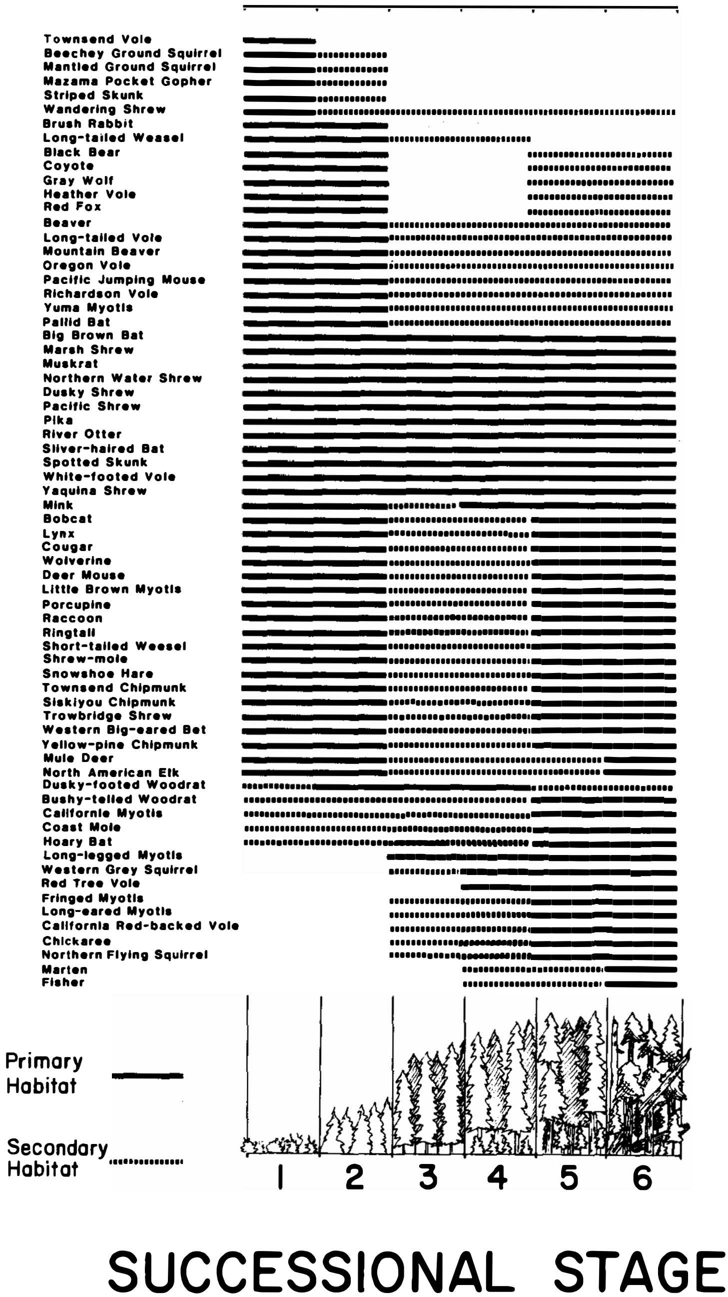


Figure 9. Ordination of western Oregon mammal species as a function of the successional stages of Douglas-fir noted in Figure 8.

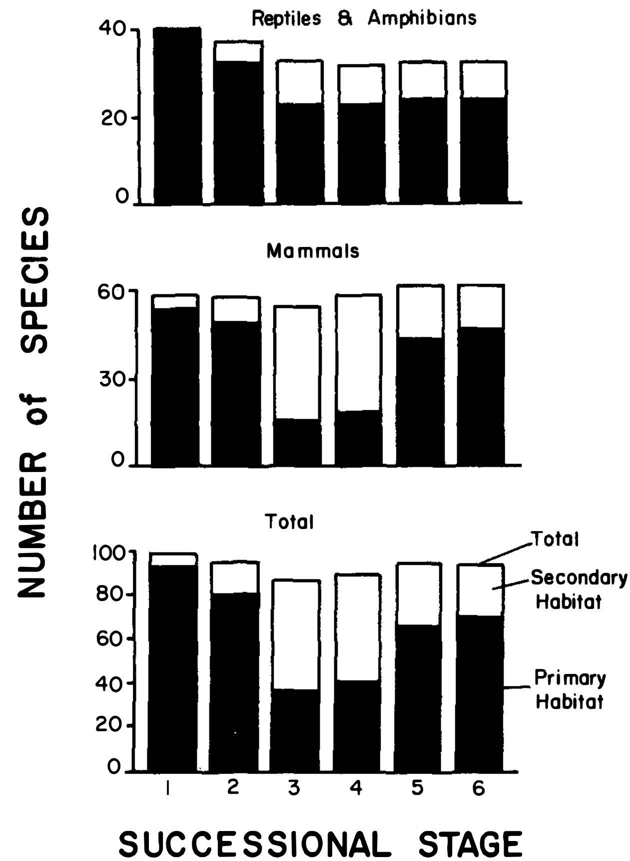


Figure 10. Number of amphibian and reptile, mammal, and total cursorial vertebrate species meeting their primary and/or secondary habitat requirements in the different successional stages illustrated in Figure 8.

The same depletion process is occurring throughout western Oregon. The grizzly (*Ursus arctos*), gray wolf (*Canis lupus*) and fisher (*Martes pennanti*) have been extirpated. Wolverines (*Gulo gulo*) and lynx (*Lynx canadensis*) are very rare. Notably, these are all top carnivores. Olterman and Verts (1972) reviewed the status of 41 Oregon mammal species of questionable status. Of those ever occurring in the western Cascades, the difference between trophic status and numerical status is revealing. Seven of the eight species (88 percent) judged to be "extirpated," "rare," or "endangered" are carnivores. Conversely, five of eight species (62 percent) in the "not rare or endangered" category are herbivores. It seems not only intuitive but true that carnivores deserve special consideration in our efforts to conserve animal community diversity.

Estimates of home range size (in ha) for herbivores, omnivores, and carnivores

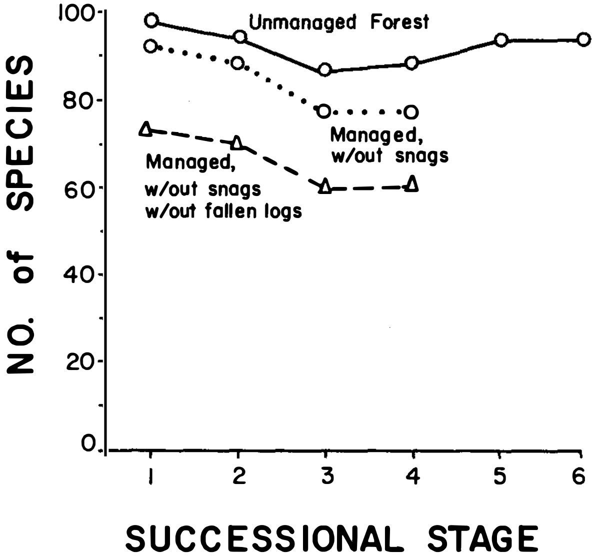


Figure 11. Number of terrestrial vertebrate species potentially occurring in an unmanaged Douglas-fir forest and two types of managed Douglas-fir forests in western Oregon.

can be obtained from equations 1, 2, and 3 where W represents weight in grams (Harestad and Bunnell 1979):

$$R_H = 0.002W^{1.02} \quad (1)$$
$$R_O = 0.059W^{0.92} \quad (2)$$
$$^1R_C = 0.022W^{1.30} \quad (3)$$

Based on these equations, the projected range size for a 145 pound (66 kg) cougar (*Felis concolor*) is over 100,000 acres (440,000 ha), a 40 pound bobcat (*Lynx rufus*) is 19,000 acres (7,700 ha), a 35 pound (16 kg) wolverine is 16,000 acres (6,500 ha), a 25 pound (11 kg) otter (*Lutra canadensis*) is 10,000 acres (4,000 ha), a 15 pound (6.8 kg) fisher is 5,000 acres (2,000 ha), and a 125 pound (57 kg) blackbear (*Ursus americanus*) is 3,500 acres (1,400 ha). Compare these home range estimates with the size of the 10 largest old growth Douglas-fir stands in the Siuslaw N.F.: 971 (390), 734 (300), 655 (265), 640 (260), 572 (230), 536 (220), 509 (205), 478 (195), 457 (185), 304 (125) acres (ha). It becomes immediately obvious that none of the species listed could be contained by or expected to exist totally within even the largest existing old growth stand. Paying no regard to minimum population size, the six widest-ranging mammal species presently occurring in the Suislaw N.F. could not be contained by even the largest existing old growth islands.

We realize that these species are not restricted to old-growth, and that their survival is not totally dependent on the preservation of islands of old-growth. We

[1]Revised equation based on data published in Harestad and Bunnell 1979.

cite the statistics to demonstrate that old-growth set asides, in and of themselves, will not suffice as a conservation strategy for many of the wider-ranging species. Conversely, if the largest existing old-growth islands (at least in the Siuslaw N.F.) are not sufficiently large to support the full complement of native species, it is relevant to one of the often heard debates, "either a smaller number of large areas or a larger number of smaller areas." This does not argue against the choice of large old-growth islands for habitat management but, for any given acreage commitment, the extremes of strategy are few large areas versus many small areas. Because of the above and other considerations mentioned previously, it seems that some of the emphasis should now be changed from the old-growth system to the system of old-growth. We recommend development of an interdependent system of strategically located habitat islands interconnected by habitat corridors. Specific design recommendations are forthcoming. The adequacy of a tract of old-growth for any given species or for preserving a full complement of species is not only dependent upon the nature and size of the tract, but the degree of insularity and the setting within which the tract occurs. A 50-acre (20 ha) tract demarcated by flagging tape and surrounded by hundreds of acres of similar habitat would have a much different habitat value than a 50-acre tract surrounded by clearcut.

Bond (1957) noted that because of climatic changes induced by clearing, small, isolated stands of midwestern hardwood forest tended toward drier "preclimax" conditions. He went on to state (p. 374) that, "Recognition of the relationship between woods size and relative climaxness helps explain why there are more species in this study preferring large woods than those preferring smaller woods." Wind penetration studies conducted in the Cascades tend to support the rule of thumb that a peripheral strip of remaining forest "three-tree-heights" wide will be climatically impacted by clearcutting (Dr. L. Fritschen, pers. comm.). Based on a tree height of 250 feet (78 m), a peripheral strip 750 feet (232 m) wide would be required to buffer the core area of an old-growth stand from climatic impact.

Curtis (1956) described a number of plant ecology changes believed to result from the insularization of Wisconsin woodlots. Kendeigh (1944) observed that when forest stands were less than about 50 acres (20 ha) the proportion of "edge species" of birds became so great as to invalidate use of the plot for censusing "forest interior" species. Several authors have addressed the minimum size concept (e.g., Anderson and Robbins 1981, Lovejoy and Oren 1981) and most conclude that something will be lost no matter what minimum size is chosen.

We suggest that minimum size is not a constant that can be discovered, but rather a variable depending on the specific objective, the surroundings, and the circumstances. In order to maintain its old-growth character we believe that an area totally surrounded by clearcut or regeneration stands would need to be 10 times as large as an old-growth area surrounded by mature timber. The size of stands should be inversely proportional to the insularity caused by surrounding young growth. Based on our surveys and related research we believe that a 62 acre (25 ha) patch will maintain its integrity as an old-growth stand if surrounded by mature timber. As progressively more of the periphery is cut away, the stand size would need to be increased accordingly (Figure 12).

Considering old-growth island size a variable rather than a constant should offer increased flexibility to forest managers and provide incentive for the management of long rotation islands. An interdependent system of long rotation islands con-

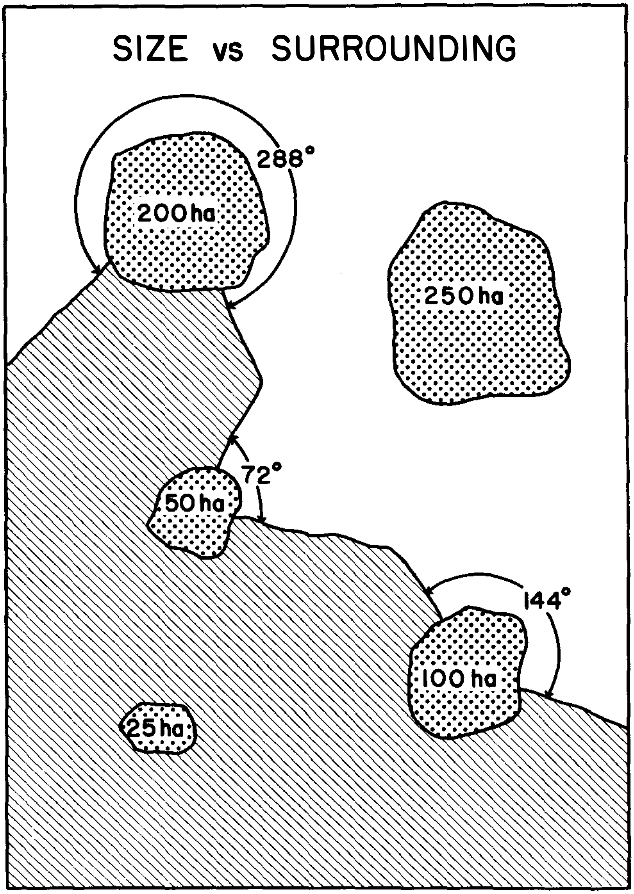


Figure 12. Inverse relation between recommended size of old-growth stands and the degree of insularity determined by surroundings.

taining old-growth stands that are interconnected by travel corridors should address the habitat requirements of old-growth wildlife species as well as the wide ranging species dependent upon several habitat types. Further research into old-growth as a habitat type as well as the characteristics of an ideal system of old-growth stands is badly needed.

Summary

Perceptions of the significance of old-growth harvesting in western Oregon and western Washington have been quite recent. While there has been a modest 5 percent reduction in commercial forest acreage, the reduction in softwood net volume, softwood sawtimber, and large diameter sawtimber has been 18 percent, 21 percent, and 34 percent, respectively. Cutting predominated on low elevation sites during early decades but has since shifted to predominantly high elevation

sites. Approximately 25 percent of the Willamette N.F. remains in old-growth. The largest old-growth Douglas-fir stand remaining in the Siuslaw N.F. is less than 1,000 acres (400 ha); the median size is 31 acres (12.5 ha), and the mean is 68 acres (27.6 ha).

Vertebrate species diversity declines inversely with elevation and yet most old-growth set-aside areas occur at high elevations. Vertebrate species diversity is high in very early and very late stages of the Douglas-fir successional sequence. This suggests that an inter-dependent system of clearcuts and old-growth stands should be interspersed throughout the managed forest. We believe habitat island size should be treated as a variable rather than a constant. Recommended size is inverse to the degree the stand is exposed to clearcuts and young stands. Long rotation management islands that buffer the old-growth stands will minimize the old-growth acreage required as set-asides.

Acknowledgements

We thank Jerry Franklin and Jack Thomas for encouraging us in this research and manuscript preparation and Robert Ethington, Director of the PNW Forest and Range Experiment Station, for his enthusiastic support. Financial support derived from the Bureau of Land Management and a University of Florida sabbatic leave. Thanks are due Charlie Phillips for help with Siuslaw N.F. data; Brian O'Kelley and Andreas Richter assisted in data analysis and graphics. Sarah Green and Bob Frenkel helped produce Figure 7. John Gordon, Rolf Anderson, Ron Saddler, Len Ruggiero, Henry Gholz, and Duane Dippon provided helpful comments on the manuscript. This is journal series contribution 3715 of the Fla. Agric. Exp. Sta., Gainesville.

Literature Cited

Adams, D. M. 1977. Impacts of national forest timber harvest scheduling policies on softwood, stumpage, lumber, and plywood markets: an econometric analysis. Res. Bull. 15. Forest Res. Lab., Oregon State Univ., Corvallis. 56 pp.

Anderson, S. H., and C. S. Robbins. 1981. Habitat size and bird community management. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:511–520.

Aney, W. W. 1967. Wildlife of the Willamette basin, present status. Basin Invest. Sect., Oregon State Game Comm., Portland. 138 pp.

Bailey, V. 1936. The mammals and life zones of Oregon. North Amer. Fauna, No. 55. USDA Bur. Biol. Surv., Washington, D.C. 416 pp.

Beuter, J. H., K. N. Johnson, and H. L. Scheurman. 1976. Timber for Oregon's tomorrow, an analysis of reasonably possible occurrences. Res. Bull. 19. Forest Res. Lab., Oregon State Univ., Corvallis. 111 pp.

Bond, R. R. 1957. Ecological distribution of breeding birds in the upland forests of southern Wisconsin. Ecol. Monogr. 27:351–384.

Brodie, J. D., R. O. McMahon, and W. H. Gavelis. 1978. Oregon's forest resources: their contribution in the state's economy. Res. Bull. 23. Forest Res. Lab., Oregon State Univ., Corvallis. 79 pp.

Burke, C. J. 1979. Historic fires in the central western Cascades, Oregon. M.S. Thesis. Oregon State Univ., Corvallis. 130 pp.

Curtis, J. T. 1956. The modification of mid-latitude grasslands and forests by man. Pages 721–736 *in* W. L. Thomas, Jr., ed. Man's role in changing the face of the earth. Univ. Chicago Press, Chicago.

Darlington, P. J., Jr. 1957. Zoogeography: the geographical distribution of animals. John Wiley and Sons, Inc., New York. 675 pp.

Edmonds, R. L., ed. 1977. Coniferous forest biome, summary of research and synthesis July 1975–1976. Coniferous Forest Biome Internal Rep. 164. College of Forest Resources, Univ. Washington, Seattle. 96 pp.

Franklin, J. F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. Gen. Tech. Rep. PNW-118. USDA For. Serv., Portland, Ore. 48 pp.

Harestad, A. S., and F. L. Bunnell. 1979. Home range and body weight—a re-evaluation. Ecology 60(2):389–402.

Harris, L. D. 1980. Forest and wildlife dynamics in the southeast. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 45:307–322.

———, and P. Kangas. 1979. Designing future landscapes from principles of form and function. Pages 725–729 *in* Our national landscape, Proceed. conf. on applied tech. for anal. and manage. of the visual resource. Gen. Tech. Rep. PSW-35. USDA For. Serv., Berkeley, Cal.

Harris, L. D., and W. R. Marion. 1981. Forest stand scheduling for wildlife in the multiple use forest. Proceed. Ann. Conf. Soc. Amer. For. P. 209–214.

Hutchison, J. M., K. E. Thompson, and J. D. Fortune, Jr. 1966. The fish and wildlife resources of the upper Willamette basin, Oregon, and their water requirements. Basin Invest. Sect., Oregon State Game Comm., Portland.

Kendeigh, S. C. 1944. Measurement of bird populations. Ecol. Monogr. 14:67–106.

Langille, H. D., F. G. Plummer, A. Dodwell, T. F. Rixon, and J. B. Leiberg. 1903. Forest conditions in the Cascade Range Forest Reserve, Oregon. Series H, For. 6, Prof. Pap. 9. USDI Geological Survey, Washington, D.C. 298 pp.

Lovejoy, T. E., and D. C. Oren. 1981. The minimum critical size of ecosystems. Pages 7–12 *in* R. L. Burgess and D. M. Sharpe, eds. Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York.

Luman, I. D., and W. A. Neitro. 1980. Preservation of mature forest seral stages to provide wildlife habitat diversity. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 45:271–277.

Maser, C., R. Anderson, K. Cromack, Jr., J. T. Williams, and R. E. Martin. 1979. Dead and down woody material. Chapt. 6 *in* J. Thomas, ed. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Agric. Handb. No. 553. USDA Forest Serv., Washington, D.C.

Maser, C., B. R. Mate, J. F. Franklin, and C. T. Dyrness. 1981. Natural history of Oregon coast mammals. Gen. Tech. Rep. PNW-133. USDA For. Serv., Portland, Ore. 496 pp.

Meslow, E. C., C. Maser, and J. Verner. 1981. Old-growth forests as wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:329–344.

Olterman, J. H., and B. J. Verts. 1972. Endangered plants and animals of Oregon. IV. Mammals. Agric. Exp. Sta. Spec. Rep. 364. Oregon State Univ., Corvallis. 47 pp.

Paulson, J. T., and G. R. Leavengood. 1977. Timber management plan, Willamette National Forest. USDA Forest Service, Region 6, Portland, Oregon. With subsequent annual updates.

Schamberger, M. L. 1970. The mammals of Mount Rainier National Park. Ph.D. Dissert. Oregon State University, Corvallis. 121 pp.

Schoen, J. W., O. C. Wallmo, and M. D. Kirchhoff. 1981. Wildlife-forest relationships: is a re-evaluation of old-growth necessary? Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:531–544.

Sirmon, J. M. In press. Management aspects of old-growth forests. *In* D. Johnson, ed. Old-growth forests, a balanced perspective. Proceed. Conf. Feb 12–14, 1982, Eugene, Ore. Univ. Oregon Bur. Gov. Res., Eugene.

Tedder, P. L. 1979. Oregon's future timber harvest: the size of things to come. J. Forest. 77:714–716.

Thomas, J. W., tech. ed. 1979. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Agric. Handb. No. 553. USDA For. Serv., Washington, D.C. 512 pp.

Thomas, J. W., R. G. Anderson, C. Maser, and E. L. Bull. 1979. Snags. Chapt. 5 *in* J. W. Thomas, ed. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Agric. Handb. No. 553. USDA For. Serv., Washington, D.C.

USDA Forest Service. 1978. Forest statistics of the U.S., 1977. Review Draft. U.S. Gov. Printing Office, Washington, D.C. 133 pp.

Weisbrod, A. R. 1976. Insulatory and mammal species number in two national parks. Pages 83–87 *in* R. M. Linn, ed. Proceed. 1st Conf. Sci. Res. in Nat. Parks. Trans. and Proc. Series 5 (2 vols). U.S. Nat. Park Serv., Washington, D.C.

Biological Control of Forest Insect Outbreaks: The Use of Avian Predators

John Y. Takekawa, Edward O. Garton, and Lisa A. Langelier
Department of Wildlife
College of Forestry, Wildlife, and Range Sciences
University of Idaho, Moscow

Biological control of destructive forest insects involves managing natural enemies of the insect to control or regulate its population below an economically significant damage level. There has recently been a growing interest in the potential of biological control as an alternative to pesticides. This shift in emphasis has resulted following recognition of deleterious side effects associated with pesticide use.

Two major problems of the continual use of pesticide are the evolution of genetically resistant strains of insects and mortality of nontarget organisms, including natural enemies (Rudd 1964, Miller and Varty 1975, Varty 1975, Comins 1979). Intensive forest management has created homogeneous environments favorable for the rapid increase and spread of insect populations (Hagen et al. 1971). The use of pesticides within these forests may prolong insect outbreaks and shorten the period between eruptions (Blais 1974, Holling et al. 1979).

Predators, parasites, and pathogens may contribute significantly to the control of pest populations (Poznanin 1956, Bruns 1960, Franz 1961, Herberg 1965, Buckner 1966, Buckner 1970, Thomas et al. 1975, Wiens 1975). Birds are known to be important predators of destructive forest insects (Table 1). Eighty percent of prey in the diet of insectivorous birds in Russian forests were classified as damaging pest species (Poznanin 1956). Additionally, birds are selective in their consumption of insects. They have been reported to select for nonparasitized individuals (Franz et al. 1955, Korl'kova 1956, Buckner and Turnock 1965, Coppel and Sloan 1971, Sloan and Simmons 1973, Schlichter 1978), and they also aid in the dispersal of viruses (Franz et al. 1955, Entwistle et al 1977a, Entwistle et al. 1977b). Thus, in many instances birds have been reported to add to natural mortality without greatly decreasing the effect of other natural enemies.

In this paper, we will show that avian predation is a desirable and feasible approach for insect pest management. Management strategies for implementing biological control will be discussed.

The Case for Biological Control

Insect populations have an innate capacity for tremendous growth within a short time period. One pair of potato beetles could produce 60 million offspring in one season, and one pair of houseflies could produce 91 trillion offspring in just five months (Henderson 1927). Therefore, effective control requires maintaining a very high level of mortality. For example, female adults of the western spruce budworm (*Choristoneura occidentalis*) produce an average of 66 female offspring (R. W. Campbell, unpubl. data). Natural mortality factors must eliminate 65 of the 66 female offspring or 98.5 percent annually to prevent population increases.

Mortality factors that control insect populations are classified as density-independent factors such as site characteristics, climate, and weather, and density-dependent factors, including natural enemies. Density-independent factors are nonregulatory because they cause a constant level of mortality over varying insect densities (Huffaker et al. 1971). Density-dependent factors may exert a regulatory pressure on a population by increasing in effectiveness as an insect increases in abundance. This type of relationship is exhibited by many natural enemies and has been termed a negative-feedback loop (Hagen et al. 1971).

Reliable biological control agents are identified by four characteristics: (1) adaptability to different environments or changing conditions, (2) an ability to search a large area, implying good mobility, (3) a large power of increase relative to the prey, and (4) other characteristics specific to the prey (Huffaker et al. 1971).

Avian predators have all of these qualities except the ability to reproduce as quickly as their prey (Morris et al. 1958). Birds are able to survive in areas without high concentrations of one particular pest insect. They may therefore be able to prevent outbreaks more readily than other natural enemies, such as parasites or pathogens, which tend to be very host-specific. Flocking species such as evening grosbeaks (*Hesperiphona vespertina*) concentrate at locations where insects are very abundant. Their intensive predation may shorten the duration of outbreaks (Blais and Parks 1964).

The regulating effect exerted by avian predators may be separated into two density-dependent responses (Solomon 1949, Holling 1959). A functional response is seen when the number of insects one bird consumes increases as the density of insects increases. A numerical response is seen when the number of predators increases as the density of insects increases. This response may be seen immediately through migration, but it is also seen after a time lag following higher reproduction or survival of young. The total response of a bird to an insect is the product of its functional and numerical responses.

Many researchers have documented the importance of avian predators in the control of destructive insects (Table 1). Songbirds may respond strongly to increases in the abundance of their prey (Morris et al. 1958, Gage et al. 1970, Koplin 1972, Morse 1978). Avian predation is very important at endemic levels, contributing at epidemic densities, and ineffectual under pandemic conditions in the control of insect pests (Thomas et al. 1975).

The effectiveness of birds at regulating forest insects at low, endemic levels has not been studied. Their potential role in preventing outbreaks remains unknown. Studies at low insect densities are lacking because the insects are extremely difficult to census with a reasonable precision. Studying avian predation at low prey density levels requires prolonged exclusion of birds from a large area to see if the frequency of outbreaks increases without birds.

Most of the evidence indicating that birds are beneficial in preventing outbreaks is indirect. Documented cases have shown that where birds are artificially increased, outbreaks have been prevented. One forested area in Germany that was supplied with nestboxes remained undamaged while adjacent lands were totally defoliated (Berlepsch 1923). Unmanaged and managed areas were obvious to distinguish in this case because an area managed for holenesting birds located 50 m (164 ft.) from the defoliation zone remained green (Appel and Schwartz 1921). In a similar study, Herberg (1960) found that, over a 33-year period, areas infested by *Bupalus piniar-*

Table 1. Avian predation on destructive insects.

Insect	Density	Stage	Avian predator(s)	% Mortality	Study
LEPIDOPTERA					
Barred red moth			tits, goldcrests	23	Gibb 1960
Barred red moth	epidemic			31	Tinbergen 1949
Black arches moth		larvae		50	Wellenstein 1959
Black-headed budworm	endemic	larvae, pupae		3–14	Gage et al. 1970
Eastern spruce budworm	epidemic	larvae		13–39	Tothill 1923
Eastern spruce budworm	epidemic	larvae		4.3	Kendeigh 1947
Eastern spruce budworm	pandemic	larvae	vireos, fringellids, chickadees	3.5–7.0	George & Mitchell 1948
Eastern spruce budworm	epidemic	larvae		37–45	Dowden et al. 1953
Eastern spruce budworm		larvae	warblers, kinglets, juncos	1.0–6.3	Morse 1978
Jack pine budworm	endemic	larvae, pupae		40–65	Mattson et al. 1968
Jack pine budworm		larvae	chipping sparrow	3.3	Simmons 1968
Western spruce budworm	epidemic	larvae, pupae	evening grosbeak, siskins, crossbills	49–87	Campbell & Torgersen 1982
Codling moth		larvae		27–93	LeRoux 1959
Codling moth		larvae		55–82	Mailloux & LeRoux 1960
Codling moth			woodpeckers	50	MacLellan & McPhee 1971
Codling moth		larvae, pupae	silvereye	53	Wearing 1975
Codling moth	endemic	larvae		95	Solomon et al. 1976
Codling moth		larvae	tits	66	Solomon & Glen 1979
Codling moth		winter larvae	blue tits	95	Glen et al. 1981
Corn earworm & fall armyworm		larvae	starlings	100	Stewart 1973

Table 1. Avian predation on destructive insects. (cont'd.)

Insect	Density	Stage	Avian predator(s)	% Mortality	Study
Douglas-fir tussock moth		larvae, pupae, eggs	nuthatches, chickadees, juncos	19, 19–49, 3–30	Torgersen & Dahlsten 1978
Douglas-fir tussock moth		eggs	mountain chickadee	16.7–71.7	Dahlsten & Copper 1979
Earworms				68	Barber 1942
European corn borer		larvae	grackles, blackbirds, starlings	12–84	Barber 1925
European and Southwestern corn borer		winter larvae		60	Wall & Whitcomb 1964
Southwestern corn borer		winter larvae	flicker	98.3	Floyd et al. 1969
Southerwestern corn borer	epidemic	winter larvae	flicker	64–82	Black et al. 1971
Larch budmoth		larvae	juneo, redpolls, chickadees	3–10	Werner 1980
Larch casebearer	endemic	winter cocoons	warblers, kinglets, chickadees	23.5	Sloan & Coppel 1968
Lodgepole needle-miner		larvae	evening grosbeak (only)	10	Dahlsten & Herman 1965
Gypsy moth		pupae	vertebrates	70	Campbell & Sloan 1976
Gypsy moth		larvae		0.4–1.1	Inozemtsev et al. 1980
Gypsy moth & tortrix viridana		larvae	4–10 nestboxes/ha	47.3–80.2	Strokov 1956
Tortrix virdana and Cacoecia crataegana		larvae	without-with nestboxes	1–2.5	Inozemtsev 1976
Pine beauty moth	epidemic		tits, goldcrests	24–34	Gibb 1960
Pine beauty moth	epidemic			32–49	Tinbergen 1949
Pine looper	epidemic		tits, goldcrests	10	Gibb 1960
Pine looper	epidemic			13	Tinbergen 1949
Pine Noctuida		larvae		2.7	Gerasimova & Unterberger 1956
Potato moth	endemic	larvae	western silvereye	66	Springett & Matthiessen 1975

Tobacco hornworm	experiment	larvae	house sparrow	100	Stewart 1969
Tobacco hornworm		larvae		58.5–100	Thurston & Pracherabmoh 1971
Tobacco insects		larvae	crows, gackles, bluebirds	47–56	Stewart 1975
Fall webworm		adults		98	Keve and Reichart 1960
White butterfly			tree sparrow, whitethroats	10–20	Roer 1957
White butterfly				3.7–8.9	Ashby & Pottinger 1974
Winter moth		larvae, female adults	titmice	0.3–2.6, 20	Betts 1955
Lepidoptera		larvae		18–63	Holmes et al. 1979
Lepidoptera		larvae		35–40	Tinbergen 1960
COLEOPTERA					
Ash borer			woodpeckers	67–81	Solomon 1975
Living beech borer		larvae	woodpeckers	39	Solomon 1969
Oak branch borer			woodpeckers	65	Solomon 1977
Poplar borer				12	Tichy 1963
Poplar borer		larvae	woodpeckers	13–65	Solomon 1969
White oak borer			woodpeckers	32	Solomon 1969
Grass grub	epidemic	larvae	starling	40–60	East & Pottinger 1975
Grass grub		larvae	starlings and gulls	8	McLennan & Pottinger 1976
Southern pine beetle			downy woodpecker	5–50	Moore 1972
Southern pine beetle			woodpeckers - summer/winter	12–30, 36–63	Kroll & Fleet 1979
Spruce beetle			woodpeckers - 3 species	45–98	Knight 1958
Spruce beetle	endemic	larvae, beetles	woodpecker	20–29	Koplin & Baldwin 1970
Spruce beetle		larvae, beetles	N. 3-toed and hairy woodpecker	52–83	Shook & Baldwin 1970
Spruce beetle		larvae, beetles	N. 3-toed and downy woodpecker	19–55	Koplin 1972
Spruce beetle	epidemic	larvae, beetles	woodpeckers	24–98	McCambridge & Knight 1972
Western pine beetle			woodpeckers	32	Otvos 1965
Western pine beetle			all but woodpeckers	8–26	Otvos 1970

Table 1. Avian predation on destructive insects.

Insect	Density	Stage	Avian predator(s)	% Mortality	Study
Pine weevil		larvae, pupae	woodpeckers	≤90	Voute 1951
Weevil		larvae, pupae	woodpeckers	95	Voute 1951
OTHER					
Sycamore aphid	endemic	adults	house sparrows	25–69	Dixon 1976
Eucosmid moth		winter larvae	blue & coal tits	50	Gibb 1966
Jumping plant louse		nymphs, adults		≤77	Clark 1964
Fox-colored sawfly			tits, goldcrest	3	Gibb 1960
Fox-colored sawfly				4	Tinbergen 1949
Pine sawfly	endemic	winter cocoons		95	Coppel & Sloan 1971
Sawfly			tits, goldcrest	18	Gibb 1960
Sawfly				24	Tinbergen 1949
Ticks			redbilled oxpecker	95.7	Bezuidenhout & Statterheim 1980

ius and managed with nest boxes did not reach epidemic levels while nearby areas required treatment with insecticide.

Birds have been known to eliminate a destructive insect population in localized outbreak areas. Several cases of localized control have been reported in Europe (Shevrynev 1892, Averin and Shevehenko 1941, Bublik 1954, Bruns 1960, Luhl and Watzek 1976). In North American literature, early work by McAtee (1927) documented the destruction of forest tent caterpillars (*Malacosoma disstria*) by 36 species of birds. Control was also obtained in a 243-hectare (600-acre) outbreak of jack-pine budworm (*Choristoneura pinus*) by several species (Mattson et al. 1968), and by robins (*Turdus migratorius*) on Indian wax scales (*Ceroplastis ceriferus*) infesting holly (Davidson 1975).

Feasibility of Biological Control

There are 1,425 species of pest insects in the United States and Canada. Successful biological control has been reported for 70 of these species. Huffaker et al. (1971) stated that this record is remarkable considering the low level of support biological control research receives in North America. The benefits of a successful biological control program can be enormous. In one documented case, introduction of parasites of the coconut scale (*Aspidiotus destructor*) on the Island of Principe resulted in savings of $2 million over a 10-year period (Huffaker et al. 1971). This represented a 200-fold return in 10 years, after an initial investment of $10,000.

The economic value of bird predation on destructive insects of forest and agricultural lands in the United States was assessed as early as 1921 by Forbush. He concluded that birds reduced insect damage by 28 percent at that time, a savings of $444 million in crop and timber losses.

The value of effective biological control may be considerable over a long time period. Pesticides, on the other hand, may bring about temporary population reductions but do not regulate insect outbreaks. The use of insecticides may prolong outbreaks and/or shorten the time between outbreaks (Holling et al. 1979, Blais 1974). Management with pesticides may require repeated insecticide applications.

Western spruce budworm have been a problem in the Pacific Northwest since the 1940s. Budworm defoliate economically valuable Douglas-fir (*Pseudotsuga menziesii*), true firs (*Abies* spp.), and spruce (*Picea* spp.). In Oregon and Washington, 5.5 million acres (2.2 million ha) were sprayed to control the budworm between 1949–1979 at a cost of $9 million (Dolph 1980). DDT was sprayed on 4.7 million acres (1.9 million ha) between 1949–1962 at a cost of approximately one dollar per acre. Recent control programs utilizing short-lived insecticides have become much more costly. The last widescale project in Washington cost $7.77 per acre (Dolph 1980).

The most effective insecticide used on the budworm (Sevin-4-Oil) decreases larval densities by 80 percent when other mortality factors are not considered (Mounts et al. 1978). In comparison, avian predators of western spruce budworm cause 72 percent of the mortality on larvae and pupae (Campbell and Torgerson 1982). Based on a cost-benefit analysis of the northern Washington area (USFS 1977a), the effect that avian predators have on the budworm is worth a minimum of $3770 per square mile in an outbreak year (Takekawa and Garton 1982). This figure does not include the potential benefits birds contribute in preventing insect outbreaks, a value which may be extremely high.

Managing Avian Predators

The Europeans have used birds to control destructive forest insects for hundreds of years (Henderson 1927, Otvos 1979). Forest birds have been legally protected since the early 1300s (Boesenberg 1970). In North America, there are 640 species of breeding birds. Of these species, 283 forage in forested areas and consume insects in 10 percent or more of their diet (Jackson 1979). Management of these species is possible through habitat alteration or through provision of specific habitat requirements.

Cutting Practices

Habitat alteration to increase bird densities is possible through silvicultural methods, snag management, and understory treatment. Cutting practices such as thinning or selective logging may be chosen to increase avian predation on defoliators by maximizing the biomass of predators relative to the volume of foliage available for the insect. Franzreb and Omhart (1978) found that selection harvesting in Arizona that did not change foliage height diversity resulted in an increase in the number of birds per unit of foliage.

Thomas (1979) presented the habitat preferences of birds in the Pacific Northwest in a format that qualitatively relates the effect of forest manipulations on bird populations. In upland spruce-fir stands, Crawford and Titterington (1979) observed bird populations along a continuum of several treatments. They concluded that bird densities were dependent upon the mix of hardwoods and softwoods, and vertical and horizontal structure of the stand, and the level of insect outbreak.

Webb et al. (1977) determined which bird species were affected by different cutting practices in hardwood forests. Garton et al. (1981) are determining how silvicultural treatments change the abundance of avian predators on western spruce budworm.

These papers and others suggest that cutting guidelines could be implemented to encourage avian predators of destructive forest insects, especially in areas where insects are a chronic problem. The most economically feasible way to manage for avian predators is based on a favorable cost-benefit analysis. The expense of applying a certain cutting practice should be offset by the benefit derived from additional avian predation.

Snag Management

The benefit of leaving snags for cavity nesting birds has been well-documented (Thomas et al. 1975, McClelland and Frissell 1975, Scott et al. 1977, Scott 1979, McClelland 1979). In North America, 85 species use cavities, and the majority of these birds are insectivorous (Scott et al. 1977). Forest Service snag policy recognizes the value of leaving snags for birds and recommends that snags and other forest components beneficial to wildlife should be retained (USFS 1977b).

Woodpeckers (Picidae) are primary snag users and are known to contribute significantly to the mortality of Coleopteran adults and larvae (Knight 1958, Otvos

1965, 1970, Koplin and Baldwin 1970, Shook and Baldwin 1970, Koplin 1972, McCambridge and Knight 1972, Moore 1972, Kroll and Fleet 1979). Snag management is essential to maintain populations of these valuable predators since they do not seem to respond to nest boxes.

Undergrowth Management

Habitat conditions for desired bird species may be enhanced by altering the understory of a forest. Kilgore (1971) reported that clearing and prescribed burning of understory brush and saplings in Sequoia forests changed the species composition of the bird community but not total biomass. Bock and Lynch (1970) found greater numbers of species on burned plots when compared to unburned plots. Brush-ground feeders and granivorous species were more abundant in burned areas, while foliage-searching birds predominated in unburned areas.

Our observations in Pacific Northwest forests over the past three years suggest that the understory layer may be one of the most important components determining avian predator numbers. Most birds select patchy habitats with well-developed shrub layers (DeLoach 1970, Thomas et al 1978). The importance of stand structure on predator effectiveness was demonstrated for woodpeckers (Shook and Baldwin 1970). Woodpecker predation on spruce beetle (*Dedroctonus engelmannii*) ranged from 71 percent in open areas to 83 percent in semi-open areas, and to 52 percent in densely stocked areas where insect densities were the same.

These studies suggest that understory management in insect-damaged areas should maintain a semi-open canopy where openings are interspersed to promote a good shrub layer. Our research on avian predators of the budworm seems to support this contention.

Nestboxes

Outside of a few research plots (Dahlsten and Herman 1965, Dahlsten and Copper 1979), there are few cases in North America where manipulations have been used to encourage avian predators of insects. Manipulations are widely used to increase bird densities in European forests (Henderson 1927, von Haartman 1956, Bruns 1960, Franz 1961, Campbell 1968, McFarlane 1976, Otvos 1979). The most commonly used management practice is to erect nest boxes to attract insectivorous holenesting species. Thomas et al. (1975) reported that 400,000 nest boxes are in use in western European forests and 300,000 are established in Spain where management favors *Parus, Certhia,* and *Sitta* species (Ceballos 1968).

Pfeifer (1963) reported 6- and 25-fold increases in numbers of adult birds on sites where nest boxes, nest pockets, bundles, and branch piles were added. A 22-year study conducted in Czechoslovakia (Tichy 1967) tested several nesting treatments in a pine stand with poor site conditions. Two experimental stands were censused initially from 1955 through 1957. In 1957, nest boxes were supplied at densities of 5 and 7 boxes per hectare. Bird densities increased 4 and 5 times in the first year of management. In subsequent years, other techniques were applied, resulting in a 19-fold increase from 1955–1966. One surprising aspect of the study was an increase in species diversity. Nestboxes increased diversity 2.5 times while the other manipulations caused a 5-fold increase. By 1966, the number of species had increased 8 times above the initial level.

A study in Russia by Pyl'tisina (1956) showed that when nest boxes were provided, Lepidopteran larval densities decreased 9.5 and 4 times, far greater than adjacent control plots, which declined 4 and 2.5 times. On plots with *Ocneria dispar* and *Tortrix viridana* outbreaks, densities of 4 nestboxes per hectare resulted in avian control of 47.3 percent. Where 10 nests were supplied per hectare, birds accounted for 80.2 percent and strongly contributed to control the outbreak. Further studies on *T. viridana* indicated that avian-caused mortality increased from 1.9 percent without nest boxes to 54 percent with 10 boxes per hectare, 98.1 percent with 15 boxes per hectare, and 99.2 percent mortality with 20 artificial nests per hectare.

Strokov (1956) found that 12–18 nests per hectare was the most efficient nest density to use when the habitat was poor. At higher bird densities, it was possible to use only 5 nests per hectare to achieve the same result. They also found that gourds could be used effectively as artificial nests in place of wood or concrete-and-sawdust boxes at one-third the cost.

Other Methods

Our studies on avian predators of the western spruce budworm in the Pacific Northwest have identified flocking species such as the evening grosbeak (*Hesperiphona vespertina*), pine siskin (*Pinus spinus*), and red crossbill (*Loxia curvirostra*) as the most important avian predators at low epidemic levels. The 283 insectivorous species in North America are 70 percent migrant and 30 percent resident, and only 23 percent nest in cavities while 42 percent nest on the ground. Sixty-seven percent of these birds forage on shrubs, 55 percent forage on trees, and 28 percent are flycatchers. This suggests that other avian species beside holenesters may be important biological control agents in North American forests.

Studies in Russia and Czechoslovakia have shown that other manipulations may be effective in increasing the densities of forest birds. Ground-nesting birds were studied in Russian forests by Titaeva (1956). Thorough investigations were made of 170 nests, identifying variables associated with the nesting area, the microsite, and the nesting spots. He found that certain microsites on the ground were used repeatedly by the same types of birds, and shrub-nesting species selected the same type of tree or bush. Nest sites were created by trimming bushes to create branch clusters and by setting out artificial bifurcations of 2–3 bound branches. Nest platforms were also provided for *Turdus* spp. The greatest success resulted from trimming thickets to create nest sites in areas where the thickets were interspersed with open glades. A similar study by Tichy (1967) showed that adding pine pockets and bundles, managing undergrowth, binding brush thickets, and supplementing winter foods resulted in 4- and 5-fold increases in species inhabiting a pine woods.

Transplant studies have shown that birds can be transferred to areas of insect infestations with good results. Different techniques that have been tried include releasing adults (Treus and Uspenskii 1956), releasing nestlings (Schcerbakov 1956), and releasing nestlings with adults at a ratio of 10:2 (Polivarov 1956). These researchers concluded that transporting adult birds early in the breeding season to areas managed with nest boxes resulted in the best holenester increases (Poznanin 1956).

Other potential methods to enhance birds are feasible. Williams and Koenig

(1980) studied the water dependence of birds and suggested that the local distribution of some species may be limited by the availability of water. Water was especially important for birds inhabiting mesic areas where seasonal droughts occurred. Open water sources were used by 24 of 45 species and almost all granivorous bird species used them frequently. Granivorous species made up the majority of the avian predators that we studied consuming budworm. Their water dependence may allow management of their densities by supplying water sources.

During our first two field seasons (1979–80), we noticed a 10-fold increase in birds misnetted near a log that had been salted to attract game animals. Bird species depend on the availability of trace elements in their diet and sodium may be limiting in some cases. Studies by Lawrence (1980) and Dennis (1975) on birds attracted to feeders point out that many granivorous birds are highly attracted by crystalline salt. Supplying salt for birds may be one means of attracting flocking birds to potential outbreak areas.

Discussion

European forest managers have long used manipulations and management practices to increase avian predation on forest insects. Very little effort has been directed at songbird management in North America. The discrepancy between the two continents is puzzling.

European forests are largely in private ownership and are much more intensively managed than are North American forests. This suggests that in Europe, management for birds may simply replace species lost through intensive forest management. However, studies in North America have shown that nest box manipulations can increase bird densities (Dahlsten and Herman 1965, Dahlsten and Copper 1979). Perhaps it is more important to note that most chemical insecticide manufacturers are based in the United States and thus, management with insecticides has been strongly encouraged in this country.

Objective evaluation of biological control management must weigh the benefit of using birds against the costs of increasing avian densities over a long period. Simulation modeling may be used to imitate the growth of stands subject to periodic pest outbreaks. The difference between predicted yields with and without birds could be used to evaluate the economic worth of avian predation.

Recent budworm studies suggest that certain small areas having favorable microclimates may harbor pockets of the budworm. These populations increase to pandemic levels when favorable conditions allow rapid population growth (Wellington 1981, Long 1981). If these centers are responsible for outbreaks, biological control management may be applied very efficiently in small areas to achieve population regulation over extensive regions.

Acknowledgements

We wish to acknowledge the U.S. Forest Service Western Spruce Budworm Program (CANUSA) for funding support and Dr. Winifred B. Kessler for editing the manuscript.

References Cited

Appel, O., and M. Schwartz. 1921. Die bedeutung des vogelschutzes fur den pflanzenschutz. NachcB1. dtsch. Pfl SchDienst, Berl. 1:49–50.

Ashby, J. N., and R. P. Pottinger. 1974. Natural regulation of *Pieris rapae* Linnaeus (Lepidoptera: Pieridae) in Canterbury, New Zealand. N. Z. J. of Agr. Res. 17:229–239.
Averin, V. G., and V. Shevehenko. 1941 . O meropriyatiyakh po obogashcheniyu sveklovichnykh polei poleznoi dikoi plitsei, Kharkov, 1941.
Barber, G.W. 1925. The efficiency of birds in destroying overwintering larvae of the European corn borer in New England. Psyche 32:30–46.
______. 1942. Control of earworms in corn by birds. J. Econ. Entomol. 35:511–513.
Berlepsch, H. 1923. Der gesamte volgelschutz, Neudamm 10. Aufl. 301S.
Betts, M. M. 1955. The food of titmice in oak woodlands. J. Anim. Ecol. 24:282–323.
Bezuidenhout, J. D., and C. J. Stutterheim. 1980. A critical evaluation of the role played by the red-billed oxpecker *Buphagus erythrorhynchus* in the biological control of ticks. Onderstepoort J. of Veterinary Res. 47:51–75.
Black, E. R., F. M. Davis, and C. A. Henderson. 1971. The flicker and the southwestern corn borer in Mississippi. Proc. Tall Timbers Conf. Ecol. 2:285–292.
Blais, J. R. 1974. The policy of keeping trees alive via spray operations may hasten the recurrence of spruce budworm. For. Chron. 50(1):19–21.
______, and G. H. Parks. 1964. Interaction of evening grosbeak (*Hesperiphona vespertina*) and the spruce budworm (*Choristoneura fumiferana* (Clem.)) in a localized budworm outbreak treated with DDT in Quebec. Can. J. Zool. 42:1017–1024.
Bock, C. E., and J. F. Lynch. 1970. Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. Condor 72:182–189.
Boesenberg, K. 1970. Deutsche akademie der landwirt-schaftswissenschaft (Tagungsberichte) 110:71.
Bruns, H. 1960. The economic importance of birds in the forest. Bird Study 7(4):193–208.
Bublik, G.P. 1954. Ptitsy-druz'ya sada. Sad i Ogorod No. 2.
Buckner, C. H. 1966. The role of vertebrate predators in the biological control of insects. Ann. Rev. Entomol. 11:470–499.
______. 1970. The role of vertebrates in the integrated approach to control. USDA Forest Service Insect and Dis. Lab., Hamden, Conn.
Buckner, C. H., and W. J. Turnock. 1965. Avian predation on the larch sawfly, *Pristiphora erichsonii* (Htg.), *(Hymenoptera: Tenthredinidae)*. Ecology 46:223–236.
Campbell, B. 1968. The Dean nestbox study, 1942–1964. Forestry 41:27–28.
Campbell, R. W., and R. J. Sloan. 1976. Influence of behavioral evolution on gypsy moth pupal survival in sparse populations. Environ. Entomol. 5(6):1211–1217.
______, and T. R. Torgersen. 1982. Compensatory mortality in defoliator population dynamics. Environ. Entomol. (In press).
Ceballos, P. 1968. Proteccion de aves insectivoras. Boletin Servicio Plagas Forestales 115:79–85.
Clark, L. 1964. Predation by birds in relation to the population density of *Cardiaspina albitextura*. Austr. J. Zool. 12:349–361.
Comins, H. N. 1979. The control of adaptable pests. Pages 217–225 *in* G.A. Norton and C. S. Holling, eds. Pest Management, Pergamon Press, N.Y.
Coppel, M., and N. Sloan. 1971. Avian predation, an important adjunct in the suppression of larch casebearer and introduced pine sawfly populations in Wisconsin forests. Proc. Tall Timbers Conf. on Ecol. 2:259–272.
Crawford, H. S., and R. W. Titterington. 1979. Effects of silvicultural practices on bird communities in upland spruce-fir stands. Pages 110–119 *in* Proc. of Symp. Management of Northcentral and Northeastern Forest Nongame Birds. USDA For. Serv., Amherst, Mass. 268 pp.
Dahlsten, D. L., and W. A. Copper 1979. The use of nesting boxes to study the biology of the mountain chickadee (*Parus gambeli*), and its impact on selected forest insects. Pages 217-260 *in* J. G. Dickson, R. N. Conner, R. R. Fleet, J. C. Kroll, and J. A. Jackson, eds. The role of insectivorous birds in forest ecosystems. Academic Press, N.Y. 381 pp.
Dahlsten, D. L., and S. G. Herman. 1965. Birds as predators of destructive forest insects. California Agric. (Sept.):8–10.
Davidson, J. A. 1975. A report of Indian wax scale controlled by birds. Proc. Entomol. Soc. Wash. 77(1):165.

DeLoach, C. J. 1970. The effect of habitat diversity on predation. Proc. Tall Timb. Conf. on Ecol. 2:223–242.

Dennis, J. V. 1975. A complete guide to bird feeding. Alfred A. Knopf, N.Y. 286pp.

Dixon, A. F. G. 1976. Timing of egg hatch and viability of the sycamore aphid *Drepanosephrem plantanoides* at bud burst of sycamore *Acer pseudoplatanus*. J. Anim. Ecol. 45(2):593–603.

Dolph, R. E. 1980. Budworm activity in Oregon and Washington 1947–1979. (R6-FIDM-033-1980). USDA Forest Service, Pacific Northwest Region, Portland, Ore. 54pp.

Dowden, P., H. Jaynes, and V. Carolin. 1953. The role of birds in a spruce budworm outbreak in Maine. J. Econ. Entomol. 46:307–312.

East, R., and R. P. Pottinger. 1975. Starling (*Sturnus vulgaris* L.) predation on grass grub (*Costelytra zealandica* (White), Melolonhinae) populations in Canterbury. N.Z. J. of Agr. Res. 18:417–452.

Entwistle, P., P. Adams, and H. Evans. 1977a. Epizootiology of a nuclear polyhedrosis virus in European spruce sawfly (*Gilpinia hercyniae*): The status of birds as dispersal agents of the virus during the larva season. J. Invert. Path. 29:354–360.

———. 1977b. Epizootiology of a nuclear polyhedrosis virus in European spruce sawfly (*Gilpinia hercyniae*): Birds as dispersal agents of the virus during winter. J. Invert. Path. 30(1):15–19

Floyd, E. H., L. Mason, and S. Phillips. 1969. Survival of overwintering southwestern corn borers in corn stalks in Louisiana. J. Econ. Entomol. 62:1016–1019.

Forbush, E. H. 1921. The utility of birds. Bull. No. 9. Mass. Dep. of Agr., Boston. 83pp.

Franz, J. M. 1961. Biological control of pest insects in Europe. Ann. Rev. Entomol. 6:183–200.

Franz, J. M., A. Krieg, and R. Langenbuch. 1955. (n.t.). Viren. Z. Pfl. Ban. 62:724ff.

Franzreb, K. E., and R. D. Omhart. 1978. The effects of timber harvesting on breeding birds in a mixed-coniferous forest. Condor 80:431–441.

Gage, S. H., C. A. Miller, and L. J. Mook. 1970. The feeding response of some forest birds to the black-headed budworm. Can. J. Zool. 48:359–366.

Garton, E. O., J. Y. Takekawa, and L. A. Langelier. 1981. Impact and management of vertebrate predation on western spruce budworm. Proposal to Canada/U.S. Spruce Budworm Project West. 78pp. (Unpubl.).

George, J. L., and R. T. Mitchell. 1948. Calculations on the extent of spruce budworm control by insectivorous birds. J. Forestry 46:454–455.

Gerasimova, T. O., and V. K. Unterberger. 1956. Experiments on the attraction of insectivorous birds to pine groves and a study of their feeding habits. Pages 49–54 *in* L. P. Poznanin, ed. Ways and means of using birds in combating noxious insects. USDC. Israel program for scientific translations. 138pp.

Gibb, J. A. 1960. Populations of tits and goldcrests and their food supply in pine plantations. Ibis 102:163–208.

———. 1966. Tit predation and the abundance of *Ernarmonia conicolana* (Heyl.) on Weeting Health, Norfolk, 1962–3. J. Anim. Ecol. 35:43f.f.

Glen, D. M., N. F. Milson, and C. W. Wiltshire. 1981. The effect of predation by blue-tits (*Parus caeruleus*) on the sex-ratio of codling moth (*Cydia pomonella*). J. Appl. Ecol. 18:133–140.

Hagen, K. S., R. van den Bosch, and D. L. Dahlsten. 1971. The importance of natually-occurring biological control in the western United States. Pages 253–293 *in* C. B. Huffaker, ed. Biological control. Plenum Press, N.Y. 511pp.

Henderson, J. 1927. The practical value of birds. Macmillan Company, N.Y. 342pp.

Herberg, M. 1960. Drei Jahrzehnte vogelhege zur neiderhaltung waldschadlicher insekten durch die ansiedlung von hohlenbrutern. Archiv fur Forstwesen 9(1):1015–1047.

Herberg, M. 1965. Bird protection for control of injurious insects and its results. Anz-Schadlingk 38pt. 9pp.(Summary in Rev. Appl. Entomol. 55: 495. 1967).

Holling, C. S. 1959. The components of predation as revealed by a study of small mammal predation of the European pine sawfly. Can. Entomol. 91:293–320.

Holling, C. S., D. D. Jones, and W. C. Clark. 1979. Ecological policy design: a case study of forest and pest management. Pages 13–90 *in* G. A. Norton and C. S. Holling, eds. Pest management. Pergamon Press, N.Y.

Holmes, R. T., J. C. Schultz, and P. Nothnagle. 1979. Bird predation on forest insects: an exclosure experiment. Science 206:462–463.

Huffaker, C. B., P. S. Messenger, and Paul DeBach. 1971. The natural enemy component in natural control and the theory of biological control. Pages 16–67 *in* C. B. Huffaker, ed. Biological Control. Plenum Press, N.Y. 511pp.

Inozemtsev, A. A. 1976. The dynamics of the trophic links of forest insectivorous birds and their significance in invertebrate population density control. Zh. Obshch. Biol. 37(2):192–204.

———, S. A. Ezhova, S. L. Pereshkol'nik, and C. L. Frenkina. 1980. Evaluation of the total effect of insectivorous birds on invertebrates in an oak-hornbeam forest. Ekologiya 1:65–75.

Jackson, J. A. 1979. Insectivorous birds and North American forest ecosystems. Pages 1–7 *in* J. G. Dickson, R. N. Conner, R. R. Fleet, J. C. Kroll, and J. A. Jackson, eds. The role of insectivorous birds in forest ecosystems. Academic Press, N.Y. 381pp.

Kendeigh, S. C. 1947. Bird population studies in the coniferous forest biome during a spruce budworm outbreak. Biol. Bull. Ontario Dep. Lands and Forests, Maple. No. 1.

Keve, A., and G. Reichart. 1960. Die rolle der vogel bei der abrwhr des amerikanischen barenspinners. Falke 7:20–26.

Kilgore, B. M. 1971. Reponses of breeding bird populations to habitat changes in a giant sequoia forest. Amer. Midl. Natur. 85:135–152.

Knight, F. B. 1958. The effects of woodpeckers on populations of the Engelmann spruce beetle. J. Econ. Entomol. 51:603–607.

Koplin, J. 1972. Measuring impact of woodpeckers on spruce beetles. J. Wildl. Manage. 36:308–319.

———, and P. Baldwin. 1970. Woodpecker predation on an endemic population of Engelmann spruce beetles. Amer. Midl. Natur. 83:510–515.

Korol'Kova, G. E. 1956. Studies of the action of insectivorous birds on mass pests in oak forests. Page 55 *in* L. P. Poznanin, ed. Ways and means of using birds in combatting noxious insects. Ministry of Agriculture of USSR, Moscow. 138 pp.

Kroll, J. C., and R. R. Fleet. 1979. Impact of Woodpecker predation on overwintering within-tree populations of the southern pine beetle (*Dendroctonus frontalis*). Pages 269–282 *in* J. G. Dickson, R. N. Conner, R. R. Fleet, insectivorous birds in forest ecosystems. Academic Press, N.Y. 381pp.

Lawrence, L. 1980. To whom the wilderness speaks. McGraw-Hill, Toronto. 180pp.

LeRoux, E. J. 1959. Importance and control of the codling moth, *Carpocapsa pomonella*(L.) (Lepidoptera:Tortricidae), on apple in Quebec. Rep. pomol. Fruit Grow. Soc. Quebec 1959:45–60.

Long, G. 1981. Dispersal. Presentation at the Western Spurce Budworm Conference, 1981. Portland, Ore.

Luhl, V. R., and G. Watzek. 1976. Die wirkung von hohlenbrutenden kleinvogeln auf kunstlich ausgebrachte schadlicher forst insekten. Allgemeine Forst und Jagdzeitung 147(6–7):113–115.

MacLellan, C. R., and A. W. MacPhee. 1971. Cases of naturally-occurring biological control in Canada. Pages 312–328 *in* C. B. Huffaker, ed. Biological control. Plenum Press, N.Y. 511pp.

Mailloux, M., and E. J. LeRoux. 1960. Further observations on the life-history and habits of the codling moth (*Carpocapsa pommonella* (L.) Lepidoptera:Tortricidae), in apple orchards of southwestern Quebec. Rep. pomol. Fruit Grow. Soc. Quebec 1960:45–56.

Mattson, W. J., F. B. Knight, D. C. Allen, and J. L. Foltz. 1968. Vertebrate predation on the jack-pine budworm in Michigan. J. Econ. Enomol. 61:229–234.

McAtee, W. 1927. The relation of birds to woodlots in New York State. Roosevelt Wildl. Bull. 4:7–152.

McCambridge, W., and F. Knight. 1972. Factors affecting spruce, beetles during a small outbreak. Ecology 53:830–839.

McClelland, B. R. 1979. The pileated woodpecker in forests of the northern Rocky Mountains. Pages 283–299 *in* J. G. Dickson, R. N. Conner, R. R. Fleet, J. C. Kroll, and J. A. Jackson, eds. The role of insectivorous birds in forest ecosystems. Academic Press, N.Y. 381pp.

______, and S. S. Frissell. 1975. Identifying forest snags useful for nesting birds. J. For. 73:414–417.

Miller, C. A., and I. W. Varty. 1975. Biological methods of spruce budworm control. For. Chron. 51(4):150–152.

McFarlane, R. W. 1976. Birds as agents of biological control. The Biologist 58(1):123–140.

McLennan, J. A. and R. P. Pottinger. 1976. Mortality of grass grub *Costelytra zealandica* and earthworms Lumbricidae during autumn cultivation. N. Z. J. Agric. Res. 19(2):257–263.

Moore, G. 1972. Southern pine beetle mortality in North Carolina caused by parasites and predators. Environ. Entomol. 1:58–65.

Morris, R. F., W. F. Cheshire, C. A. Miller, and D. G. Mott. 1958. The numerical response of avian and mammalian predators during a gradation of the spruce budworm. Ecology 39:487–494.

Morse, D. H. 1978. Populations of bay-breasted and Cape May warblers during an outbreak of the spruce budworm. Wilson Bull. 90(3):404–413.

Mounts, J., R. E. Dolph, D. McComb, and T. F. Gregg. 1978. 1977 Western Spruce Budworm Control Program. USDA, U.S. Forest Service, Portland, Ore. 33pp.

Otvos, I. 1965. Studies on avian predators of *Dendroctonus brevicomis* LeConte (Coleoptera: Scolytidae) with special reference to Picidae. Can. Entomol. 97:1184–1199.

______. 1970. Avian predation of the western pine beetle, Pages 119–127 *in* C. R. Stark and D. L. Dahlsten, eds. Studies on the population dynamics of the western pine beetle. Univ. Calif., Div. of Agric. Sciences, Davis.

______. 1979. The effects of insectivorous bird activities in forest ecosystems: an evaluation. Pages 341–374 *in* J. G. Dickson, R. N. Conner, R. R. Fleet, J. C. Kroll, and J. A. Jackson, eds. The role of insectivorous birds in forest ecosystems. Academic Press, N.Y. 381pp.

Pfeifer, S. 1963. Dichte und Dynamik von Brutpopulationen zweier deutscher Waldgebiete 1949–1961. Proc. XIII Int. Ornithol. Congr.: 754–765.

Polivarov; V. M. 1956. An experiment on the mass transfer of the flycatcher (*Muscicapa hypoleuca*) in steppe oak groves. Pages 111–112 *in* P. L. Poznanin ed. Ways and means of using birds in combating noxious insects. USDC, Israel program for scientific translations. 138pp.

Poznanin, L. P., ed. 1956. Ways and means of using birds in combating noxious insects. USDC, Israel program for scientific translations. 138pp.

Pyl'tsina, L. M. 1956. Action of attacted birds on the population of harmful insects. Pages 56–58 *in* L. P. Poznanin, ed. Ways and means of using birds in combating noxious insects. USDC, Israel program for scientific translations. 138pp.

Roer, H. 1957. Tagschmetterlinge als vorzugsnahrung einiger singvogel. J. Orn. Lpz. 98:416–420.

Rudd, R. L. 1964. Pesticides and the living landscape . Univ. of Wisconsin Press, Madison. 320pp.

Schcerbakov, I. D. 1956. Requirements of the flycatcher (*Muscicapa hypoleuca*) and the great titmouse as to nesting areas and artificial nests. Pages 64–73 *in* P. L. Poznanin, ed. Ways and means of using birds in combating noxious insects. USDC, Israel program for scientific translations. 138pp.

Schlichter, L. 1978. Winter predation by black-capped chickadees and downy woodpeckers on inhabitants of the goldenrod ball gall. Can. Field. Natur. 92(1):71–74.

Scott, V. E. 1979. Bird response to snag removal in Ponderosa pine. J. For. 77(1):26–28.

______, K. E. Evans, D. R. Patton, and C. P. Stone. 1977. Cavity-nesting birds of North American forests. Agric. Handbook 511. USDA, Forest Service Washington, D.C. 112pp.

Shevryrev, I. Y. 1892. Nasekomoyadnye ptitsy i oblesenie stepei. Sel'skoe Khozyaistvo i Lesovodstvo.

Shook, R., and P. Baldwin. 1970. Woodpecker predation on bark beetles in Englemann spruce logs as related to stand density. Can. Entomol. 102:1345–1354.

Simmons, G. A. 1968. Interrelationship of the chipping sparrow and the jack pine budworm. MS Thesis. Michigan Tech. Univ. 50 pp.

Sloan, N., and H. C. Coppel. 1968. Ecological implications of bird predators on the larch casebearer in Wisconsin. J. Econ. Entomol. 61:1067–1070.

Sloan, N. F., and G. A. Simmons. 1973. Foraging behavior of the chipping sparrow in response to high populations of jack pine budworm. Amer. Midl. Natur. 90:210–215.

Solomon, J. D. 1969. Woodpecker predation on insect borers in living hardwoods. Ann. Entomol. Soc. Amer. 62:1214–1215.

______. 1975. Biology of an Ash borer, *Podonesia hyringae* Ann. Entomol. Soc. Amer. 68:325–328.

______. 1977. Biology and habits of the oak branch borer. Ann. Entomol. Soc. Amer. 62:57–59.

Solomon, M. E. 1949. The natural control of animal populations. J. Anim. Ecol. 18:1–35.

______, and D. M. Glen. 1979. Prey density and rates of predation by tits (*Parus* spp.) on larvae of codling moth (*Cydia pomonella*) under bark. J. Appl. Ecol. 16(1):49–60.

Solomon, M. E., D. M. Glen, D. A. Kendall, and N. F. Wilson. 1976. Predation of overwintering larvae of codling moth (*Cydia pomonella*(L.)) by birds. J. Appl. Ecol. 13:341–352.

Springett, B. P., and J. N. Matthiessen. 1975. Predation on potato moth *Phthorimaea operculella* Lepidoptera Gelechiidae by the western silvereye *Zosterops gouldi* Aves Zosteropidae. Austral. J. Zool. 23:65–70.

Stewart, P. A. 1969. House sparrows and a field infestation of tobacco hornworm larvae. J. Econ. Entomol. 62(4):956–957.

______. 1973. Starlings eat larvae on corn ears without eating corn. Auk 90(4):911–912.

______. 1975. Cases of birds reducing or eliminating infestations of tobacco insects. Wilson Bull. 87(1):107–109.

Strokov, V. V. 1956. Influence of hollow-nesting birds on the breeding grounds of the *Ocneria dispar* and *Tortrix viridana*. Pages 59–63 *in* P. L. Poznanin, ed. Ways and means of using birds in combating noxious insects. USDC, Israel progam for scientific translations. 138pp.

Takekawa, J. Y. and E. O. Garton. 1982. How much is an evening grosbeak worth? J. For. (in review).

Thomas, J. W., ed. 1979. Wildlife habitat in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handbook No. 553. U.S. Dep. Agriculture, Washington, D.C. 509pp.

______, G. L. Croach, R. S. Bumstead, and L. D. Bryant. 1975. Silvicultural options and habitat values in coniferous forests. Pages 272–287 *in* D. R. Smith, ed. Proc. Symp. on Management of Forest and Range Habitats for Nongame Birds. Gen. Tech. Rep. WO-1. USDA For. Serv. Washington, D.C. 343pp.

Thomas, J., C. Maser, and J. E. Rodiek. 1978. Edges—their interspersion, resulting diversity, and its measurement. Pages 91–100 *in* R. M. DeGraaf, ed. Proceeding of the Workshop on Nongame Bird Habitat Management in the Coniferous Forests of the western United States. USDA For. Serv. Gen. Tech. Rep. PNW-64 Pacific Northwest Forest and Range Exp. Station, Portland, Ore. 100pp.

Thurston, R., and O. Pracherabmoh. 1971. Predation by birds on tobacco hornworm larvae infesting tobacco. J. Econ. Entomol. 1548–1549.

Tichy, V. 1963. Prace vyzkumnych ustavii lesnickych CSSR 26:49.

______. 1967. Kvantitativni a Kvalitativni zvysovani hustoty populace ptactva v lese. Lesnicky Casopis 13(3):261–276.

Tinbergen, L. 1949. Boxvogels en insekten. Ned. Bosch Tijdschr. 21:91–105.

______. 1960. The natural control of insects in pine woods. I. Factors influencing the intensity of predation by songbirds. Archives Neerlandaises de Zoologie 13:265–343.

Titaeva, N. N. 1956. Experiments on the attraction of birds to the Oka Reserve. Pages 98–100 *in* P. L. Poznanin, ed. Ways and means of using birds in combating noxious insects. USDC, Israel program for scientific translations. 138pp.

Torgersen, T. R., and D. L. Dahlsten. 1978. Natural mortality of the Douglas-fir tussock moth. *In* M. H. Brookes, R. W. Stark, and R. W. Campbell, eds. The Douglas-fir Tussock Moth: a Synthesis. USDA, USFS Tech. Bull 1585. 331pp.

Tothill, J. D. 1923. Notes on the outbreaks of spruce budworm, forest tent caterpillar, and larch sawfly. Proc. Acadian Ent. Soc. 1922. 8:172–192.

Treus, V. D. and G. A. Uspenskii. 1956. Experiments on transmigration of the flycatcher (*Muscicapa hypoleuca*)to the parks of Ascania Nova. Pages 113–116 *in* P. L. Poznanin, ed. Ways and means of using birds in combating noxious insects. USDC, Israel program for scientific translations. 138pp.

U.S. Forest Service. 1977a. 1977 final environmental statement addendum to the final 1976 cooperative western spruce budworm pest management plan. FES (Adm)-76-7. USDA, U.S. Forest Service, PNW, Portland, Ore. 110pp.

______. 1977. Wildlife management policy. Manual. Title 2630.3. USDA For. Serv., Portland Ore. Washington, D.C.

Varty, I. W. 1975. Forest spraying and environmental integrity. For. Chron. 5(4):146–149.

von Haartman, L. 1956. Territory in the pied flycatcher. Ibis 98(3):461–475.

Voute, A. D. 1951. Zur frage der regulurung der inseckent-populationsdichte durch rauberische Tierarten. Z. angew. Ent. 33:47–52.

Wall, M. L., and W. H. Whitcomb. 1964. The effect of bird predators of winter survival of the southwestern and European corn borers in Arkansas. J. Kansas Entomol. Soc. 37:187–192.

Wearing, C. H. 1975. Integrated control of apple pests in New Zealand. 2. Field estimation of fifth-instar larval and pupal mortalities of codling moth by tagging with cobalt-58. N. Z. J. Zool. 2:135–149.

Webb, W. L., D. F. Behrend, and B. Saisorn. 1977. Effect of logging on songbird populations in a northern hardwood forest. Wildlife Monograph No. 55. The Wildlife Society, Washington, D.C. 35pp.

Wellenstein, G. 1959. Moglichkeiten und grenzen des einsatzes von krankheitseiregun nutzinsekten und vogeln impraktischen forstschutz. Forstw. Zbl. 78:150–166.

Wellington. 1981. Weather. Presentation for the Western Spruce Budworm Conference, 1981. Portland.

Werner, R. A. 1980. Biology and behavior of a larch bud moth *Zeirphera* sp. in Alaska USA. Res. Note, PNW, O(356) USDA For. Serv., Portland, Ore. 8pp.

Williams, P. L., and W. D. Koenig. 1980. Water dependence of birds in a temperate oak woodland. Auk 97:339–350.

Wiens, J. A. 1975. Avian communities, energetics and functions in coniferous forest habitats. Pages 226-261 *in* D. R. Smith, ed. Proc. Symp. on Management of Forest and Range Habitats for Nongame Birds. Gen. Tech. Rept. WO-1. USDA For. Serv., Washington, D.C. 343pp.

Current Challenges in Resource Management

Chairman:
DAVID L. TRAUGER
Chief
Division of Wildlife Ecology Research
U.S. Fish and Wildlife Service
Washington, D.C.
Cochairman:
ROBERT S. COOK
Chairman
Department of Fisheries and Wildlife Biology
Colorado State University
Fort Collins

Restoring Natural Conditions in a Boreal Forest Park

Glen F. Cole
Voyageurs National Park
International Falls, Minnesota

Introduction

Voyageurs National Park is located in northern Minnesota (Figure 1). Its northern and eastern boundaries parallel a historic fur trade route that influenced the location of the boundary between the United States and Canada. About two-thirds of the park's 344-square-mile (891 km^2) area is land, and the remainder is made up of numerous small and large lakes. The interspersion of forested land, massive rock outcrops and lakes make the park very scenic. It is also somewhat unique because it is the only U.S. park on the mainland in a southern boreal forest region. Isle Royale National Park is also in this region, but its biota is characteristic of island areas.

History of the Park

The park has a long history of human use. People from Asia emigrated into the area after the retreat of the last glaciers about 11,000 years ago (Martin et al. 1947). Their descendants became Sioux Indians, who were displaced by Chippewa Indians during the 1700s (Danziger 1978). European men traveled through the park and traded with these Indian people for furs between the 1660s and 1850s (Nute 1941).

Minnesota became a state in 1858, and in 1891 its representatives asked that a national park be established in the as yet unsettled area. This was not done and periods of uncontrolled hunting, logging, homesteading, and resort and summer home development followed. Dams were constructed at the outlets of Rainy and Namakan Lakes in the early 1900s. Facilities for generating up to 20 Mw occur at the Rainy Lake dam. State representatives again requested that a park be established in 1960. This finally occurred in 1975. According to its legislation, Voyageurs is supposed to conserve its scenery, natural and historic objects, and wildlife and

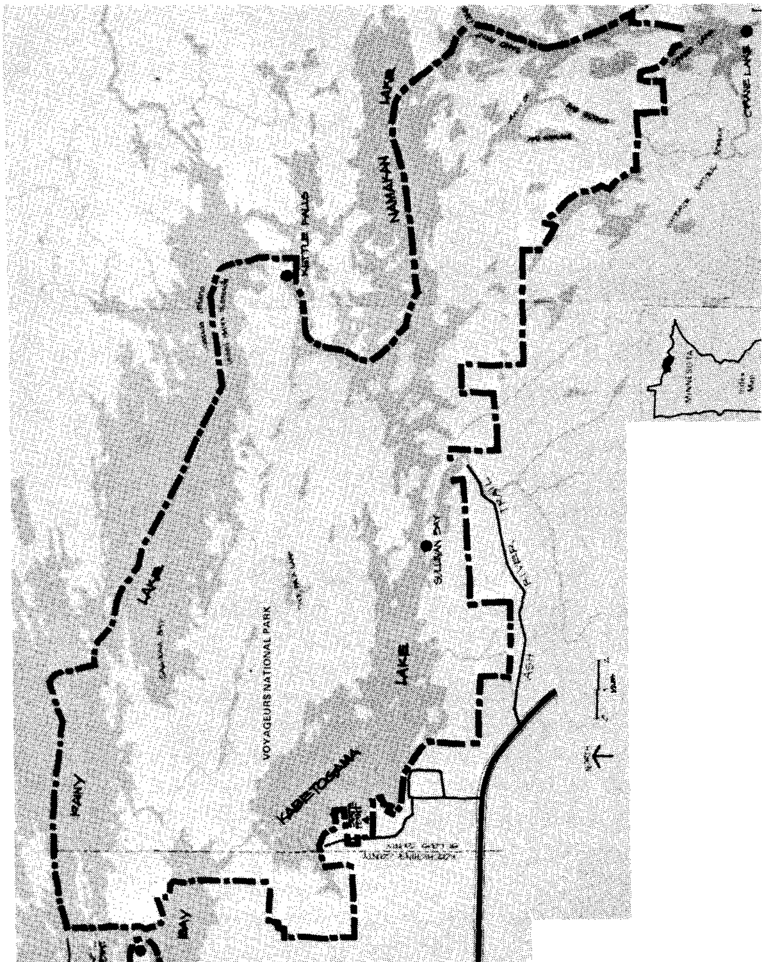


Figure 1. Location and boundaries of Voyageurs National Park.

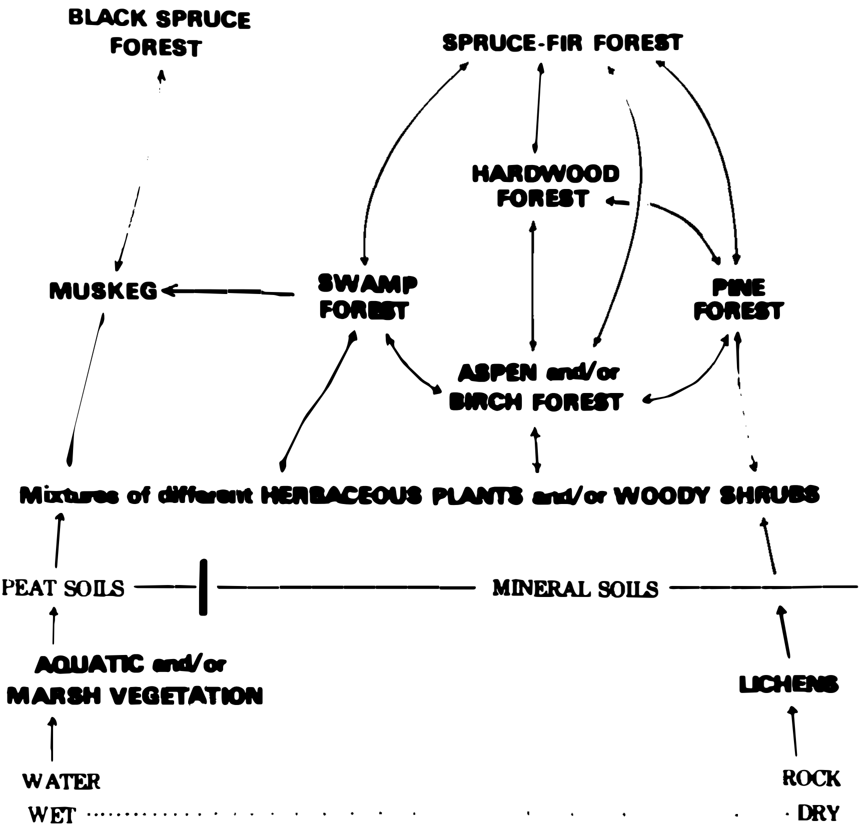


Figure 2. Plant community successional relationships in Voyageurs National Park: Succession converges toward Black Spruce or Spruce-Fir climaxes. Disturbances set back succession or maintain subclimaxes. Raised water tables allow Muskeg to replace Swamp Forests (Heinselman 1970).

provide for the enjoyment of same in ways that leave unimpaired conditions for future generations.

The establishment of the park led to a series of research studies on its vegetation and wildlife. This paper summarizes findings on what original conditions were like, the changes that have occurred over the past 100 years, and points out actions that could restore more natural conditions.

Vegetation

Succession and Disturbances

Figure 2 summarizes relationships reported by Cole (1979), Kurmis et al. (1980), and Coffman et al. (1980). In the absence of disturbances, succession is toward two types of climax vegetation. These are white spruce-balsam fir (*Picea glauca-Abis balsamea*) dominated communities on mineral soils, and black spruce (*P. mariana*) dominated communities on peat soils. Disturbances from fire, insects, flooding, or logging can set back these and other less advanced successional stages as shown. Additionally, periodic fires allow stands of white, red or jack pine (*Pinus strobus, P. resinosa, P. banksiana*) to replace themselves on drier sites. These pine stands are called subclimaxes, recognizing that without occasional fires they become seral stages. Natural fire frequencies in the region have been estimated at 70 to 150 years (Heinselman 1973, Swain 1973).

Original Vegetation

Early land surveys (1881–94) and logging company and fire records (Coffman et al. 1980) show that a fire-maintained mosaic of climax, subclimax, and seral forest vegetation occurred in the park before large scale logging began in 1913. Selective removals of large sawlogs, which averaged 2,750 board feet per acre, were 53 percent white and red pine and 47 percent other species. The size of logs taken indicate the latter were mostly mature white spruce. Later logging from 1930 to 1972 continued to cut large trees away from lake shores, but mainly removed smaller spruce, balsam fir, and aspen (*Populus tremuloides*) for pulpwood.

Present Vegetation

Studies by Kurmis et al. (1980), Coffman et al. (1980), and Swain (1981) show that logging and/or a series of fires up to 1936 set back a large portion of the original vegetational mosaic on mineral soils to aspen and/or white birch (*Betula paperifera*) forests. Mature spruce-fir forests appear to have been replaced to a greater extent than mature stands of pine. Swamp forests dominated by white cedar (*Thuja occidentalis*) or black ash (*Fraxinus nigra*) persisted on wet mineral soils. Black spruce forests and muskeg (stunted black spruce, evergreen shrubs, spagnum moss) that are representative of original conditions persisted on peat soils. Some lichen species may have become less abundant because of logging (Wetmore 1980).

Succession and natural disturbances can be expected to restore or maintain a representative natural forest vegetation in the park. However, fires have been effectively suppressed since the 1940s. If continued, this will allow pines to be replaced by other vegetation and cause other reductions in vegetational diversity.

Wildlife

Absent and Declining Species

Faunal records show that the native wildlife in this southern boreal forest region is a highly diverse mixture of northern and southern or resident and migrant species. The recent original fauna included at least 48 mammals, 241 resident and migrant bird species, 15 reptiles and amphibians, and 28 fish species. Since the early 1920s three mammal species have become absent, and an additional five have declined to remnant numbers (Table 1). At least 12 other mammal, bird, or fish species have become less abundant than previously on all or large portions of the park. Further study is expected to add to this list.

Main Causes

Table 1 lists what were considered the main causes for different species becoming absent or less abundant in the park. Market and subsistence hunting from the early 1890s to 1920s appeared to eliminate eventually woodland caribou and elk from the area and reduce moose to very low numbers. The failure of these moose to respond to subsequent protection from hunting, increases in seral vegetation, or recent declines in white-tailed deer, in combination with rare occurrences of twin young, suggested the possibility that their reproduction had been depressed by inbreeding (Franklin 1980, Senner 1980, Soule 1980). White-tailed deer harbored a meningeal parasite (*Parelaphostrongylus tenuis*) that could cause mortality in moose (or caribou) as functions of deer densities and other variables (Cole 1981), but such mortality would have tended to increase rather than decrease twinning. Genetic influences on moose twinning rates have been previously reported by Houston (1968). Mortality from trapping, shooting, or fishing contributed to some other species becoming less abundant, but such effects mainly occurred because other causes lowered a species reproductive success or habitat security (Errington 1946).

Table 1. Native wildlife species presently absent (A), reduced to remnant numbers (R), or less abundant than previously (L), in Voyageurs National Park.

Species	Status	Probable main cause
Woodland caribou (*Rangifer tarandus*)	A	
Elk (*Cervus elaphus*)	A	Uncontrolled
Moose (*Alces alces*)	R	hunting
White-tailed deer (*Odocoileus virginianus*)	L	Maturing forests
Grey wolf (*Canis lupus*)	L	
Coyote (*Canis latrans*)	L	
Red fox (*Vulpes fulva*)	L	
Wolverine (*Gulo luscus*)	A	
Canada lynx (*Lynx canadensis*)	R	Reduced food
Bobcat (*Lynx rufus*)	R	
Raven (*Corvus corax*)	L	
Bald eagle (*Haliaeetis leucocephalus*)	L	
Porcupine (*Erithizon dorsatum*)	R	
Red squirrel (*Tamasciurus hudsonicus*)	L	Logging
Pine marten (*Martes americana*)	R	
Beaver (*Castor canadensis*)	L	
Muskrat (*Odonata ziebethicus*)	L	Regulated
Loon (*Gavia immer*)	L	water levels
Walleye (*Stizostedion vitreum*)	L	in four large
Northern pike (*Esox lucius*)	L	lakes

The absence of competition from native cervids and increased seral vegetation from logging allowed white-tailed deer to increase to densities of 20 or more per square mile by the late 1930s (Erickson et al. 1961). Declines to the present low densities of five or less deer per square mile in the park were associated with progressively maturing forests, an increased frequency of harsh winters during the 1960s (Mech and Karns 1977), and, by the mid-1970s, the deer population declining below levels that could fully compensate for predation by wolves, which remained at densities of about one per 10 square miles. According to Pimlott (1967), wolves at these densities can cause uncompensated mortality after deer decline below 10 per square mile, and wolves must either switch to alternative prey or decline along with deer. Declines of deer to about one per square mile and of wolves from one per 10 square miles to one per 25 square miles occurred in an adjacent Superior National Forest area (Mech and Karns 1977, Floyd et al 1979).

A variety of carnivore species became less abundant as white-tailed deer declined. This suggested that declines in carnivores were caused by increased inter- and intraspecies competition for reduced food. However, such competition may have only occurred because species that previously provided alternative food were less abundant or absent. Calculations indicate that the amount of food the present less diverse cervid fauna provides to carnivores during critical winter and spring periods is one-third of pre-1920 or 1936–60 levels (Table 2). To date, wolves have been less adversely affected than smaller carnivores that mainly scavenge on cervids, but they have slowly declined from 41 individuals in 1976 to 30 in 1981. In comparison to other Lake State areas, where they may be less dependent on cervid carrion, the bald eagles that nested in the park area had low reproductive success (Grim, unpublished data).

Declines of porcupines to remnant status were also associated with declines of white-tailed deer, and probably largely caused by increased predation from food-stressed carnivores. However, predators may have only had these effects because logging reduced overmature trees with cavities. These allow porcupines to elude predators (Powell and Brander 1977). Declines in red squirrels and pine marten probably resulted from logging or associated slash fires temporarily reducing the amount and distribution of superior squirrel habitat (interspersions of mature spruce-fir and pine).

Records since 1941 (U.S. Army Corps of Engineers, unpublished data) show that Namakan, Kabetogama, and Sand Point lakes have been fluctuated an average of about 9 feet (3 m) each year to maintain fluctuations of about 3.5 feet (1.2 m) on Rainy Lake. Other records from a large upstream lake (Lac La Croix) suggest that natural fluctuations would have averaged about 4 feet (1.3 m) on Rainy Lake and, because of smaller storage capacities and constricting narrows, about 5 feet (1.7 m) on the other lakes. Natural fluctuations also differed from regulated fluctuations by usually peaking in late May or early June instead of late June or early July, by generally declining instead of being relatively stable over summer and fall, and by declining about 2 (0.7 m) instead of 6 (2 m) feet (only in lakes with 9-foot fluctuations) over winter periods. About half of these 6-foot declines appeared to be intentional drawdowns to avoid floods or ice damage to docks. Because Rainy Lake has three times the storage capacity of other lakes, allowing it to fluctuate 4 instead of 3.5 feet would reduce the 9-foot fluctuations on other lakes to 7.5 feet (2.5 m). These could be further reduced to 5-foot fluctuations in most

Table 2. Hypothesized November-April cervid-carnivore relationships in Voyageurs National Park for pre-1920, interim and present periods.

Species and periods	Density per square mile[a]	Total no. within 240 square miles[b]	Av. 20% overwinter mortality of cervids utilized by carnivores[c] No.	Av. wt. lbs.[d]	Biomass lbs.
Pre-1920					
Caribou	2	480	96	200	19,200
Moose	2	480	96	400	38,400
White-tailed deer	1	240	48	90	4,320
Elk	0.5	120	24	300	7,200
	5.5	1,320	264		69,120
1936–60					
Caribou	0				
Moose	?				
White-tailed deer	16	3,840	768	90	69,120
Elk	0				
1978–81					
Caribou	0				
Moose	0.1	24	5	400	2,000
White-tailed deer	5	1,200	240	90	21,600
Elk	0				
	5.1	1,224	245		23,600

[a]Pre-1920 densities were never documented and hypothesized values were apportioned by assuming the average biomass production from four species was equal to that from deer alone during the 1936–60 period, and by inferring relative species abundance from historical accounts, interviews with early residents, and studies elsewhere. The 1936–60 density of 16 deer per square mile is the average of estimates for northern Minnesota by Erickson et al. (1961). These progressively decline from 20 to 13 deer per square mile. Estimated densities for 1978–81 tentatively assume that maximum winter counts of deer per mile on transects × 2 approximated deer per square mile, and about half of the moose that were actually present were accounted for by aerial and ground counts.
[b]Excludes 100 square miles of large lake areas.
[c]Assumed minimum overwinter mortality rates for naturally regulated or lightly exploited cervid populations extrapolated from Cole (1978).
[d]Assume overwinter mortality is ⅔ subadults and ⅓ adults.

years by only making additional drawdowns for flood control if they were necessary.

The six-foot (2 m) declines in lake levels over winter periods increased the vulnerability of beaver and muskrats to predators by leaving their lodges and food apart from water or frozen in ice. They also dewatered marsh areas to the extent that northern pike had marginal spawning conditions (Kallemeyn, unpublished data). Maintaining stable lake levels over summer and fall periods reduced the availability of wave-washed gravel for shoal spawning walleye. Chevalier's (1977) findings suggest this lowered the reproductive success of shoal spawning stocks to the extent that they could not fully compensate for mortality from fishing.

Regulated lake levels lowered loon reproduction rates by flooding nests. Only occasional young were noted from 1976 to 1978. Systematic counts in 1979 and

1980 (N = 338) gave adult:young ratios that varied from 5 to 6:1 on Rainy Lake, 13 to 60:1 on the lakes with the greatest fluctuations and 2 to 2.5:1 on 18 smaller lakes with natural fluctuations. Regulated lake levels approximated the magnitude and timing of natural fluctuations to the greatest extent in 1981 and counts (N = 169) gave adult:young ratios of 3:1 and 5:1 on Rainy and the other regulated lakes, respectively. Part of the differences between lakes could be due to human disturbances and small lakes having greater proportions of experienced breeders. Other obvious effects were that extensive beds of wild rice (*Zizania palustris*) were replaced by other aquatic vegetation in the lakes with 9-foot fluctuations, but still occur in Rainy Lake.

Discussion

The information in previous sections identifies four major man-caused problems (i.e. changes from natural conditions). These are:

1. Preventing all forest fires prevents the park from having a natural forest vegetation.
2. Two of the park's four native cervid species are absent and a third persists in precariously low numbers.
3. Reduced food for carnivores is causing further declines in the numbers and kinds of native wildlife species in the park.
4. Regulated lake levels are having adverse effects on wild rice, fish, and other wildlife.

Some possible solutions to these problems, in the form of hypotheses that can be tested by research, follow.

1. Allowing fires to burn within designated areas where they can be confined (by natural barriers or control) will reestablish mosaics of forest vegetation comparable to those before logging.
2. Introductions will reestablish viable populations of woodland caribou, moose, and/or elk.
3. Reestablishing caribou, moose, and/or elk populations will increase food for native carnivores.
4. The present adverse effects of regulating lake levels on various aquatic species can be reduced, without serious conflicts with other presently authorized uses of water, by approximating the magnitude and timing of natural fluctuations in most years and reducing the extreme fluctuations from occasional natural floods or droughts.

Alternatives to these solutions range from doing nothing to employing actions that solve one problem, but not others. For example, one alternative to reestablishing caribou, moose, or elk populations to provide food for carnivores is to prescribe burn forests to maintain high numbers of white-tailed deer. This would not restore the park's native cervid fauna or maintain a natural forest vegetation. Doing nothing seems certain to result in more native species becoming less abundant or absent. These and other alternatives relating to cervid introductions or fire are covered in greater detail in planning or environmental impact documents.

Alternative ways of regulating lake levels are being explored with different users of water and an International Joint Commission, which must authorize any changes. It is intended that any actions to correct problems be monitored and evaluated by research. This approach has been previously used to correct similar problems in other national parks (Hayden 1971, Kilgore 1971, Houston 1971). The introductions of native cervids should be of particular interest because they would allow various hypotheses about the effects of parasites, interspecies competition, and inbreeding to be tested in the field. More important, however, these and other appropriate actions could assure that representative examples of natural southern boreal forest environments and their native wildlife are preserved in Voyageurs National Park.

References

Chevalier, J. R. 1977. Changes in walleye (*Stizostedian vitreum vitreum*) population in Rainy Lake and factors in abundance 1924–75. J. Fish. Res. Board Can. 34:1696–1702.

Coffman, M. S., L. Rakestraw and J. E. Ferris. 1980. The fire and logging history of Voyageurs National Park. Final Report. Mich. Tech. Univer. 108 pp. memo.

Cole, G. F. 1978. A naturally regulated elk population. Proc. Symposium on National Regulation of Wildlife Populations. NW Sec. Wildl. Soc. Meeting, Vancouver, B.C. In Press.

______. 1979. Mission-oriented research in Voyageurs National Park. Proc. Second Conf. on Scientific Research in the National Parks. Nov. 26–30, 1979. San Francisco, Calif.

______. 1981. Alternative hypotheses on ecological effects of meningeal parasite (*Parelophostrongylus tenuis*). J. Min. Acad. Sci. Vol. 47, No. 1. 8–10.

Danziger, E. J. 1978. The Chippewas of Lake Superior. University of Oklahoma Press.

Erickson, A. B., V. Gunvalson, D. Burcalow, M. Stenlund, and L. Blankenship. 1961. The white-tailed deer of Minnesota. Minnesota Div. of Game and Fish Tech. Bull. No. 5. 64 pp.

Errington, P. L. 1946. Predation and vertebrate populations. Quart. Rev. Biol. 21, 2:144–177 and 21, 3:221–245.

Floyd, T. T., L. D. Mech, and M. E. Nelson. 1979. An improved method of censusing deer in deciduous-coniferous forests. J. Wildl. Manage. 43:258–261.

Franklin, I. R. 1980. Evolutionary change in small populations. Pages 135–149 *in* Conservation Biology: an evolutionary-ecological perspective, Soule, M. E. and B. A. Wilcox eds. Sinauer Assoc., Inc., Sunderland, Mass.

Hayden, P. S. 1971. The status of research on the snake river cutthroat trout in Grand Teton National Park. Pages 39–47 *in* Research in the Parks. U.S. Dept. of Interior, National Park Service Symposium Series, No. 1, 1976.

Heinselman, M. L. 1970. Landscape evolution, peatland types and the environment in the Lake Agassiz Peatlands Natural Area in Minnesota. Ecol. Monogr. 40:235–261.

______. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quart. Res. 3:329–382.

Houston, D. B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Natural History Assoc. and National Park Ser. Tech. Bull. No. 1. 110 pp.

______. 1971. Research on ungulates in Northern Yellowstone National Park. Pages 11–27 *in* Research in the Parks. U.S. Dept. of Interior, National Park Service Symposium Series, No. 1. 1976.

Kilgore, B. M. 1971. The role of fire in a giant sequoia-mixed conifer forest. Pages 93–116 *in* Research in the Parks. U.S. Dept. of Interior, National Park Service Symposium Series, No. 1. 1976.

Kurmis, V., L. C. Merriam, Jr., N. Aaseng and S. Webb. 1980. Primary plant communities in Voyageurs National Park. Rept. No. 3. College of Forestry. Univer. of Minnesota. 94 pp. memo.

Martin, P. S., G. Quimby and D. Collier. 1947. Indians before Columbus. Univ. of Chicago Press.

Mech, L. D., and P. D. Karns. 1977. Role of the wolf in a deer decline in the Superior National Forest. USDA For. Serv. Res. Pap. NC-148. 23 pp.

Nute, G. L. 1941. The Voyageur's Highway. Pub. of the Minnesota Historical Society, St. Paul.

Pimlott, D. H. 1967. Wolf predation and ungulate populations. Am. Zool. 7:267–278.

Powell, R. A., and R. B. Brander. 1977. Adaptions of fishers and porcupines to their predator prey system. Pages 45–53 *in* Proc. of the 1975 predator symposium, R. L. Phillips and C. Jonkel eds. Amer. Soc. of Mammologists 55th Annual Meeting, June 16–19, 1975, University of Montana, Missoula.
Senner, J. W. 1980. Interbreeding depression and the survival of zoo populations. Pages 209–224 *in* Conservation Biology: an evolutionary-ecological perspective, Soule, M. E. and B. A. Wilcox eds. Sinauer Asso. Inc., Sunderland, Mass.
Soule, M. E. 1980. Thresholds for survival: Maintaining fitness and evolutionary potential. Page 209–224 *in* Conservation Biology: an evolutionary-ecological perspective. Soule, M. E. and B. A. Wilcox eds. Sinauer Asso. Inc., Sunderland, Mass.
Swain, A. M. 1973. A history of fire and vegetation in northeastern Minnesota as recorded in lake sediments. Quart. Res. 3:383–396.
______. 1981. Vegetation and fire history at Voyageurs National Park. Final Report to Nat. Park Serv. Center for Climatic Research, Univer. of Wisconsin. 15 pp. memo.
Wetmore, C. M. 1980. Lichens of Voyageurs National Park. Final Rep. 37 pp. memo.

In Search of a Diversity Ethic For Wildlife Management

Fred B. Samson
Colorado Cooperative Wildlife Research Unit
Department of Fishery and Wildlife Biology
Colorado State University, Fort Collins

Fritz L. Knopf
Denver Wildlife Research Center
Fort Collins, Colorado

Introduction

As the century nears its end and demand for food and competition for land escalate, a most important issue facing conservationists will be the preservation of a mosaic of habitats in which can be preserved a representative cross-section of native species. The need to resolve this issue is emphasized in the *Global 2000 Report to the President* (Council on Environmental Quality 1980) which predicts that, worldwide, 500,000 to 2 million species will become extinct by the year 2000 and that the rate will increase from one per day in 1980 to one per hour by century's end (Myers 1979). Although these extinctions will largely occur in developing countries (Norman 1981), over 500 species and subspecies of flora and fauna have become extinct in North America since the Puritans arrived at Plymouth Rock in 1620 (Spinks 1979). This most critical need, to preserve habitat so that floral and faunal diversity can be maintained, rests not only on the loss of genetic diversity and scientific-medical properties, but on the long term consumptive, nonconsumptive, and social values of plants and wildlife to mankind.

Historically, formulating principles of conservation worldwide, and particularly in North America (Leopold 1933), has to a great extent rested on the concept of diversity. Even recently, the National Forest Management Act (1976) has required land managers to provide for a diversity of plant and animal communities in order to meet overall multiple-use objectives. Other federal, state, and private agencies use biotic diversity as a measure of ecosystem quality and assume diversity is an ecologically sound concept applicable to land management. In spite of its popularity, diversity has often been sharply criticized owing to the ambiguity of definitions and indices (Peet 1974, Routledge 1979). This has led Hurlbert (1971) to recommend that we abandon the concept and concentrate on other aspects of species-abundance patterns. Nevertheless, diversity continues to occupy the attention of wildlife and land managers, and the concept will almost surely continue to play a role in future management of wildlife.

Resource managers have emphasized principally alpha, or within-habitat, diversity; few have acknowledged the importance of beta, or between-habitats, diversity. Gamma diversity, a measure of all species in a geographic area, has been largely ignored. Though not new concepts, beta and gamma diversity are highly relevant to wildlife conservation. This paper reviews these diversity measures with the objective of establishing the timeliness of incorporating beta and gamma diversity as integral parts of the comprehensive planning process in resource management. Two criteria are used: (1) the ecological, geographical, and organizational level of resolution and (2) the current, long-range, and biotic usefulness of each measure of diversity. Thus, the emphasis is on the use of diversity in management situations rather than in a theoretical or mathematical framework. The lack of mathematical support for diversity indices and the unavailability of acceptable statistical procedures to compare indices are addressed elsewhere (Routledge 1980, Alatolo 1981, Wolda 1981).

Definitions

Of particular importance to the concept of alpha diversity are species richness, the number of species in a community, and the equitability or evenness with which importance is distributed among the species. The measure of alpha diversity rests on an estimate of the number of species within a community and where each species is weighted by its abundance. H', the Shannon Weaver index (Peet 1974), or a plethora of alternatives (h', H, $O^{H'}$, D, $1/d$, and others) are then computed to provide an index to local diversity. Evenness is generally measured by dividing H' by the maximum possible diversity for a given number of species.

The amount of species turnover between habitat types or the change in species composition along environmental gradients exemplify beta diversity. Whittaker (1970) approaches the measurement of β diversity by estimating the relative similarity of samples drawn from adjacent, but different communities. An increase in beta diversity is attributable to an increase in ecological distance between samples drawn from two communities. Calculations of the degree by which the samples differ from one another include Coefficient of Community (*CC*), the ratio of species shared by Sample A and B to the total number of species occurring in Sample A plus Sample B (similarity index) or Euclidean Distance (ED).

Gamma diversity is the total number of specie to be found in all the available habitats in a fairly large geographic area (Whittaker 1970).

Review of Diversity

Alpha diversity reflects the number and relative abundance of species populations in a habitat type. The popularity of the classic relationship (MacArthur and MacArthur 1961) between bird species diversity and foliage height diversity has reinforced the extensive and widespread use of alpha diversity in wildlife management, particularly for nongame wildlife. With respect to nongame birds and alpha diversity, the rationale of "if it works, use it" may be misleading in terms of biology and ecological properties. The biological and ecological flaws are at least four. First, the relationship does not hold in all forest communities (Balda 1975), appearing confounded by floristics (Franzreb 1978, Holmes and Robinson 1981) and the availability of food resources (Karr 1971). Second, ignored are differences attributable to the increase in species number with increasing area, and "many combinations of species richness and relative abundance can produce the same value of the index" (James and Rathbun 1981:785). Third, the diversity of breeding populations between consecutive years on a site may reflect events during the nonbreeding season (Lack 1954, Fretwell 1972) and/or weather related phenomena that influence the availability of resources in spring (Cody 1981). Fourth, an emphasis on alpha diversity in habitat management favors the "edge" species, the common, widespread species. Ignored are those species that require large, contiguous habitat units (Robbins 1979). All problems in use of alpha diversity cannot be highlighted in this review. Other papers in recent books by Cody and Diamond (1975), Soule and Wilcox (1980), and Keast and Morton (1980) give further biological background to reconsider alpha diversity in wildlife management whether for birds, mammals, invertebrates, or plants.

Most measures of alpha diversity ignore the spatial distribution of individuals and the composition dynamics of communities. Although two communities may exhibit the same species diversity, one could be composed of species that intermingle at random and the second of monospecific patches (Peterson 1976). Further, two communities may possess identical alpha diversity values yet not have a species in common. The importance of spatial patterns of individuals and species has long been recognized as important by ecologists and is a focal point in the consideration of within- and between-habitat diversity. Few will argue from an ecological viewpoint the fact that total number of species increases along an ecocline, desert to dry grassland to prairie to oak woodland to oak-hickory forest to mesophytic forest, for example. Importantly, some habitats along an ecocline may have low alpha diversity—dry grassland, prairies, mature woodlands—yet make a substantial contribution to the beta diversity of a habitat gradient. If alpha habitat diversity were maximized through management along an entire ecocline, you would achieve a uniformly high alpha diversity, but this would reduce beta diversity by excluding species adversely affected by diminished habitat size and/or habitat heterogeneity (Faaborg 1980).

A number of plausible ecological concepts—climatic instability, productivity of ecosystems, or the interaction of the two—exist that may determine patterns in gamma diversity. Unfortunately, studies of wildlife distribution and abundance and habitat characteristics on a regional-continental scale are few. Of those available, biogeographic and evolutionary influences are particularly important and clear habitat associations are often lacking. For example, habitat size, a biogeographic feature, is most important to the distribution of big game (Picton 1979) and birds (Thompson 1978) in the northern Rocky Mountains, to mammals and birds of the Inter-mountain Region (Brown 1978), and to the birds of the eastern forest (Robbins 1979) and northern forest/bog habitat (Anderson and Robbins 1981). There is, moreover, information from an evolutionary viewpoint that bird populations of the grassland-steppe habitat vary largely independently of one another; responses of birds to habitat characteristics differ at levels of local, regional or continental scales, and some species apparently occur independent of most habitat features (Weins and Rotenberry 1981).

Relevance to Management

Table 1 summarizes the level of resolution and potential for use of each diversity type in management. The points with respect to alpha and beta diversity are illustrated in two case studies of nongame bird habitats.

Case Study: Tallgrass Prairie Community

The first is of an ecologically simplistic system, the tallgrass prairie of the east central Great Plains. Four prairie relicts in each of four size categories, 0–10 ha,

Table 1. Selected characteristics of alpha, beta, and gamma diversity.

	Diversity		
	Alpha	Beta	Gamma
Resolution			
organismal	population/communities	communities	communities/ecosystems
geographic	local	ecocline	regional/continental
ecological	questionable	good	good
Management Use			
current	extensive	limited	limited
long-range	negative	useful	useful
biotic	uncertain	excellent	excellent

>10–30 ha, >30–100 ha, and >100 ha, and located in central and southwest Missouri served as study sites. Each relict was visited during the breeding seasons of 1978–80; at each location the surveys were taken within a few days of the same date each year. Number of breeding bird species for all relicts less than 30 ha and in 20 ha blocks located at random in the >30–100 ha (n = 2) and >100 ha (n = 3) were surveyed using the flush method (Wiens 1969) or spotmap method (Williams 1936). The minimum criteria for breeding was satisfied if a territorial male was seen on four or more of the five censuses and if a female was detected. Because of the lek behavior in early spring of the greater prairie chicken (*Tympanuchus cupido*), supporting census information was obtained from unpublished Pittman-Robertson reports of the Missouri Department of Conservation. An index (D′) of local grassland-shrub diversity (Wiens 1974, Roth 1976) was calculated each year along a transect extending the longest axis of each relict. Other measurements included size of relict, isolation from similar habitat (Sullivan and Schaffer 1976), and shape (Lind 1974) as an index to edge.

Using stepwise multiple regression, the four variables, area, habitat heterogeneity, edge, and isolation, were tested for their relationship to number of species that colonized the 16 prairie relicts. Of the four, size of relict contributed significantly to the annual number of bird species, 1978–80 (Table 2). Vegetation, heterogeneity, edge, and isolation made a contribution to annual number of species, but the effect was minor. The pattern of prairie or forest edge birds differed somewhat from that of the prairie birds. Again, prairie size made the major contribution, but the effect of within habitat heterogeneity and edge increased.

The striking feature in species use of prairie relicts is the high frequency of nonprairie birds, the brown-headed cowbird (*Molothrus ater*), field sparrow (*Spizella pusilla*), bobwhite (*Colinus virginianus*), red-winged blackbird (*Agelaius phoeniceus*), common grackle (*Quiscalus quiscula*), brown thrasher (*Toxostoma rufum*), bluejay (*Cyanocitta cristata*), on small prairies (Table 3). Although within habitat diversity or total bird species diversity varied little across the size range of prairie relicts, number of prairie species did increase (R^2 = 0.88, $P<0.05$) with size of prairie. The ability of relict size to explain species distribution rests on the habitat size-dependency of selected prairie species (Samson 1980). The second prominent characteristic of small prairie relicts is the high rate of species turnover.

Table 2. Relative contributions of independent variables to the multiple correlation coefficient, R^2, for the annual number of bird species.

	Annual species list					
	Prairie birds			Prairie-forest edge birds		
	1978	1979	1980	1978	1979	1980
Area	0.8641[a,b]	0.8000[b]	0.8081[b]	0.3667	0.3223	0.4076[c]
Habitat heterogeneity	0.0358	0.0453	0.0519	0.1949	0.2313	0.0681
Edge	0.0013	0.0009	0.0050	0.1033	0.1129	0.0681
Isolation	0.0001	0.0000	0.0001	0.0003	0.0009	0.0121

[a]Multiple correlation coefficient(R^2).
[b]Significant at 0.01 level.
[c]Significant at 0.05 level.

Table 3. Mean values of bird community characteristics of the study prairies during the breeding seasons 1978–1980. (Species codes in footnotes follow Klimkiewicz and Robbins [1978]).

	0–10 ha (n = 4)	>10–30 ha (n = 4)	>30–100 ha (n = 4)	>100 ha (n = 4)
Prairie birds[a]				
Number	2.2	3.8	5.3	6.0
Species diversity (H')	0.371	0.98	1.698	1.19
Evenness (J)	0.535	0.81	0.95	0.66
Annual turnover (%)	33.0	21.0	12.0	0.0
Prairie-forest edge birds[b]				
Number	10.8	15.2	16.0	16.0
Species diversity (H')	2.53	2.44	2.40	2.64
Evenness (J)	0.89	0.88	0.88	0.80
Annual turnover (%)	12.0	3.4	0.0	0.0

[a]GPCH, UPSA, WEME, DICK, GRSP, HESP.
[b]GOBW, MODO, YSFL, EAKI, HOLA, BLJA, MOEK, BRTH, AMRO, YELL, RWBL, COGR, BHCO, INBU, AMGO, FISP.

These rates ranged from 0 to 45 percent on relicts of 0–10 ha, 5 to 33 percent on relicts of > 10–30 ha, 5 to 15 percent on relicts of >30–100 ha; only relicts of about 160 ha were able to maintain stable prairie bird communities from year to year.

Thus, management solely by within-habitat bird species diversity may not be an appropriate strategy since: (1) diversity indices often reflect a greater change in the distribution of individuals among the species versus a change in species composition as may exist along a habitat-size gradient, (2) assuming that a stable bird community is an acceptable management goal, knowledge beyond species numbers and the distribution of individuals is required, and (3) critical habitat size requirements of certain species are not addressed. Lastly, analysis of variance revealed no significant differences in the vegetation heterogeneity between the four size categories of prairie relicts. Clearly, management to maximize alpha, or within-habitat, diversity holds little potential for increasing or stabilizing the distribution of native prairie birds. Rather, it provided new habitats for cowbirds, blackbirds, and other non-prairie species that may adversely affect the abundance of prairie species. Alpha diversity management of prairies would only have adverse impacts upon native prairie species by promoting community and ecosystemic instability, and if carried to the extreme (tree plantings, brush invasion, etc. to maximize prairie edge) would represent management for extinction of those species. Gamma diversity management would favor greatest regional diversity through the management of some small units for prairie margin species while promoting native prairie species through community and ecosystemic stability by keeping most land in large, generally undisturbed blocks. Already, virtually all remaining populations of prairie chickens occur on large blocks of (often privately owned) native rangeland (Cannon and Knopf 1980, Samson 1980).

Case Study: Western Forest Communities

The second case study is of a more complex system ecologically: the forest communities of Jackson Hole, Wyoming. In 1952 and 1954, Salt (1957) surveyed the avifauna of this region for comparison to ecological counterparts of the Sierra Nevada. Six plant communities were identified based upon physiognomy. These included lodgepole pine (*Pinus contorta*) forest, lodgepole-spruce-fir ecological interface, spruce-fir forest, willow-sedge swamp, scrub meadow, and flatland aspen (*Populus tremuloides*) stand. Each site was surveyed for birds repeatedly using standard strip-transect techniques. See Salt (1957) for details of the study sites and methodology.

The six study sites represented three basic vegetative types: coniferous forest, deciduous forest, wetland communities. Salt (1957:375) compared the foraging niches of birds in these three communities schematically along foliage profiles. The spruce-fir and aspen communities had 19 species each, while the willow-sedge community comprised 15. We calculated a simple alpha diversity coefficient for each (Table 4) using the Simpson Index (*D*). The riparian, willow-sedge community and spruce-fir community had comparable alpha diversities that were higher than the aspen sites. The standard conclusion drawn in practice is that the coniferous and riparian sites should receive management priority due to the greater diversity

Table 4. Comparison of species richness, alpha and beta diversity for three major vegetative communities, Jackson Hole, Wyoming 1952–1954 based on data in Salt (1957).

	Species richness	Alpha diversity $(D)^a$	Beta diversity	
			Comparison	$(CC)^b$
1. Spruce-Fir	19	0.91	1::2	0.12
2. Willow-Sedge	15	0.88	2::3	0.65
3. Aspen-Flatland	19	0.77	3::1	0.11

[a]D = Simpson index $(1 - \Sigma(p_i)^2)$
[b]CC = Community coefficient $(2\, S_{ab}/(S_a + S_b)$

of nongame birds found in these vegetative types. However, simple Community Coefficient (*CC*) calculations demonstrated dramatic similarity between the riparian and aspen sites, and markedly greater beta diversity (decreased similarity) when either was compared to the coniferous type. This pattern of similarity/dissimilarity is visually illustrated in Figure 1.

We expanded the analysis (Table 5) to identify any unique components within the conifer community. Alpha diversity calculations were comparable for the lodgepole forest, spruce-fir forest, and the ecotone of the two. Beta diversity calculations, however, revealed that the ecotone alpha diversity was derived primarily from the spruce-fir component, the lodgepole community showed much greater beta diversity (i.e., decreased similarity) when compared to the other two conifer stands. The expanded analysis of the deciduous community showed no clear pattern of beta diversity between sites.

From these comparisons we conclude that forests in the Jackson Hole area should be managed to assure the maintenance of stands of lodgepole pine and spruce-fir, at least from a nongame bird perspective. We would recommend minimization of ecotones (edge) in an area—*not a single species was unique to the ecotone*. The suggestion to intensify lodgepole pine emphasis may be received skeptically since the pine forest contained the lowest species richness of the sites. When one examines the continental distribution of species in each, however, five of the eight species in lodgepole pine are restricted to the western half of North America, while 13 of the 19 species recorded in spruce-fir range continent-wide. Management for lodgepole pine sites would favor management of a western-derived avifauna while management towards spruce-fir could result, ultimately, in a single coniferous avifauna across North America comprised of many ecological generalists. Thus, the beta diversity analysis has led to gamma diversity considerations in management.

Further, beta diversity analysis revealed little need to narrow management of deciduous communities to a single vegetative type. Of the 25 species recorded in deciduous sites, 17 are continent-wide in distribution—being derived from eastern deciduous forests. Of the remaining eight species, one was also present in the coniferous stands, leaving only seven species tied specifically to western deciduous communities: 4/7 occur in willow-sedge, 5/7 in scrub-meadow, and 6/7 in aspen stands. No deciduous site was dominated by a western avifauna. Aspen showed the greatest number of western representatives, and probably should receive primary management consideration. The current emphasis on riparian habitats in the western states has been from an alpha diversity perspective, not beta or gamma. Whereas riparian communities support a somewhat unique avifauna within the Jackson Hole vicinity, the Jackson Hole riparian avifauna is really tangential to the deciduous eastern forest and, secondarily, aspen from which it is derived. A more intensive analysis of riparian avifaunas (Knopf, in prep.) will address patterns of beta diversity for such *Salix-Populus* communities.

Conclusions

An ethic is defined as the "discipline dealing with what is good and bad. . .[leading to] principles of conduct governing individuals or groups of professionals" (Woolf 1974:393). If the ultimate goal of wildlife management is for the optimal mainte-

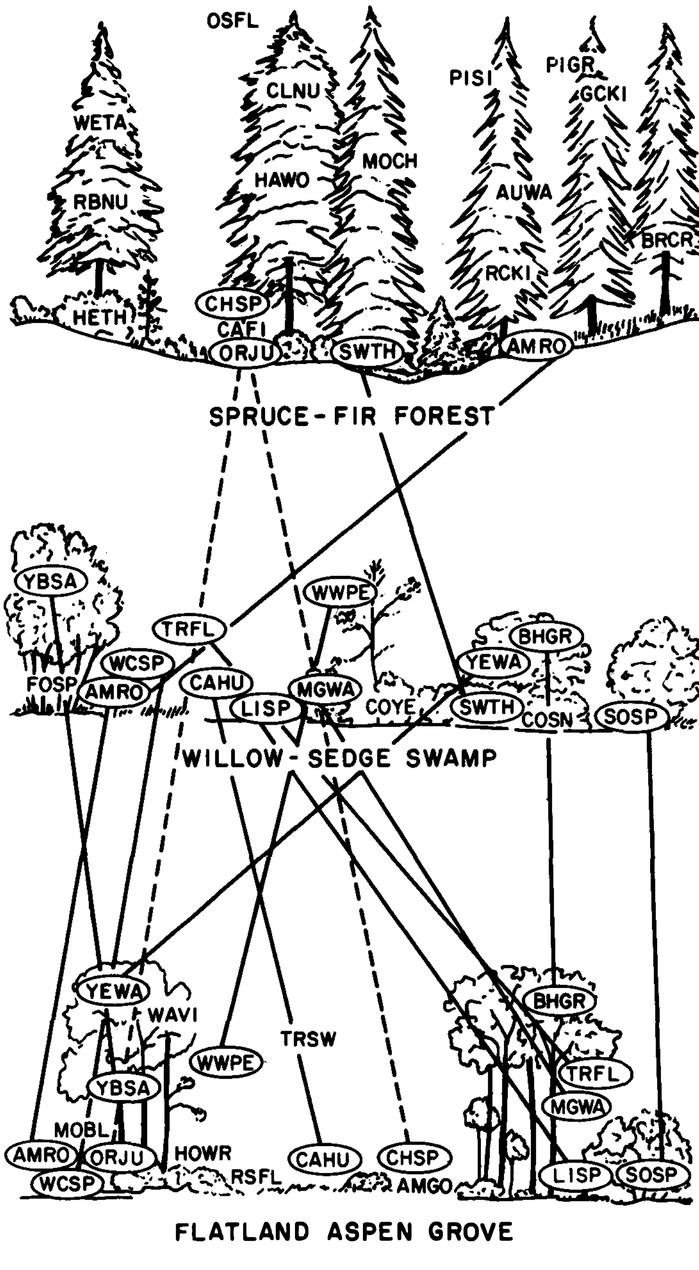


Figure 1. Vegetative community affinities of birds at Jackson Hole, Wyoming demonstrating similarity of riparian and aspen avifaunas, and the greater uniqueness of the conifer avifauna. (After Salt 1957:375). For legend of bird species codes see Klimkiewicz and Robbins (1978).

Table 5. Alpha and beta diversity comparison of 3 coniferous and 3 deciduous habitat types at Jackson Hole, Wyoming 1952–1954 based on data in Salt (1957).

	Species richness	Alpha diversity $(D)^a$	Beta diversity	
			Comparison	CC^b
Coniferous				
1. Lodgepole pine	8	0.82	1::2	0.55
2. Lodgepole-spruce-fir	14	0.89	2::3	0.79
3. Spruce-fir	19	0.91	3::1	0.52
Deciduous				
1. Willow-sedge swamp	15	0.88	1::2	0.48
2. Scrub-meadow	14	0.91	2::3	0.61
3. Flatland-aspen	19	0.77	3::1	0.65

[a]D = Simpson Index $(1 - \Sigma(p_i)^2)$
[b]CC = Community Coefficient $(2S_{ab}/(S_a + S_b))$

nance of the total resource, including consumptive, nonconsumptive, and esthetic values, the conduct of management should emphasize the type of ecological community mix that will provide assurance of system maintenance.

Thus, in conclusion, we propose a direction and methodology for future wildlife management based on current ecological knowledge within the context of the three levels of diversity:

1. *Minimize practices promoting site-specific diversity.* An aggregate community (plants, animals, or the interaction of the two) is not simply predictable by alpha diversity but depends to a great extent on the geographic scale of definition.
2. *Emphasize between-habitat diversity at the management unit level.* The distribution, abundance, and stability of a community or ecosystem cannot be approached piecemeal, overlooking the interaction of habitat types and associated wildlife communities. The potential for species richness is ordinarily much higher between than within vegetative communities, even when the within-habitat wildlife community may be depauparate. In practical terms, it is critical that land/wildlife managers understand within-versus between-habitat diversity in any resource system being managed.
3. *Implement a "top down" or gamma-beta-alpha diversity approach at the regional/national decision-making levels.* This approach should emphasize the economic/ecological/esthetic values of ecosystems, followed by an internal analysis of between-habitat species associations. Although local demands for alpha diversity often emerge, the current state of scientific/ecological knowledge suggests that continuation of alpha diversity management may have dire ecological consequences for the native wildlife of North America.

The most likely future approach to wildlife management rests with (1) identifying important resources within an area, (2) determining the extent and ecological value of each resource and (3) the incorporation of a resource-based diversity index into regional and local planning procedures. The extent to which diversity and its applications are developed in the next few years will play a major role in preserving North American and worldwide biotic diversity. Unfortunately, the emergence of diversity as a respectable cornerstone for wildlife management has been slowed by an emphasis on alpha rather than higher (beta and gamma) diversity. The purpose of this paper was to identify this handicap.

Acknowledgments

We thank Michael A. Bogan, Keith E. Evans, Walter D. Graul, Chandler S. Robbins, and Dixie Smith for comments and suggestions

Literature Cited

Alatolo, R. V. 1981. Problems in the measurement of evenness in ecology. Oikos 37:199–204.

Anderson, S. H., and C. S. Robbins. 1981. Habitat size and bird community management. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:511–520.

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59–80 *in* D. R. Smith, ed. Symposium on management of forest and range habitats for nongame birds. Gen. Tech. Rep. WO-1. USDA For. Serv., Washington, D.C. 343 pp.

Brown, J. G. 1978. The theory of insular biogeography on the distribution of boreal birds and mammals. Pages 209–277 *in* K. T. Harper and J. L. Reveal, eds. Intermountain biogeography: a symposium. Great Basin Natur. Memoirs No. 2. 268 pp.

Cannon, R. W., and F. L. Knopf. 1980. Distribution and status of lesser prairie chickens in Oklahoma. Pages 71–74 *in* P. A. Vohs and F. L. Knopf, eds. Prairie grouse symposium. Oklahoma State University Press, Stillwater. 89 pp.

Cody, M. L. 1981. Habitat selection in birds: the role of vegetation structure, competitors, and productivity. BioScience 31:107–113.

______, and J. M. Diamond. 1975. Ecology and evolution of communities. Harvard University Press, Cambridge, Mass. 545 pp.

Council on Environmental Quality. 1980. The global 2000 report to the president. U.S. Gov. Print. Off., Washington, D.C. 604 pp.

Faaborg, J. 1980. Potential uses and abuses of diversity concepts in wildlife management. Trans. Missouri Acad. of Sci. 14:41–49.

Franzreb, K. E. 1978. Tree species used by birds in logged and unlogged mixed-coniferous forests. Wilson Bull. 90:221–238.

Fretwell, S. D. 1972. Populations in a seasonal environment. Princeton University Press, Princeton, N. J. 217 pp.

Holmes, R. T., and S. K. Robinson. 1981. Tree species preferences of foraging insectivorous birds in a northern hardwoods forest. Oecologia 48:31–35

Hurlbert, S. H. 1971. The nonconcept of species diversity: a critique and alternative parameters. Ecology 52:577–586.

James, F. G., and S. Rathbun. 1981. Rarefaction, relative abundance, and diversity of avian communities. Auk 98:785–800.

Karr, J. R. 1971. Structure of avian communities in selected Panama and Illinois habitats. Ecol. Monogr. 41:207–233.

Keast, A., and E. S. Morton. 1980. Migrant birds in the neotropics: ecology, behavior, distribution, and conservation. Smithsonian Institution Press, Washington, D.C. 576 pp.

Klimkiewicz, M. K., and C. S. Robbins. 1978. Standard abbreviations for common names of birds. N. Amer. Bird Bander 3:16–25.

Lack, D. 1954. The natural regulation of animal numbers. Clarendon Press, Oxford. 343 pp.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York. 481 pp.

Lind, O. T. 1974. Handbook of common methods in limnology. Mosby, St. Louis, Mo. 221 pp.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594–598.

Myers, N. 1979. The sinking ark. Pergamon Press, New York. 307 pp.

Norman, C. 1981. The threat to one million species. Science 214:1105–1107.

Peet, R. K. 1974. The measurement of species diversity. Ann. Rev. Ecol. Syst. 5:285–307.
Peterson, C. H. 1976. Measurement of community pattern by indices of local segregation and species diversity. J. Ecol. 64:157–169.
Picton, H. D. 1979. The application of insular biogeographic theory to the conservation of large mammals in the northern Rocky Mountains. Biol. Conserv. 15:73–79.
Robbins, C. S. 1979. Effect of forest fragmentation on bird populations. Pages 198–212 *in* R. M. DeGraff and K. E. Evans, eds. Management of north central and northeastern forests for nongame birds. Gen. Tech. Rep. NC-51, USDA For. Serv., St. Paul, Minn.
Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57:773–782.
Routledge, R. D. 1979. Diversity indices: which ones are admissible. J. Theor. Biol. 76:503–515.
______. 1980. The form of species-abundance distributions. J. Theor. Biol. 82:547–558.
Salt, G. W. 1957. An analysis of avifaunas in the Teton Mountains and Jackson Hole, Wyoming. Condor 59:373–393.
Samson, F. B. 1980. Island biogeography and the conservation of prairie birds. *In* C. Kucera, ed. The seventh North Amer. prairie conf. Springfield, Mo. (in press)
Soule, M. E., and B. A. Wilcox. 1980. Conservation biology. Sinauer Associates Inc., Sunderland, Mass. 395 pp.
Spinks, J. L. 1979. Perspective. Pages 17–24 *in* The endangered species: a symposium. Great Basin Natur. Memoirs No. 3. 171 pp.
Sullivan, A. L., and M. C. Shaffer. 1976. Biogeography of the megazoo. Science 189:13–17.
Thompson, L. S. 1978. Species abundance and habitat relations of an insular mountain avifauna. Condor 80:1–14.
Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithol. Monog. 8:1–93.
______. 1974. Habitat heterogeneity and avian community structure in North American grasslands. Amer. Midl. Natur. 91:195–213.
______, and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrub steppe environments. Ecol. Monogr. 51:21–41.
Whittaker, R. H. 1970. Communities and ecosystems. Macmillan, New York. 162 pp.
Williams, A. B. 1936. The composition and dynamics of a beech-maple climax community. Ecol. Monogr. 6:317–408.
Wolda, H. 1981. Similarity indices, sample size and diversity. Oceologia 50:296–302.
Woolf, H. B. 1974. Webster's new collegiate dictionary. Merriam Co., Springfield, Mass. 1536 pp.

Public Support For Nongame and Endangered Wildlife Management: Which Way Is It Going?

Jeffrey J. Jackson
Georgia Cooperative Extension Service
University of Georgia, Athens

Surveys of attitudes, activities, and knowledge pertaining to wildlife, notably those of Kellert (1979, 1980a, 1980b) show that the interest of the American public in a great diversity of wildlife runs broad and deep. In particular, there is growing public interest in wild animals, both endangered and common, that are not usually associated with sport hunting. For convenience, wildlife administrators refer to these species as "nongame" wildlife. Many wildlife management agencies have responded to this groundswell of interest by enlarging the scope of their management efforts and programs for the public.

New methods of funding management programs have been discovered. Best known is the "nongame checkoff." Taxpayers can check a box on their state income tax return that allows an amount to be deducted and returned to the state for management of nongame species.

The idea that hunters and fishermen were the only ones willing to pay for access to wildlife is no longer true (Schick et al. 1976). People interested in nongame and endangered wildlife are themselves often hunters and fishermen (Lyons 1982, Witter et al. 1980). This coalition of consumptive and nonconsumptive users of wildlife ought to be a source of strong public support for public wildlife management agencies.

Yet, public support for nongame programs seems weaker than it should be. Despite favorable surveys and trends, wildlife professionals are still fighting the same rear guard battles, trying to save habitats, species, and budgets. Why isn't support stronger? Could the surveys be wrong? Social scientists have documented the importance of question wording involved with attitude/opinion research. Filion (1981) reported that even with factual information questions put to hunters, their responses depended on question wording and the amount of effort required to respond.

But even if surveys indicating a majority of Americans are interested in nongame wildlife are entirely correct, they should not be interpreted to mean public support for management programs will follow. I define public support as an action by people that requires a sacrifice of money, goods, or time to achieve their goals. In other words, attitudes are passive and they cost nothing; support is active and it costs.

A classic example of general public attitude overridden by a minority of active supporters is the leghold trap issue. According to Kellert's (1979) survey, 78 percent of all Americans oppose use of leghold traps as a method of taking wildlife. During the 4 month period January–April, 1982, about 75 pieces of anti-leghold trap legislation were introduced into state legislatures. Despite public attitudes, not one of these measures passed. The minority that lobbies to retain use of leghold traps is willing to make the sacrifices that produce support.

Further, all sectors of the public do not have an equal capacity to support wildlife management. The landowning and land using (primarily timber managers and agriculturists, but also including many hunters, trappers and others) minority is the public that controls, to a large extent, the future of wildlife on land it owns/manages/uses.

When I speak of "the public" and "public support," I am referring mainly to this landowning and using minority. The opinions expressed were developed as a result of contact with this public, "my public" in the course of my work as an Extension wildlife specialist in the Southeast, particularly Georgia. An Extension worker has more contact with this public, and it is a different public than wildlife agencies usually reach (Berryman 1960).

This segment of the public is characterized by strong dominionistic and utilitarian attitudes toward animals (Kellert 1980b). It is a public that does not now have wildlife management as a high priority.

I believe public support for nongame management would be a lot stronger if it weren't hindered by four problems. They are:

1. Nongame terminology confuses people;
2. Laws protecting nongame species are, in some states, inconsistent and selectively enforced;
3. Attitudes toward wildlife are polarized; and,
4. Nongame enthusiasts have been wrongly perceived to be anti-management and anti-hunting.

Four Problem Areas That Contribute To Weak Support

Nongame is a Poor Name

Nongame sounds like non-entity. The term, *nongame,* cannot be used to describe wildlife. For example, how shall we identify a bird such as a cardinal? We could call it a "nongame species." We could add that it is a relatively "non-migratory bird." It is a "species for nonconsumptive use." We could also say that it is "webless." These terms are all acceptable jargon with wildlife professionals, yet they tell what the bird *is not*. Let's tell what it *is* . . . it's a cardinal, or a songbird, to the average person. It's a cardinal to me as well.

Biologists would do well to use adjectives to describe wildlife values or characteristics. By this I mean terms like *furbearing, trophy, bait, sport, edible, song* or *raptorial.* Non-descriptive terms like *nongame* reduce the public's ability to value and understand wildlife. Used with discretion, value adjectives can increase the public's appreciation and understanding of wildlife.[1]

The public is also confused by the term, *nongame,* because everyone has a different idea of what it means. Bird watchers think we are discussing songbirds, while reptile hobbyists may assume we are speaking of kingsnakes. *Nongame* is a term of administrative convenience; it has no biological raison d'être. So, of course the public is further confused.

Some states have tacked nongame divisions onto their management organizations. In the past, the state agency reponsible for managing the peoples' wildlife

[1]See Brocke (1979) for a discussion of nongame terminology.

has been called the game department; adding "nongame" was a handy way to inform the public of new activities within the agency. But it is not necessary or desirable to split biologists into game and nongame subject matter staff. A game versus nongame split can make it too convenient for special interest groups to classify wildlife as "mine and yours" (Brocke 1979). These division will push wildlife management further into the political arena.

Nongame has been a difficult handle for wildlife professionals to work under. For example, the Southeastern section of the Wildlife Society tried to organize nongame subcommittees within standing committees, including those for forest wildlife, wetlands, and farm wildlife. These subcommittees grappled with organizational questions such as: What species should be dealt with? What should be our mission? Eventually, the subcommittees were combined under a new heading, the "Nongame Committee." This committee debated the same issues. No central purpose emerged, other than to support nongame legislation. Attendance by state agencies was poor. The chairmanship changed frequently.

Likewise, when the Nongame Association of North America met at the 1982 North American Wildlife and Natural Resources Conference, the same questions emerged. "What should be the mission of the Association?" Some of those present questioned the need of such an association because it might be devisive. At the end, the consensus seemed to be that the mission of the association could be to serve as a clearinghouse for information pertaining to nongame administration.

I believe wildlife administrators will find their work made simpler if they do not isolate nongame as a separate category. (The above discussion excepts endangered species, which, for reasons of the special and urgent needs of the species, can be given special recognition.)

Renaming the game agency the wildlife agency, as proposed by Scheffer (1976), or the conservation department are suggestions with merit. In Missouri's Conservation Department, for example, "nongame" never appears as an administrative division. Nongame species are integrated under a variety of divisions.

Let us also avoid interchanging *nongame* with *nonconsumptive*. There is hardly any kind of wildlife that we don't consume either directly, or indirectly by destroying (consuming) habitat. The term, *nonconsumptive,* applies only to *activities,* such as wildlife viewing and photography. Nonconsumptive activities focus on both game and nongame wildlife. Lyons (1982) identified 55 percent of all Americans over age 16 as nonconsumptive users of wildlife. An important percentage of them were hunters and fishermen. The stereotype of the nonconsumptive user as the unusual person is really a myth; in fact, this user represents the mainstream of American wildlife interest. Although the demand for nonconsumptive uses of wildlife is high (More 1979 Arthur and Wilson 1979), nonconsumptive use isn't necessarily better than consumptive use. There is room for many kinds of use of common wildlife.

"Nongame" has become an easy handle to use. I think we're stuck with the term. However, lets replace "nongame management" with "wildlife management" wherever we can, especially in dealing with the public.

Nongame Laws Are Inconsistent and Selectively Enforced

Laws are made by people and are made to solve a particular problem at a particular time. Some of them cause new problems not forseen at the time they were written. Though more input by wildlife managers would help, it's doubtful that even they could produce perfect wildlife law.

For convenience, I have divided wildlife laws into three categories. They are: Laws that protect the environment; laws that protect habitats; and laws that protect individual animals.

The first group of laws is one where there is no quarrel between wildlife managers and informed public. Clean air and clean water help to keep wildlife populations, and the plants that support them, in a healthy condition.

Laws in category two, specifically those to reward practices that protect habitats, find favor with wildlife managers and landowners. An example is Minnesota's law, passed in 1980, to exempt landowners from property taxes on land maintained in native prairie.

Environmental protection laws, combined with those that encourage landowners to protect valuable wildlife habitats, can be termed carrot and stick laws. They are set up to encourage acts that benefit wildlife environments and also punish undesirable behavior.

It is the third category of wildlife law, laws that protect individual animals from direct human interference, that is beginning to alienate "my public." It often seems to the public that new laws are cutting off their access to common animals by classifying them as nongame for nonconsumptive purposes only. Also, obscure, endangered, slimy, or scaly creatures are perceived to be holding up progress.

This growing resentment with laws that protect individual animals can now be exploited to set back wildlife management achievements. I believe these feelings are exploited by politicians in the name of improving the economy. Note the following comment by Interior Secretary James Watt when he keynoted the 1981 meeting of the Outdoor Writers of American Association in Louisville, Kentucky, "Too often in the recent past there has been a strong tendency to write people out of the equation," Watt said. "This administration begins with the notion that all Americans have a right to enjoy and benefit from their natural heritage."

Why do those remarks strike a favorable response? One reason is that some so-called nongame laws seem inconsistent, authoritarian, and aimed to benefit no one at all. Further, much of the land owning and wildlife using public is mistrustful of the apparent linkage between nongame and the term, *nonconsumptive,* which rightly refers only to wildlife related activities.

My public reacts negatively when they discover that common animals have tax paid support to protect them. These remarks exclude laws protecting birds, which are relatively well accepted. An attempt to support wildlife law that does not address a real need tends to weaken public support. Think of the conservation officer who lives in the community where he enforces law. Will his case against a boy keeping a common toad be thrown out of court? If two or three such cases are dismissed, his credibility is damaged. He knows from experience that he needs public support to enforce the law.

The trend toward an increasing number of arrests, combined with a declining rate of convictions from 1968 to 1972, was associated with an increase in the number of special laws that conservation officers had to enforce (Morse 1972). This trend puts pressure on conservation officers to concentrate their efforts where public support makes convictions easier.

Conservation officers know how the public values animals. Snails and spiders have low value to most people. A turtle has more value. As we go up the animal kingdom to increasingly complex forms, such as birds and mammals, we find they are valued most of all. (See Kellert 1980b, for a discussion of animal preference in America). There is also a value hierarchy within a class. Within the mammals, for example, the rat is at the bottom of the value scale. A squirrel, though he's just a rat with a bushy tail that can sit upright, is perceived by the public to be a desirable animal.

Some people, however, are passionately interested in animals scorned by the general public. Reptile hobbyists are an example. But they, too, are often unhappy with law enforcement. In some states they complain that they can't possess common reptiles and amphibians for personal study. Some wildlife professionals have difficulty obtaining permits for their research. I know one reptile keeper at a public zoo who has quit propagating an endangered crocodile because the administrative burden caused by the new baby crocodiles was too heavy. Meanwhile, rattlesnake roundups continue in the same state. Underground snake markets are thriving. During the recent "Operation Snake Sting" in Atlanta, federal undercover wildlife agents revealed the extent of the illegal trade in reptiles. Reptile hobbyists would like to operate legally so they could help police their ranks. Currently, in some states they must either abandon their interest or break the law.

The 1982 Missouri Wildlife Code, (Missouri Department of Conservation 1982) has an example of a good law that reptile hobbyests can support. It allows that "A maximum of five specimens of other native wildlife . . . excepted as listed . . . may be taken and possessed alive by a resident . . . without a permit."

In addition to state laws that protect common species, there is growing objection from some segments of the public to the threatened and endangered species list. The *Endangered Species Technical Bulletin,* June 1981, shows 13 insects on the list, 25 clams, 16 amphibians, and 80 reptiles. Wildlife managers should continue to identify species in need of special protection and list habitats critical to the survival of rare and endangered wildlife, but we should not brandish the list until strong public support is on our side. The endangered species list can also be viewed as a stack of cards. As the stack gets higher and higher, the risk that public support will weaken and topple the whole stack becomes greater.

Organizations interested in protecting all wildlife weaken public support for lists if they attempt to add common species to protected species lists. A recent example was the move by a protectionist organization to place bobcats, a common animal in some states, in a category so that the export of their hides would be illegal. This effort was dubbed the "bobcat suit." The protectionists' success brought an immediate outcry from many wildlife biologists, the National Animal Damage Control organization and the editors of *Field and Stream* and *Outdoor Life* magazines (February, 1982 issues). They all objected to the misuse of a list that was intended to protect rare species.

Wildlife managers have done well to protect whooping cranes and bald eagles. Public support is with them. For common species and those with weak public support, an approach that uses mainly environmental and habitat protection laws is a better method in the long run.

Management of nongame and endangered species is compatible with management of ecosystems that focuses on key species, usually "steno species" (ecological indicators with narrow tolerance ranges). As long as the selected steno species are maintained, the entire ecosystem can be assumed healthy. (See Odum and Odum 1971).

Graul et al. (1976) recommend this steno species-ecosystem approach because it places ecosystem management within the grasp of many more wildlife personnel. I believe it is also the best management approach for promotion to the public. It would help them better understand the purpose of lists and of laws that protect indicators of environmental quality.

Public Attitudes on Wildlfie Uses Are Polarized.

Getting groups with disparate interests to agree on what's best for wildlife and people is not easy. Attitudes toward various kinds of wildlife are often polarized; disagreements are usually due to attitude clashes. This was brought clearly to the attention of wildlife professionals by Kellert's (1980b) study on American attitudes toward wildlife.

Kellert's classification of the attitudes we all hold toward wildlife has been very helpful in understanding why Americans view wildlife the way we do. Kellert identified 9 categories of attitudes toward wildlife: naturalistic, ecologistic, humanistic, moralistic, scientistic, aesthetic, utilitarian, domionistic and negativistic (including neutralistic). His results suggest that the most common attitudes toward animals are, by far, the moralistic (20%), utilitarian (20%), humanistic (35%) and negativistic (37%) ones. Only 7 percent are strongly ecologistic, and this is the sector that actively supports conservation.

Kellert pointed out that holders of certain attitudes may clash with those who hold contradictory attitudes. The seriousness of these clashes varies with the attitudes. For example, people with scientistic attitudes show curiosity about the physical and biological attributes of animals, and desire more knowledge. Scientistic attitudes are highly compatable with naturalistic attitudes, but rarely clash with other attitude groups. On the other hand, strongly moralistic people (mainly interested in ethical concerns for animal welfare) are likely to hold humanistic attitudes also, but clash with a broad spectrum of other attitudes, including utilitarian, dominionistic, scientistic, ecologistic, and negativistic. Attitudes have their roots in morality, religion, politics, and self-interest. They are emotional factors over which we have little control.

To understand the pro-management versus anti-management division between wildlife interest groups, we must examine the attitudes toward wildlife of their membership. For example, anti-hunting members of an animal protection organization in Michigan ranked ecological, aesthetic, and existence values as the most important values of wildlife (Shaw 1977). Michigan deer hunters ranked the same three wildlife values as most important (Shaw 1975). Although they perceive wildlife to be important for the same reasons, there is a clash of moralistic/humanistic attitudes versus a combination of naturalistic/dominionistic/ecologistic attitudes between their memberships.

For a person with an emotional and spiritual attachment to wildlife, the pursuit of his interest can be considered a religious rite (Clarke 1973), whatever his set of attitudes, and whether he is pro- or anti-management. Changing the attitudes of persons with a strongly moralistic/humanistic orientation so that they might agree with the desirability of population management practices often seems out of the question.

In general, people with a limited spectrum of strongly held attitudes are active in debating and forcing wildlife issues of the anti-management versus pro-management kind. Such individuals seem to me to be characterized by an incomplete set of attitudes. They pose a problem for wildlife professionals interested in management of a diversity of species for multiple uses.

A well informed manager involved in debating a complex wildlife management issue needs a broad spectrum of attitudes in order to make sound judgments. He must remember that people management is an important part of wildlife management; neither management of habitats nor of populations can occur unless people do something, or if they don't do something. A conspicuous attitude bias on the part of a professional manager tends to develop strong enemies as well as strong allies.

If attitudes are strongly held, any argument tends to intensify them (Shay 1977). When management decisions involve polarized attitudes, often the best that a manager can do is to recognize what the attitudes are, and to hold to the political center insofar as possible.

Interest in Nongame Wildlife Has Been Wrongly Perceived as Anti-management and Anti-hunting

The ranks of many wildlife interest citizens groups are growing. The National Wildlife Federation's (1982) *1982 Conservation Directory* lists 481 state and 371 national professional and citizens groups. Some are interested in a broad range of wildlife and environmental issues; some are devoted to a single group of related species, or even a single species. Others are interested primarily in certain kinds of wildlife related activities. Where does the person interested in nongame species fit in?

I made a telephone survey of three major anti-hunting and anti-management organizations (Fund for Animals, Humane Society of the United States, and Friends of Animals). I asked if the nongame movement was helping to increase their membership. Some of the persons I spoke with didn't know what the nongame movement was. Their responses were all similar. Their membership increases in response to a well-publicized cruelty issue, such as killing burros or clubbing harp seals. The combined membership of these three organizations is under 500,000.

I asked the same question of three major wildlife organizations that, in general, favor wildlife management, or at least are not opposed to it (National Audubon Society, National Wildlife Federation, and Sierra Club.) All said they had experienced considerable growth in membership in response to the Reagan Administration's attempt to dismantle environmental safeguards. There is also an increased interest in *all* wildlife, they indicated. These three organizations have a combined membership of well over 5 million.

My public, however, suspects that nongame enthusiasts have thrown in with the anti-management camp. For example, the editor of *Wildlife Harvest,* a magazine for managers of hunting resorts, stated the following in an editorial called, "Wildlife 'Check-off?' " "There's some justified concern that when anti-hunters' funds are involved in 'wildlife management' that they'll try to wield more influence on the game managers." The editor has apparently equated anti-hunter with a person interested in nongame species.

This idea has also been expressed in journals for wildlife professionals, for example by Scheffer (1976) who stated, "I see the nongame movement as . . . mainly a reaction against killing."

There is no new split or conflict in the ranks of wildlife interest groups. What *is* new is that the mainstream of wildlife interest in the U.S. is shifting to nonconsumptive uses that include both game and nongame species. Hunters and other consumers are among the supporters of nongame activities and programs (Witter et al. 1980, Lyons 1982).

How Can We Enlist Public Support for Nongame and Endangered Wildlife Management?

Wildlife managers can keep all wildlife management together, both biologically and administratively, by adopting a steno species-ecosystem approach for nongame management programs so as to avoid isolating nongame from game management.

A wildlife agency that builds a strong image as the benefactor of all wildlife will increase its stength in the minds of the non-hunting public (Shay 1977). Vigorous image-building involvement in nongame programs is vital (Todd 1980), as is the development of effective promotion and marketing skills among wildlife agencies and wildlife personnel (Schick et al. 1976).

Support from rural landowners, particularly farmers and forest landowners, is essential to nongame and all wildlife interests because this minority controls land use and access to the majority of wildlife resources. This audience can be effectively reached with promotional information and management recommendations via a delivery system that is already in place in the 50 states, the Cooperative Extension Service (see Miller 1981, Benson 1977.) Many agencies with wildlife information could tap into the Extension delivery system.

In summary, wildlife professionals will be most successful in enlisting public support for nongame and endangered wildlife management if it can be kept in the mainstream of wildlife management programs. Toward this end, terminology applying to nongame wildlife can be improved. Laws protecting nongames species should address real needs. Diverse attitudes toward wildlife must be recognized and understood by wildlife personnel. Nongame enthusiasts and non-consumptive wildlife users need to be welcomed into the wildlife management fold.

Acknowledgements

The ideas presented here are my own opinions. They were developed by conversations and other communication with a number of persons, especially: Bob Boardman, Jim Byford, Joel Brown, Bob Carlton, Ken Chitwood, Toby Cooper, Jack Crockford, Bill Fitzwater, Bill Frazier. Frank Golley, Tom Gresham, Jay Hair, Bob Hazel, Syd Johnson, Steven Kellert, Jim Miller, Jim Kundell, Jim Morrison, Ron Odom, Gene Odum, Aaron Pass, Tony Peterle, Ernie Provost, Tom Reed, Rita Van Dorn and Jim Wilson.

References Cited

Arthur, L. M., and W. R. Wilson. 1979. Assessing the demand for wildlife resources: a first step. Wildl. Soc. Bull. 7(1):30–34

Benson, D. E. 1977. Role of extension wildlife specialists. Wildl. Soc. Bull. 5(2):56–60

Berryman, J. H. 1960. Wildlife extension: a new and potent management tool. Proc. Western Assoc. Game and Fish Commissioners 40:66–69.
Brocke, R. H. 1979. The name of the nongame. Wildl. Soc. Bull. 7(4):279–282.
Clarke, C. H. D. 1973. Conservation revisited. Wildl. Soc. Bull. 1(2):106–108.
Filion, F. L. 1981. Importance of question wording and response burden in hunting surveys. J. Wildl. Manage. 45(4):873–882.
Graul, W. D., J. Torres, and R. Denney. 1976. A species-ecosystem approach for nongame programs. Wildl. Soc. Bull. 4(2):79–80.
Kellert, S. R. 1979. Public attitudes toward critical wildlife and natural habitat issues, Phase I. PB-80-138332. Natl. Tech. Info. Serv., Arlington, Va. 138 pp.
______. 1980a. Activities of the American public relating to animals, Phase II. PB-80-194-525. Natl. Tech. Info. Serv., Arlington, Va. 178 pp.
______. 1980b. Knowledge, affection and basic attitudes toward animals in American Society, Phase III. USDI Fish and Wildl. Serv., Yale School of Forestry and Environmental Studies, New Haven, Conn. 162 pp.
Lyons, J. R. 1982. Nonconsumptive wildlife-associated recreation in the U.S. in 1980. Presented at the 47th N. Amer. Wildl. and Natur. Resour. Conf., Portland, Oregon.
Miller, J. E. 1981. Increasing educational programs in fish and wildlife. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:201–207.
Missouri Department of Conservation. 1982. Wildlife code of Missouri. Jefferson City, Missouri, 112 pp.
More, T. A. 1979. The demand for nonconsumptive wildlife uses: a review of the literature. Forest Serv. General Tech. Report NE-52. USDA N.E. Forest Exp. Sta., Bromall, Pa. 16 pp.
Morse, W. B. 1972. Wildlife law enforcement, 1972. Presented at Western Association of State Game and Fish Commissioners, July 17, 1972, Portland, Oregon.
Mullin, J. M. 1981. Wildlife "check-off"? Wildl. Harvest 12(12):10.
National Wildlife Federation. 1982. Conservation directory, 27th ed. National Wildlife Federation, Washington, D.C. 297 pp.
Odum, E. P., and H. T. Odum. 1971. Fundamentals of ecology, 3rd. ed. W. B. Saunders Co., Philadelphia.
Scheffer, V. B. 1976. The future of wildlife management. Wildl. Soc. Bull. 4(2):51–54.
Schick, B. A., T. A. More, R. M. DeGraaf and D. E. Samuel. 1976. Marketing wildlife management. Wildl. Soc. Bull. 4(2):64–68.
Shaw, W. W. 1975. Attitudes toward hunting. A study of some social and psychological determinants. Widl. Div. Rep. 2740. Michigan Dep. Natur. Resour., Lansing. 84 pp.
______. 1977. A survey of hunting opponents. Wildl. Soc. Bull. 5(1):19–24.
Shay, R. E. 1977. A sociological theory related to wildlife management. Wildl. Soc. Bull. 5:130–131.
Todd, A. W. 1980. Public relations, public education and wildlife management. Wildl. Soc. Bull. 8(1):55–60.
Witter, D. J., J. D. Wilson and G. T. Maupin. 1980. "Eagle Days" in Missouri: characteristics and enjoyment ratings of participants Wildl. Soc. Bull. 8(1):64–65.

California's Central Valley Wintering Waterfowl: Concerns and Challenges

David S. Gilmer and Michael R. Miller
U.S. Fish and Wildlife Service, Dixon, California

Richard D. Bauer
U.S. Fish and Wildlife Service, Portland, Oregon

John R. LeDonne
California Department of Fish and Game, Sacramento

Few places on the North American continent can boast of the concentrations of migratory birds that winter in the Central Valley of California. Long before agriculture and industrialization came west, this great valley served as a major wintering ground for millions of migratory birds. Fall flights of waterfowl, shorebirds, waders, raptors, and passerines returned annually to inhabit the vast wetland, riparian, and grassland habitats which covered the valley floor (Dasmann 1966, Bakker 1971).

Major changes in the Central Valley during the last century have profoundly influenced its physical and biological features. Wetland, riparian, and grassland habitats have been devastated by flood control, drainage, water diversion projects, and agricultural development. Waterfowl and other migratory birds that depend on these areas for vital wintering habitat face an uncertain future as world market demands continue to encourage agricultural, industrial, and urban growth in California.

Concerns for California's shrinking waterfowl habitat are not new. Indeed, over 30 years ago, Day (1949) described the habitat picture in the state as "discouraging." In the past, management and research efforts have focused mostly on breeding grounds. However, many species of waterfowl occupy wintering habitat for as long as eight months of the year. Furthermore, biologists have indicated that habitat quality on wintering grounds may have a major influence on waterfowl populations (Shannon 1965, Chabreck 1979, Heitmeyer and Fredrickson 1981). Recognition of the importance of wintering areas and concern for their losses have prompted increased emphasis on wintering populations and habitats in strategies for continental waterfowl management (Brace et al. 1981).

Our objectives are to describe the Central Valley as a wintering area for waterfowl, to identify problems confronting these waterfowl, to discuss current efforts to resolve these problems, and to recommend actions needed to improve waterfowl management.

Waterfowl Populations and Habitats

Each year in early August the first flights of ducks from northern breeding areas begin arriving in the Central Valley. Populations increase through the fall and by late December peak at about 5.6 million ducks and geese. Overall, about 10–12 million waterfowl and hundreds of thousands of other water-related birds annually winter in or pass through the valley. These birds originate mostly in breeding habitats primarily in Alaska and the provinces and territories of western Canada (Kozlik 1975). Based on midwinter surveys (Pacific Flyway Study Committee 1972–1981) a large-percentage of the Pacific Flyway waterfowl population winters here. Major species include whistling swans (*Cygnus columbianus*)—69 percent, Pacific white-fronted geese (*Anser albifrons frontalis*)—89 percent, lesser snow geese (*A. caerulescens caerulescens*)—90 percent, cackling Canada geese (*Branta canadensis minima*)—84 percent, pintails (*Anas acuta*)—76 percent, mallards (*A. platyrhynchos*)—25 percent, northern shovelers (*A. clypeata*)—77 percent, greenwinged teal (*A. crecca carolinensis*)—47 percent, American wigeon (*A. americana*)—62 percent, gadwalls (*A. strepera*)—50 percent, wood ducks (*Aix sponsa*)—93 percent, and canvasbacks (*Aythya valisineria*)—44 percent. The entire continental population of tule white-fronted geese (*A. a. gambelli*), endangered Aleutian Canada geese (*Branta canadensis leucopareia*), and all but a fraction of Ross' geese (*Anser rossii*), winter in the Central Valley. Altogether, about 60 percent of the Pacific Flyway waterfowl population and 18 percent of the continental population winters here.

The Central Valley extends 400 miles (640 km) nearly north and south through the heartland of California. Bounded on the east by the Sierra foothills and on the west by the Coast Ranges, the valley floor averages 40 miles (64 km) wide and encompasses 16,000 square miles (41,500 km^2). The valley is divided into three major regions: the Sacramento Valley, draining southward; the San Joaquin Valley, draining northward; and the Delta and Suisun Marsh area where the Sacramento and San Joaquin river systems meet (Figure 1). Major drainage basins that make up the Sacramento Valley are the Butte, Colusa, Sutter, Yolo, and American. The San Joaquin Valley consists of the San Joaquin Basin in the north and the Tulare Basin, which forms a closed drainage system at the southern end of the valley. In the Sacramento Valley, flood waters are contained by a system of bypasses (diked agricultural lands) that direct Sacramento River overflow around major metropolitan areas and into the Delta. On a smaller scale, similar bypasses have been constructed along the San Joaquin River.

Within the last 50 years, public works projects responding to water demands of agriculture and large metropolitan areas have produced a great network of artificial lakes and rivers interconnected by a system of aqueducts. The federally administered Central Valley Project and the associated State Water Project are the most important of these systems. A primary function of these massive conveyances is to transport water from major sources in northern California to arid regions in the south. This reliable water source, rich soils, and ideal climate have made California the nation's leading agricultural state for the past 25 years (Kahrl 1979).

Virtually all waterfowl habitat in the Central Valley today is on public lands managed for wildlife or on lands of private duck hunting clubs. Wetlands on these areas total about 300,000 acres (121,000 ha) of marsh or other flooded habitat (Table 1). Most of these wetlands are seasonal and all are managed to some degree. Up to 96,000 more acres (39,000 ha) of habitat are created if the bypasses flood during the winter (F.E. Smith, personal communication). An additional 200,000–600,000 acres (81,000–243,000 ha) of harvested rice and other grain fields provide a food resource to waterfowl if these areas are unplowed or flooded.

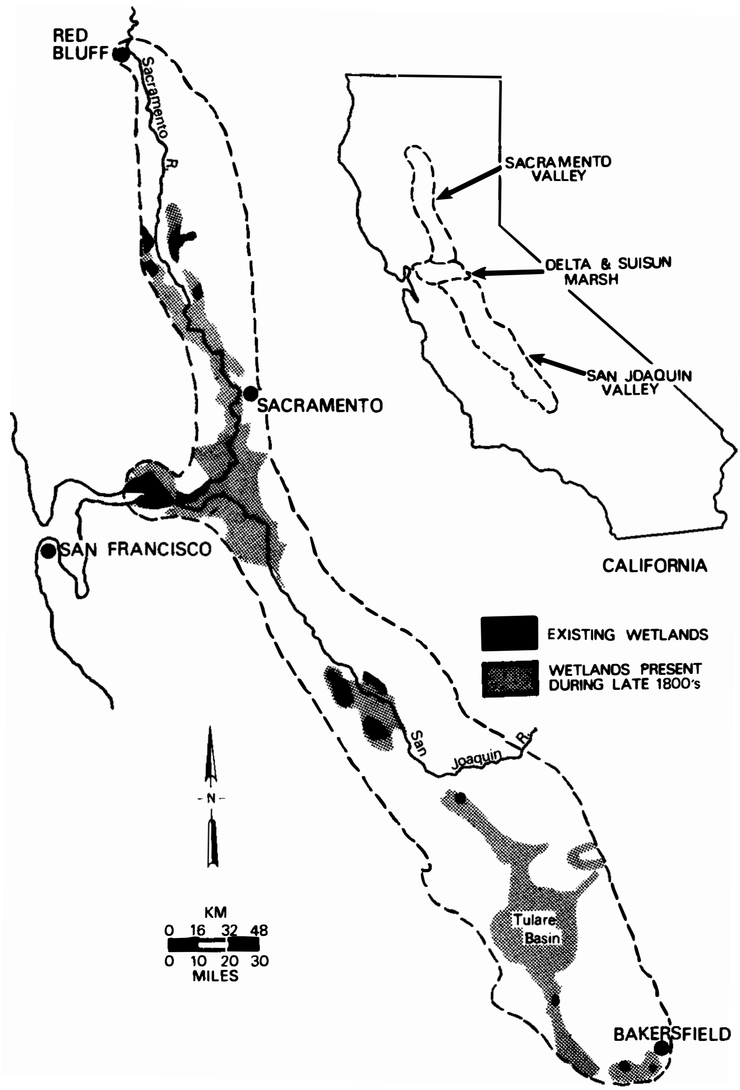


Figure 1. Major regions of the Central Valley of California and the distribution of wetlands in the Valley during the late 1800s compared to the present.

Problems Confronting Waterfowl

Habitat Resources

In the span of little more than a century, native wetland areas in the Central

Table 1. Ownership of waterfowl habitat in the Central Valley, 1979.

	Wetland area (acres)			
	Private	Federal[a]	State[b]	Total
Sacramento Valley	59,800[c]	23,500	8,400	91,700
Delta-Suisun Marsh	71,600[d]	———	13,900	85,500
San Joaquin Valley	75,800	30,600	15,400	121,800
Total	207,200[e]	54,100	37,700	299,000

[a]Includes total area for National Wildlife Refuges including: Sacramento, Delevan, Colusa, Sutter, San Luis, Merced, Kesterson, Kern, Pixley, and Butte Sink Wildlife Management Area.
[b]Includes total area for State Wildlife Areas including: Gray Lodge, Grizzly Island, Joice Island, Lower Sherman Island, Los Banos, Mendota, and Volta.
[c]Based on duck club survey (California Department of Fish and Game 1979). Includes only flooded areas. About 26,500 acres are native wetlands.
[d]Includes 18,000 acres of fresh marsh, brackish marsh, and riparian habitat in the Delta (Madrone Associates 1980) and 53,600 acres flooded in the Suisun Marsh (California Department of Fish and Game 1979).
[e]Total wetland and upland area in private duck clubs is 379,400 acres (California Department of Fish and Game 1979).

Valley have declined so drastically that they may now be described as small islands in a sea of agricultural and urban development. Before settlement, the state contained an estimated 5 million acres (2 million ha) of wetlands (Anderson and Kozlik 1964). About 4 million of this total were in the Central Valley. Closely associated with these wetlands were extensive riparian forests that covered about 900,000 acres (364,000 ha) (Katibah 1981). Recent estimates (U.S. Fish and Wildlife Service 1978) indicate that only about 6 percent of the original wetland area (Figure 1) and 11 percent of the riparian forest (Katibah 1981) now remains in the Central Valley.

Loss of native wetland habitat has been more pronounced in some regions of the Valley than in others. Most striking has been the disappearance of waterfowl habitats in the delta and the San Joaquin Valley, particularly the Tulare Basin where natural flooding once created huge water areas attracting millions of ducks (Dasmann 1966).

Encroachment by agriculture is the major threat to privately owned native marshes and grasslands in the Central Valley. The ecological, aesthetic, and recreational value of these areas has not competed effectively against strong economic incentives to grow cash crops such as cotton and rice. Operational costs of duck clubs and taxes on these lands have also been prime factors in the loss of wetlands (R.L. Gray, personal communication). Decline in hunting quality has contributed to habitat conversion in some instances.

Conversion of wetlands to rice, cotton, and other crops has caused major habitat losses in the Central Valley. Rice has been an important crop in California since 1912. Because of the aquatic nature of rice, marsh soils are ideal for its production. Total harvested acreage of rice increased from 238,000 acres (96,000 ha) in 1950 to 590,000 acres (239,000 ha) in 1981 (California Crop and Livestock Reporting Service 1981). Strong international markets during the last 5 years have stimulated rice production. In the Colusa Basin of the Sacramento Valley, wetlands declined only slightly from about 15,000 acres (6,100 ha) in 1952 to 13,000 acres (5,300 ha) in 1970. But between 1970 and 1979, 7,000 more acres (2,800 ha) were lost. Land for conversion to rice production has come mostly from duck clubs (U.S. Fish and Wildlife Service 1979, Gray 1979).

Harvested rice fields in private duck club ownership are usually reflooded in the fall to provide waterfowl hunting areas. Similarly, some ranchers also reflood their ricelands and lease them for hunting. These fields provide important feeding areas for some species of waterfowl. However, the uniform condition of ricelands reduces the diversity of food, cover, and water depth offered by marshlands; consequently a wide range of birds, including many waterfowl species, dependent on native habitats may not benefit from this conversion. For example, species dependent on marsh habitat such as gadwalls and northern shovelers may be impacted by this loss more than pintails and mallards.

Wetland losses in the southern part of the Central Valley have been caused by conversion to cotton and a variety of row crops. A 65,000-acre (26,000-ha) area of private duck clubs known as the Grasslands represents the largest tract of waterfowl habitat in the San Joaquin Valley. Large concentrations of ducks are attracted there by extensive native pasture and abundant seasonal wetlands. In spite of its value to waterfowl, 3,255 acres (1,320 ha) of habitat (19 duck clubs) were converted to croplands between 1971 and 1981. About 55 percent of this loss has occurred in the last two years (G.W. Kramer, personal communication).

Destruction of riparian forests throughout the Central Valley has reduced the availability of habitat important for food and cover (Hurst et al. 1980). This has resulted in a lowered carrying capacity for waterfowl, such as wood ducks, and dozens of other avian species that depend on these areas for wintering as well as breeding habitat.

A less obvious loss of habitat occurs when some private clubs drain flooded areas when the waterfowl hunting season closes. This practice may eliminate valuable feeding areas in late winter when adequate food becomes most critical. Loss of each parcel of habitat, no matter how small, causes a decline in the quantity and diversity of habitat available to sustain wintering waterfowl and other wildlife.

Water Resources

Water of sufficient quantity and quality is a major limiting factor for wetlands and waterfowl populations in the Central Valley. Legislation governing the allocation of surface water by the Central Valley Project and the State Water Project has assigned higher priority to agricultural and municipal needs than to fish and wildlife requirements (U.S. Water and Power Resources Service 1980). About 87 percent of the water provided by these systems is used for irrigation (Kahrl 1979). Increased demands from agricultural and municipal users will severely curtail the availability of water in the future (U.S. Water and Power Resources Service 1980). Of nine National Wildlife Refuges in the Central Valley, only three have adequate water rights or ground water sources to reasonably guarantee their future water supply. The optimum management of waterfowl habitat on refuges requires about 200,000 acre-feet (81,000 ha-m) per year (U.S. Fish and Wildlife Service 1981). The average amount received annually is about 140,000 acre-feet (57,000 ha-m). However, only 40,000 acre-feet (16,000 ha-m) are reasonably secure, and even this amount could be reduced in critical periods. State Wildlife Areas and private duck clubs are faced with a similar problem. Such water restrictions severely limit the effective management and potential expansion of waterfowl habitat in the Central Valley.

Another problem that concerns waterfowl managers is the prospect of major new water development projects (i.e., enlargement of Shasta dam and the Cottonwood Creek project). The increased water storage capability of these projects would reduce winter flooding of bypasses in the Sacramento Valley. Additional water provided by these projects may prove beneficial to waterfowl, but it could also stimulate expansion of agricultural development at the expense of native wetlands.

Periodic droughts in California have placed hardships on all water users, but waterfowl habitat has been particularly vulnerable. During critical periods, water allocations to managed wetland habitat may be reduced by as much as 75 percent (R.F. McVein, personal communication). Restricted water supplies during the 1976–1977 drought forced refuges to reduce the amount of marsh habitat. Waterfowl areas in the San Joaquin Valley without adequate ground water sources were most affected. For example, in 1977 Kern refuge maintained only 30 percent of the usual wetland acreage (T.J. Charmley, personal communication).

Ground water is not a dependable or reasonable source for the maintenance of wetland habitat in the San Joaquin Valley. Serious ground water overdraft has lowered water tables and increased pumping costs. Furthermore, utility rates have more than tripled in recent years (R. Oser, personal communication).

Water quality is sometimes a problem for wetland management. Surface water used to flood waterfowl habitat is mostly reused irrigation water. In the Sacramento Valley this water is generally of adequate quality, but in the San Joaquin Valley, salinity problems may reduce the value of water sources. Water quality problems resulting from decreased flows from the Sacramento-San Joaquin River System may threaten the future of the Suisun Marsh by allowing seawater intrusion (Miller et al. 1975, Rollins 1981).

Agricultural Practices

Crop production in the Central Valley is constantly changing as new tillage practices, genetic strains of plants, and irrigation and harvest methods are developed. As native wetlands are lost, waterfowl become more dependent on certain agricultural lands for food resources. A shift in cropping patterns on these lands could significantly alter the Central Valley's waterfowl carrying capacity (Kozlik 1974, Smith 1981) or the activity patterns of these birds (Michny 1979).

Large numbers of waterfowl can subsist in the Central Valley during winter because waste rice represents a vast food source that, for some species, partly offsets the reduction of natural wetland habitat. However, this situation is changing because new rice strains that mature more rapidly and allow harvesting with less waste are now available. Modern land leveling and effective use of herbicides are becoming standard practices (Rutger and Brandon 1981) which eliminate the habitat diversity characteristic of older rice farming methods. For instance, land leveling produces large rectangular rice fields and eliminates most of the contour levees which normally provide a source of native marsh plants valuable to waterfowl for food and cover.

Biologists have speculated that the dramatic increase in corn production on the Delta, in combination with field flooding for leaching and hunting following harvest, resulted in increased use of this area by pintails (Michny 1979). The long term availability to waterfowl of harvested Delta corn must be assessed with caution; economic factors that contributed to such a rapid increase in corn acreage could also produce an equally spectacular decline.

Production of barley, wheat, and safflower in rotation with cotton is a well established practice in the Tulare Basin. Harvested grain fields, pre-irrigated before planting cotton, provide valuable habitat for the traditional August arrival of pintails. However, serious salinity problems in the Tulare Basin are prompting the installation of tile drainage systems that may bring an end to the farming practices responsible for attracting large populations of wintering waterfowl (G.W. Kramer, personal communication).

Disease and Environmental Contaminants

Waterfowl in the Central Valley are forced to concentrate on habitat that has declined over the years. Crowded conditions, poor habitat quality, and adverse weather may contribute to the spread of disease. Botulism and avian cholera are chronic waterfowl disease problems. In some years, deaths attributed to botulism in the state have exceeded 250,000 (Hunter et al. 1970). Similarly, avian cholera losses in California one winter exceeded 70,000 birds (Rosen 1971). According to Friend (1981), the Central Valley, along with three other areas in North America, has developed into an avian cholera enzootic area. Over 33,000 waterfowl killed by disease were picked up during the 1980–81 winter season on public and private lands in California (U.S. Fish and Wildlife Service, unpublished report). In recent years lead poisoning has been found in 3 to 10 percent of the total number of dead waterfowl examined annually from sampled areas (U.S. Fish and Wildlife Service and California Department of Fish and Game, unpublished reports).

The impact of environmental contaminants on waterfowl wintering in the Central Valley has not been adequately examined, but the intensive agriculture common to the region and its heavy dependence on chemicals provide cause for concern. About 17 percent of all pesticides used in the United States are applied in California (S.M. Nash, personal communication). In 1980 over 121 million pounds (55 million kg) of registered pesticides were used in the state; about 55 percent of this was applied in counties located in the Central Valley (California Department of Food and Agriculture 1981).

Urban Populations

Already the most populous state (23.8 million), California is expected to reach 28 million by 1990 (California Population Research Unit 1981). The most significant impact of this increase will be an even greater demand on the limited spatial and water resources of the state. Loss of private duck hunting clubs to agricultural development causes more hunters to seek recreation on public hunting areas. Between 1970 and 1979, the average seasonal hunting capacity of 14 managed areas in the Central Valley was 92,000 hunter visits. On the average, demand for hunting on these areas was at capacity, and in some areas it exceeded available quotas by as much as 27 percent. An estimated 3–4 million people annually spend some time viewing wildlife in the Central Valley (U.S. Fish and Wildlife Service 1981).

As the number of resource users increases relative to the amount and distribution of wildlife habitat, it will become increasingly difficult to provide adequate opportunities for recreation and even more difficult to provide esthetically pleasing experiences. These demands must be met if managers are to maintain the public's interest in the waterfowl resource.

Current Efforts To Resolve Problems

Habitat Preservation

Concerns for habitat preservation prompted the U.S. Fish and Wildlife Service to prepare guidelines in 1976 for implementing the Migratory Bird Land Acquisition program. The Central Valley was ranked high in a nationwide priority system developed for this effort. Development of a comprehensive plan for wetland preservation (U.S. Fish and Wildlife Service 1978) was the first step in starting the program in California. Funds are obtained by the sale of Federal Migratory Bird Hunting and Conservation stamps. To date, most of the funds designated for California have been used in the Grasslands area where perpetual easements have been obtained on 11,700 acres (4,700 ha). The goal for the Grasslands is to acquire easements on a total of 48,000 acres (19,400 ha). In the Butte Sink of the Sacramento Valley, 1,154 acres (470 ha) have been protected by easement or fee purchase.

The Water Bank Program of the U.S. Department of Agriculture was originally implemented to encourage the preservation of waterfowl breeding habitat. Some provisions of this program are important for protection of wintering habitat. In the Central Valley, 22,810 acres (9,200 ha) are currently protected by Water Bank agreements (R.F. Schultze, personal communication).

The California State Legislature has been active in wetland protection. In 1976 they passed the California Wetlands Preservation Act. This legislation was broadened by the passage of Senate Concurrent Resolution No. 28 in 1979. These documents officially recognized the need to protect and restore California's wetlands. The 1979 resolution directed the Department of Fish and Game to prepare a plan by December 1982 to increase the amount of wetlands in California by 50 percent. Although this requirement does not mandate the implementation of any recommendations, it sets the stage for future legislation. Other significant state legislation that benefits waterfowl includes the 1977 Suisun Marsh Preservation Act, which protects this marsh and adjacent areas from land use changes.

Water for Wetlands

Fish and wildlife have traditionally been given low priority in the allocation of water by the Central Valley Project (CVP) and State Water Project (SWP). Authorization to protect and conserve these resources was not included as a function of the projects. Furthermore, the impacts of water development projects on fish and wildlife have not been fully recognized until recently (U.S. Bureau of Reclamation 1978), and adequate laws to insure protection of these resources are not available. Therefore, an issue of significant importance to future water supplies for waterfowl habitat in the Central Valley is the proposed reauthorization of the CVP. This legislation would give fish and wildlife equal consideration with other project purposes when allocating future CVP water supplies (see U.S. Water and Power Resources Service 1980).

Outlook for the reauthorization of the CVP is not optimistic at this time. However, for the future, Bureau of Reclamation administrators intend to fulfill some refuge needs from CVP water supplies. Negotiations between the California Department of Fish and Game, and the CVP, and SWP are being made to insure that future water needs of wildlife areas are given equal priority with agriculture and municipal needs.

Pumping ground water has created high operating costs for some refuges. Recent negotiations between the Fish and Wildlife Service and the Western Area Power Administration have tentatively resulted in provisions for low cost power for refuges. This agreement would be effective for 12 years and result in an estimated annual saving of about one million dollars in utility costs by 1994 (R. Oser, personal communication).

High soil salinity affecting about 400,000 acres (162,000 ha) of irrigated farmland in the San Joaquin Valley poses a serious threat to agricultural productivity (San Joaquin Valley Interagency Drainage Program 1979). A solution for this problem involves a system to manage and dispose of saline waters recovered from subsurface tile drains. One alternative method of disposal includes the creation of 64,000 acres (26,000 ha) of new or restored wetland habitats to receive these waters (San Joaquin Valley Interagency Drainage Program 1979). Although salt load in this water is high (up to 15 mmhos/cm EC), preliminary evaluation indicates that it has potential for marsh management (Ives et al. 1977). The Fish and Wildlife Service and the Department of Fish and Game have proposed a study to evaluate methods to use this water as a supplementary source for maintaining waterfowl habitat in the arid portions of the San Joaquin Valley. Assembly Bill No. 1376, recently passed by the California Legislature, prohibits the discharge of any San Joaquin Valley agricultural drainage water until a program to evaluate the feasibility of its use in managing waterfowl wintering habitat has been funded and initiated.

Research Accomplishments

Information obtained from numerous studies by resource agencies and academic institutions have expanded our knowledge of waterfowl ecology in the Central Valley. The Department of Fish and Game, over many years, has conducted research on a wide range of waterfowl related topics. California universities have been particularly involved in studies of the basic aspects of waterfowl biology. More recently, the Fish and Wildlife Service has initiated ecological studies identified as critical to management needs. These studies provide a source of information for addressing waterfowl problems and refining future research objectives.

Recommendations For Research and Management

People have become more aware and knowledgeable of resource issues during the past decade. Increased public attention focused on wildlife issues requires that management's decisions be based on the most accurate and credible information available. Studies designed to address specific and critical questions are required to assure accurate information for waterfowl management. The dynamic nature of the Central Valley requires that research be responsive to changing conditions associated with human impacts on the environment.

Topics that should be emphasized by research include:

1. Evaluate alternative water sources for managing wetland habitat.
2. Develop methods of using available water most effectively.
3. Assess winter food and other requirements of key species and the ability of major habitats to provide these resources.
4. Develop and evaluate methods to obtain better quantitative data on abundance and distribution of waterfowl.
5. Evaluate the influence of weather, agriculture, and hunting on the distribution and abundance of waterfowl.
6. Evaluate the cause, chronology, and magnitude of non-hunting mortality.
7. Assess the physical condition and reproductive potential of waterfowl relative to winter habitat conditions.

Topics that should be emphasized by management include:

1. Develop means to encourage landowners to preserve wetlands.
2. Complete the National Wetland Inventory in the Central Valley.
3. Monitor land use changes that influence waterfowl activity and threaten habitat.
4. Develop a plan to secure long term water sources for federal, state, and private waterfowl habitats.
5. Implement management strategies for public waterfowl areas that will enhance their carrying capacity for wintering waterfowl.

Conclusions

Today, as it did a century ago, the Central Valley provides wintering habitat for millions for waterfowl. This seems remarkable because much of the native habitats that waterfowl traditionally depended on in the Valley have been systematically eliminated over the years. Some agricultural lands provide alternative food sources for waterfowl; yet the ability of these areas to supply all requirements for wintering waterfowl populations is questionable. Furthermore, such changes may result in shifts in species composition of wintering populations over the long term.

The interest of resource managers has recently focused on wintering grounds because habitat losses on these areas have reached alarming proportions. Our understanding of the activities and requirements of wintering waterfowl is inadequate to advise managers struggling to prevent further habitat losses and attempting to effectively manage protected areas. New evidence that relates winter habitat conditions to the productivity of waterfowl adds increased urgency for the management of these habitats.

Recently, the Fish and Wildlife Service has directed research effort towards evaluation of the relation between waterfowl populations and wintering habitat in the Central Valley. We think this effort is long overdue. Waterfowl management problems in the Central Valley are complex. Solving these problems necessitates the collective expertise of federal and state resource managers, researchers, private groups, landowners, and legislators. Concerted efforts must be directed to identify the most important waterfowl problems or issues and to effectively allocate resources to accomplish desired objectives. Innovative research and management methods will be required to accomplish more with fewer resources. Great potential for cooperative effort exists.

The challenge to resource managers in the Central Valley is to maintain a place for waterfowl in a dynamic environment that is heavily impacted by human activity. At risk are a major ancestral wintering area for migratory birds and the opportunities for the use of these resources by future generations.

Acknowledgements

We kindly acknowledge the comments provided by J. C. Bartonek, E. J. Collins, D. P. Connelly, D. A. Daniel, G. W. Kramer, F. M. Kozlik, J. J. McKevitt, A. W. Miller, H. W. Miller, H. M. Ohlendorf, C. T. Osugi, D. G. Raveling, F. E. Smith, P. F. Springer, R. C. Stendell, and D. C. Zeiner on early drafts. T. J. Charmley, H. A. George, R. L. Gray, J. E. Hill, R. F. Schultze, L. B. Scott, J. L. Wilson, and G. Zahm generously provided unpublished data. W. P. Burger and J. M. Madril assisted with data summaries and drafting. E. Bartels provided library services. Technical editorial assistance was proivded by W. R. Dryer and P. F. Springer.

Literature Cited

Anderson, J. M., and F. M. Kozlik. 1964. Private duck clubs. Pages 519–526 *in* J. P. Linduska, ed. Waterfowl tomorrow. U.S. Government Printing Office, Washington, D.C. 770 pp.

Bakker, E. S. 1971. An island called California. Univ. of California Press, Berkeley. 357 pp.

Brace, R. K., R. S. Pospahala, and R. J. Blohm. 1981. Evaluation of stabilized season lengths and bag limits for hunting ducks in the United States and the Prairie Provinces of Canada. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:35–43.

California Crop and Livestock Reporting Service. 1981. Field crop statistics, California 1979–1980. Calif. Crop and Livestock Reporting Service, Sacramento. 26 pp.

California Department of Fish and Game. 1979. Duck club survey. Project No. W-3OR-26 to W-3OR-31. California Dep. Fish and Game, Sacramento. 5 pp.

California Department of Food and Agriculture. 1981. Pesticide use report—1980. California Pesticide Registration and Agricultural Productivity, Sacramento. 255 pp.

California Population Research Unit. 1981. Interim total population projections 1980–1990. Report 81 P-1. California Department of Finance, Finance and Economic Research, Sacramento.

Chabreck, R. H. 1979. Winter habitat of dabbling ducks—physical, chemical and biological aspects. Pages 133–142 *in* T. A. Bookhout, ed. Waterfowl and wetlands: an integrated review. Proc. 1977 Symp., Madison, Wisc., N. Cent. Sect., The Wildlife Society.

Dasmann, R. F. 1966. The destruction of California. Collier Books, N.Y. 223 pp.

Day, A. M. 1949. North American waterfowl. The Stackpole Co., Harrisburg, Pa. 363 pp.

Friend, M. 1981. Waterfowl management and waterfowl disease: Independent or cause and effect relationships? Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:94–103.

Gray, R. L. 1979. Water bank program protects wetlands. Outdoor California. 40:9.

Heitmeyer, M. E., and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:44–57.

Hunter, B. F., W. E. Clark, P. J. Perkins, and P. R. Coleman. 1970. Applied botulism research including management recommendations. Wildl. Manage. Progress Rep., Calif. Dep. Fish and Game, Sacramento. 87 pp.

Hurst, E., M. Hehnke, and C. C. Goude. 1980. The destruction of riparian vegetation and its impact on the avian wildlife in the Sacramento River Valley, California. American Birds 34:8–12.

Ives, J. H., C. R. Hazel, P. Gaffney, and A. W. Nelson, 1977. An evaluation of the feasibility of utilizing agricultural tile drainage water for marsh management in the San Joaquin Valley, California. Jones and Stokes Associates, Inc., Sacramento. 172 pp.

Kahrl, W. L., ed. 1979. The California water atlas. California Governor's Office of Planning and Research, Los Altos. 118 pp.

Katibah, E. F. 1981. A brief history of the riparian forests in the Central Valley of California. *In* R. E. Warner, ed. Proc. of the Calif. Riparian Systems Conf., University of California, Davis. Sept. 17–19, 1981. California Water Resources Center Report No. 55. Univ. California, Davis.

Kozlik, F. M. 1974. Waterfowl of California. California Dep. Fish and Game, Sacramento. 39 pp.

———. 1975. Management and production—West Coast habitat. Int. Waterfowl Symp. 1:88–91.

Madrone Associates. 1980. Delta wildlife habitat protection and restoration plan. Madrone Associates, Sacramento, Calif. Variable pagination.

Michny, F. J. 1979. Trends of pintails wintering in the Suisun Marsh, California based on an analysis of 20 years of aerial surveys. U.S. Fish and Wildlife Service, Sacramento, Calif. 45 pp.

Miller, A. W., R. S. Miller, H. C. Cohen, and R. F. Schultze. 1975. Suisun Marsh Study. Soil Conservation Service, Davis, Calif. 186 pp.

Pacific Flyway Study Committee. 1972–1981. Pacific flyway waterfowl reports. Nos. 67–85.

Rollins, G. L. 1981. A guide to waterfowl habitat management in the Suisun Marsh. California Dep. Fish and Game, Sacramento. 109 pp.

Rosen, M. N. 1971. Avian cholera. Pages 59–74 *in* J. W. Davis, R. C. Anderson, L. Karstad, and D. O. Trainer, eds. Infectious and parasitic diseases of wild birds. Iowa State Univ. Press, Ames. 344 pp.

Rutger, J. N., and D. M. Brandon. 1981. California rice culture. Scientific American 244:42–51.

San Joaquin Valley Interagency Drainage Program. 1979. Agricultural drainage and salt management in the San Joaquin Valley. San Joaquin Valley Interagency Drainage Program, Fresno, Calif. 167 pp. + appendices.

Shannon, W. T. 1965. Private clubs and the waterfowl resource. Trans. N. Amer. Wildl. Conf. 30:255–259.

Smith, F. E. 1981. The great Central Valley, the changes are more subtle now. Outdoor California 42:10–12, 21.

U.S. Bureau of Reclamation. 1978. Fish and wildlife—Problems, opportunities, and solutions. Total water management study for the Central Valley Basin, California. U.S. Bureau of Reclamation, Sacramento, Calif. 59 pp.

U.S. Fish and Wildlife Service. 1978. Concept plan for waterfowl wintering habitat preservation—Central Valley, California. U.S. Fish and Wildlife Service, Portland, Ore. 116 pp. + appendices.

———. 1979. Land acquisition ascertainment report for the Colusa Basin wetlands. U.S. Fish and Wildlife Service, Portland, Ore. 57 pp.

———. 1981. Strategy plan, Central Valley of California. U.S. Fish and Wildlife Service, Portland, Ore. 37 pp.

U.S. Water and Power Resources Service. 1980. Environmental statement on the reauthorization of the CVP and the coordinated operating agreement for CVP-SWP. U.S. Water and Power Resources Service, Sacramento, Calif. Variable pagination.

Current Status and Management Challenges For Tule White-Fronted Geese

Daniel E. Timm
Alaska Department of Fish and Game, Anchorage

Michael L. Wege and David S. Gilmer
U.S. Fish and Wildlife Service, Dixon, California

Introduction

Since large, dark tule white-fronted geese (*Anser albifrons gambelli* Hartlaub) were first described in Texas over a century ago by Hartlaub (1852), and again 65 years later in California by Swarth and Bryant (1917), tule geese have been the subject of at least 14 studies in California and 8 attempts to locate summering birds in the Artic. Central questions of these efforts have been: Is the tule goose a distinct subspecies? What is their range and population size? How can the birds be identified? and What threatens their existence?

The purpose of this paper is to present the current status of tule geese, including taxonomy, distribution, population size, and management challenges, and to provide management recommendations. Intensive work on tule geese in Calfornia by the U.S. Fish and Wildlife Service since 1978 and in Alaska by the Department of Fish and Game since 1979 has provided the basis for this paper.

Taxonomy

Verification of Nesting Grounds

During 1980 and 1981, morphological data were obtained from 88 molting whitefronts in Redoubt Bay and Susitna Flats, Cook Inlet, Alaska (Figure 1). Measurements for adults with young ($N = 49$) were combined with those without ($N = 39$) because there was no significant difference ($P > 0.01$) for any data set.

Comparisons of culmen, diagonal tarsus, and nare to bill tip lengths (Baldwin et al. 1931) for both sexes of *gambelli* from Cook Inlet and California showed no differences ($P > 0.05$). Differences in these measurements between *gambelli* from Cook Inlet and Pacific whitefronts (*A. a. frontalis*) from California were highly significant for both sexes ($P < 0.001$). All *gambelli* captured at Redoubt Bay exhibited the diagnostic chocolate brown head and neck and blackish back described by Bauer (1979) and Krogman (1979).

During the two winters 1979–80 and 1980–81, 200 *gambelli* and about 1,000 *frontalis* (C. Ely, personal communication) were individually marked in California with plastic collars. After known losses, a maximum of 178 collared *gambelli* could have been observed during the following summers, of which 44 (24.7 percent) were positively identified in Cook Inlet in 1980 and 1981. One marked and two unmarked *frontalis* were seen summering in Cook Inlet.

Subspecies classification would have been inappropriate had there been a homogeneous mix of large and dark whitefronts with smaller and lighter birds on the

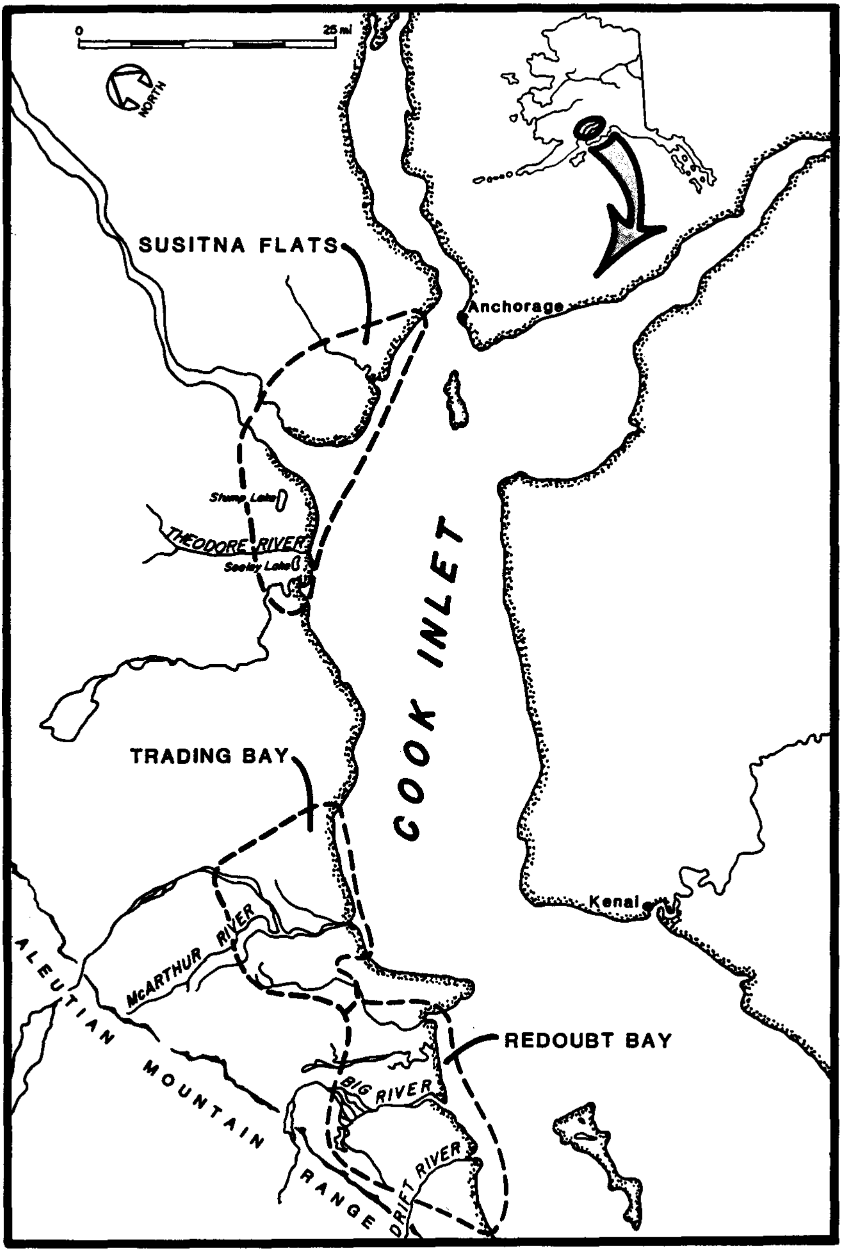


Figure 1. Upper Cook Inlet, Alaska.

breeding grounds. Sympatry with *frontalis* would have warranted full species classification whereas an allopatric relationship would dictate subspecific recognition (Ratti 1980).

We consider *gambelli* to be a distinct subspecies based on its geographical isolation from other whitefronts on the breeding grounds (Gabrielson and Lincoln 1959, D. Timm, unpublished data), distinctive morphological traits, and distribution and behavior of marked birds on migration and wintering areas (tule geese tend to segregate from other whitefronts).

Nomenclature

Elgas (1970) presented morphological data for eight relatively large and dark whitefronts he captured in Old Crow Flats of northwestern Yukon, about 600 miles (960 km) northeast of Cook Inlet. Since recoveries of smaller, lighter colored birds banded there came from the Central Flyway, Delacour and Ripley (1975) believe that the large dark birds from Old Crow Flats are the ones described in Texas by Hartlaub (1852). Consequently, they called tule geese wintering in California *elgasi,* and those in Texas *gambelli.*

In our opinion, a third subspecies has not been substantiated, particularly in view of morphological data from about 1,550 whitefronts captured at 34 locations in 14 regions of Alaska and Canada (Lensink and Timm, in preparation). Although relatively large and small individuals are found in a given area, significant differences in average size of morphological characteristics may occur between areas that are relatively close geographically. Whitefronts from coastal tundra are generally smaller than those found in interior taiga and boreal forest regions. Whitefronts from one area of central Alaska were (except for weight) as large as but lighter colored than *gambelli* from Cook Inlet.

Three of 258 (1.2 percent) *gambelli* marked in Cook Inlet were reported in the Central Flyway, compared to 3 of 687 (0.4 percent) *frontalis* recovered there that were banded on the Yukon-Kuskokwim Delta of Alaska (Timm and Dau 1979). The "type" *gambelli* (Hartlaub 1852) from Texas could therefore have come from Cook Inlet, Alaska. Only one whitefront subspecies (*frontalis*) is presently recognized in Texas (American Ornithologists Union 1957:65).

Distribution and Migration

Summer

Nesting in Redoubt Bay has been documented only near the Big River drainage (Figure 1), despite ground searches for nests and aerial surveys for goslings in other parts of the Bay. In 1981, no nests were found in a 6.3 square mile (10.1 km^2) area searched north of Big River. Whitefronts have not been recorded summering in Cook Inlet outside of Redoubt Bay and Susitna Flats, except on rare instances (Gabrielson and Lincoln 1959:134, Timm 1980). However, a recent report (S. McDowell, personal communication) of tule geese summering in the upper McArthur River drainage (Figure 1) demands further investigation.

Redoubt Bay is characterized by a transition from intertidal mud to brackish marsh, fresh marsh, expanses of poorly drained sweet gale (*Myrica gale*) and dwarf birch (*Betula nana*), alder-willow (*Alnus* spp.-*Salix* spp.) thickets, aspen-spruce-birch (*Populus* spp.-*Picea* spp.-*Betula* spp.) forest, and alluvial glacial plain terminating at rugged mountains and glaciers within 12 miles (19.3 km) of saltwater. Although over 100 goslings were seen in the upper brushy and tree covered areas of the Big River drainage at least 9 miles (14.4 km) from salt water, no nests were found there in 1981 in a 1.3 square mile (2.1 km^2) area. In 1980 and 1981, 11 nests were discovered in a 9.6 square mile (15.5 km^2) area of lower Big River in brackish and freshwater marsh. Nest sites were typical of other whitefronts (Ely 1979).

Nests have not been located on Susitna Flats, although goslings were seen near Stump Lake and on Seeley Lake (Figure 1). According to a local fisherman (C. Brauch, personal communication), tule geese nest near Seeley Lake on brackish marsh flats, similar to habitat in Redoubt Bay, and near beaver ponds 0.5 to 1.5 miles (0.8 to 2.3 km) up the Theodore River. Adults reportedly bring young downriver from these ponds to Seeley Lake for rearing, a behavior we have observed in Redoubt Bay.

In 1980, nest initiation (date first egg laid) was during May 9–May 16, and hatching occurred June 10–June 16 ($N=7$). Nesting was initiated about one week earlier in 1981 because of an earlier thaw.

In Redoubt Bay, family groups congregate near the mouth of Big River for brood rearing. Other brood rearing and the primary area for molting of nonproducing adults and subadults occurs farther up the Big River and its tributaries in large expanses of shallow glacial and rain water. The first flightless nonbreeders were seen June 19, 1981, and by July 27 about 95 percent of the nonbreeding adults and 50 percent of the breeders could fly.

Migration

Neck collaring of 200 and 342 *gambelli* on the wintering and summering grounds, respectively, has enabled us to identify major use areas. Over 20,000 observations of these birds have been made in three years.

Several hundred tule geese had arrived at Redoubt Bay by April 23 and April 20 in 1980 and 1981, respectively, when investigators arrived. Major departures of tule geese from the Klamath Basin in California occurred April 8, 15–16, and 28–29, 1980, and April 10 and 20–22, 1981. Three marked individuals traveled about 1,900 miles (3,050 km) between northern California and Redoubt Bay in a maximum of four days.

Tule geese begin to leave the Big River area by mid-August, based on locations of radio transmitter-equipped birds (8 in 1980 and 20 in 1981). Aerial and ground surveys in 1980 and 1981 indicated that only 100–150 tule geese in Redoubt Bay and 300–350 on Susitna Flats remained until September 1 (opening of hunting season).

Tule geese first arrived at Summer Lake, Oregon (a major fall staging area), on August 28 and 30, 1980 and 1981, respectively (S. Denney, personal communication). First arrivals in the Malheur National Wildlife Refuge (NWR) vicinity occurred August 26 and 25 in 1980 and 1981, respectively (S. Thompson, personal communication). Tule geese had departed both Summer Lake and Malheur NWR by October 1, 1981.

Observations of neck-collared *gambelli* revealed that, unlike *frontalis*, apparently over half of all tule geese overfly the Klamath Basin and are early arrivals at Sacramento NWR. C. Ely (personal communication) has observed up to 1,500 tule geese in the Klamath Basin during early October. Tule geese concentrate on Lower Klamath NWR, unlike Pacific whitefronts that prefer Tule Lake NWR. Tule geese depart the Klamath Basin by early December.

Of the three tule geese (two locals, one yearling) marked in Alaska and reported in the Central Flyway the first year after banding, one bird was seen December 15 on the Kirwin NWR in northcentral Kansas, and two were shot in southeastern Texas on November 25 and December 27.

Locations of neck-collared birds reported throughout North America are presented in Figure 2.

Winter

Tule geese arrive at Sacramento and Delevan NWR's during mid-September, and by late October 1981 they had peaked at about 3,500 birds. By late September they arrive at Grizzly Island State Wildlife Management Area (SWMA), where up to 1,500 individuals occur during the hunting season. Some birds travel between the Sacramento Valley and Grizzly Island throughout the winter.

Although a few neck-collared birds have been observed on Colusa and Sutter NWRs and in the Butte Sink, the primary wintering areas are the Sacramento and Delevan NWRs and Grizzly Island SWMA. Unconfirmed reports indicate that a few tule geese occur in the San Joaquin Valley of California and in western Mexico, although no marked birds have been reported from these regions.

From arrival in September until the opening of hunting season, tule geese feed primarily in harvested rice fields throughout the Sacramento and Delevan NWRs. Roosting and loafing occur in areas of open water and stands of bulrush (*Scirpus* spp.) and cattail (*Typha* spp.). After the hunting season opens on portions of these Refuges, tule geese shift to off-refuge harvested rice fields and to closed portions of refuges containing primarily flooded unharvested rice.

If winter rains flood uplands and fallow rice fields that contain bulrush, some birds will feed, loaf and roost in these fields. The use of these areas is delayed or nonexistent without adequate rainfall. When the hunting season ends in mid-January, the geese increase their use of off-refuge rice fields.

Tule geese begin to leave the Sacramento Valley in early February, and by early March 1,500 to 2,000 birds will have arrived in the Klamath Basin. The rest of the population (apparently most subadults) use an as yet undiscovered spring migration staging area(s).

Population Status

Recruitment

Based on winter surveys, young comprised an estimated 30 percent ($N = 2{,}500$) of the population in 1979, 34 percent ($N = 2{,}500$) in 1980, and 37 percent ($N = 2{,}300$) in 1981. In comparison, at Redoubt Bay during late May 1980, young comprised 29 percent ($N = 762$), and April 20 through late May 1981, 34 percent ($N = 1{,}284$), of the population.

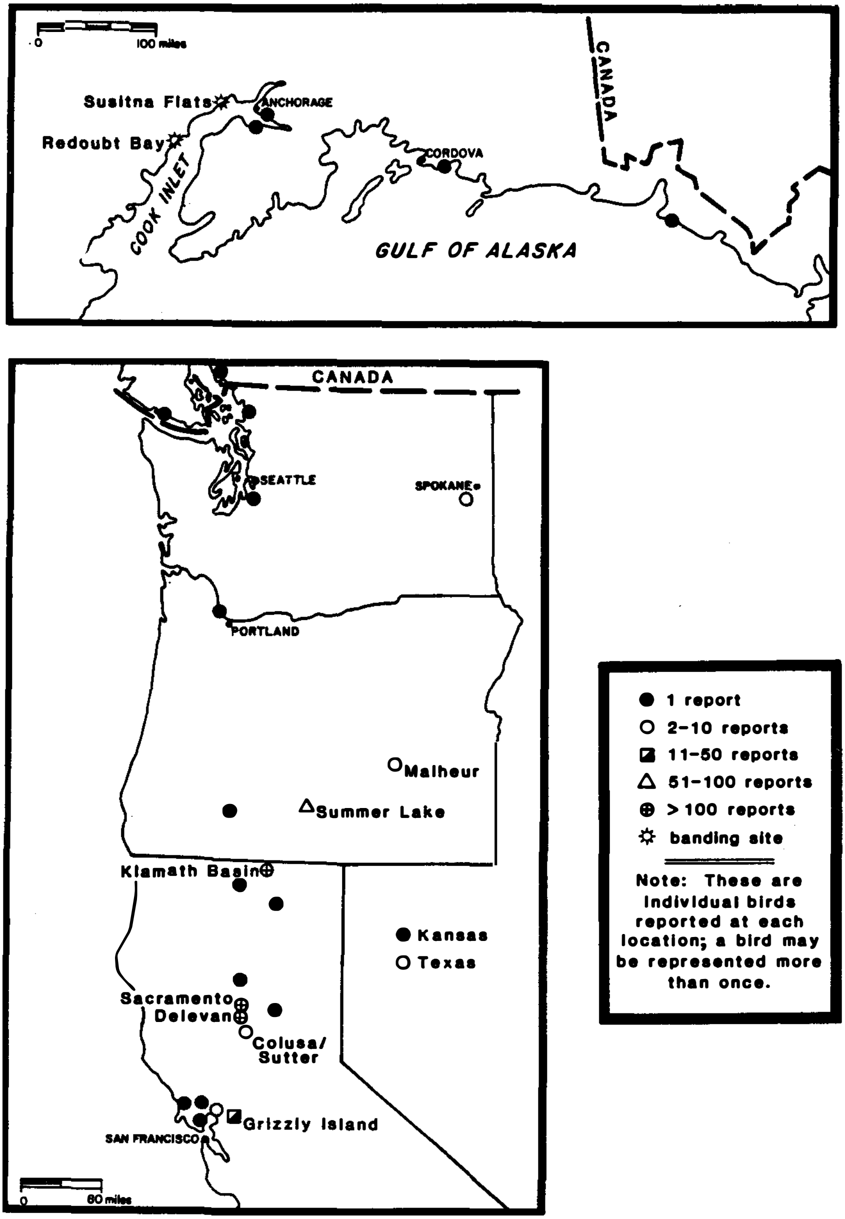


Figure 2. Reports from 342 tule geese neck-collared in 1980 and 1981, upper Cook Inlet, Alaska.

Survival and Mortality

Of 291 tule geese neck-collared in Alaska in 1980, 258 (88.7 percent) were reported within 18 months after banding. An annual collar loss rate of 19 percent (D. Timm, unpublished data) was measured for Canada geese (*Branta canadensis*) with glued neck collars. If a collar loss rate of 12 percent is assumed for tule geese, virtually all marked birds were reported.

In 1980, 45 adults and 78 locals were collared in family groups. Of these, 28 adults (62.2 percent) and 49 locals (62.8 percent) were seen alive after the 1980–81 hunting season. If 12 percent of the geese lost their collars the first year, survival of both adults and locals was 71 percent. Of 168 geese captured in flocks of subadults and unsuccessful breeders, 73 (43.5 percent) were seen alive after the hunting season. An additional 60 (35.7 percent) were seen before the season but not after, adding evidence that undiscovered spring staging area(s) are used primarily by subadults. Substantially greater mortality of subadults was unlikely since their direct band recovery rate was identical to that of older birds.

Direct band recovery rates for 78 locals, 98 yearlings, and 115 older geese neck-collared in Alaska were 11.5 percent, 12.2 percent, and 12.2 percent, respectively. Hunting recoveries (35) were from California (74 percent), Alaska (20 percent), and Texas (6 percent).

Of 70 tule geese neck-collared in California during the winter of 1979–80, a maximum of 59 birds were alive after that hunting season. Again assuming 12 percent collar loss, at least 43 (83 percent survival) were alive after the 1980–81 season.

Considering (1) the difficulty of observing geese that disperse after the hunting season, but a minimum 71 percent survival of locals, (2) band recovery rates that indicate only modest hunting mortality, assuming high reporting rates of collared birds, and (3) annual survival of at least 83 percent for geese marked in California, we conclude that population survival was 80 percent or more the first year after banding.

Reductions in the bag limit for white-fronted geese and shortened hunting seasons resulted in a large decrease of both whitefront subspecies harvested at Sacramento and Delevan NWRs during the 1979–80 and 1980–81 seasons. For example, during the 1978–79 season, 812 birds were taken compared with 111 and 148 during the following two hunting seasons. The proportion of tule geese in the total white-fronted goose harvest increased from 38 percent of the harvest in 1978, to 60 percent in 1979 and 46 percent in 1980. Despite this increase, the proportion of immature tule geese in the harvest remained constant (36 to 40 percent) during all three seasons. Except in 1980, the proportion of immature Pacific whitefronts in the harvest was about twice that of tule geese (76 percent in 1978, 70 percent in 1979, 47 percent in 1980).

Population Size

Coordinated surveys on September 14 and 21, 1981 were made on Summer Lake SWMA, and near Malheur, Klamath Basin, Sacramento and Delevan NWRs. Population estimates from these surveys indicated at least 3,500 tule geese. Most of the geese were seen at Summer Lake (2,130 on September 14 and 1,930 on September 21). Previous estimates of tule geese ranged up to 2,500 (Bauer 1979).

Some geese were likely still north of Oregon on the 14th, since one collared bird was shot at Susitna Flats, Alaska on September 12, 1981. Others were undoubtedly scattered outside of the count areas. After considering these factors, we conclude that the subspecies numbers at least 3,500 geese and likely over 4,000. Based on our field observations of relative abundance in California from 1978 through 1981, we believe that the tule goose population has approximately doubled in size, probably in response to reduced harvest in California.

During late July aerial surveys in Cook Inlet, 35mm photos revealed 1,537 birds in 1980 and 1,146 in 1981. In Redoubt Bay we counted 1,273 adults and 146 goslings in 1980, and 927 adults and 131 young in 1981.

Although birds are missed during aerial counts, the disparity between wintering ground estimates (>3,500 geese including >30 percent young) and breeding ground estimates (1,550 geese including 15 percent young) is disconcerting. However, based on extensive fixed-wing and helicopter surveys throughout upper Cook Inlet in 1980 and 1981, and on ground searches in Redoubt Bay, the production of tule geese in upper Cook Inlet occurs only in the Big River drainage of Redoubt Bay and on western portions of Susitna Flats. Although it is unlikely that >2,500 tule geese summer on these two areas, the recent report of whitefronts in the upper McArthur River drainage cannot be discounted. Apparently all tule geese molt in Redoubt Bay and Susitna Flats also, except for a one time use of Trading Bay by 110 adults in 1974.

During spring 1980, 59 (3.6 percent) of 1,652 tule geese checked for neck collars in Redoubt Bay had been marked in California. Using the Lincoln Index we estimated a spring population of 1,450 birds in Redoubt Bay. Field-age ratios indicated yearlings comprised 26 percent of the observed geese, compared with 24 percent yearlings in the collared sample.

Reports of whitefronts nesting in Tuxedni Bay, 30 miles (48 km) southwest of Big River (H. Keiser, personal communication), and of several hundred white-fronted geese in 1981 in Chinitna Bay, 65 miles (104 km) southwest of Big River in lower Cook Inlet (R. Haeg, personal communication), indicate that these areas should be searched.

Nesting populations of tule geese may exist outside of Cook Inlet. For example, apparently at least one other population of large, dark whitetronts is located in the Old Crow Flats, and populations of large whitefronts occur elsewhere in Alaska (see section on *Taxonomy*). The Arctic is large and at best moderately explored for whitefronts.

Habitat Status

Most major tule goose concentration areas are managed by State conservation agencies or the U.S. Fish and Wildlife Service. These include: Susitna Flats; Summer Lake SWMA; Malheur (substantial use also occurs in surrounding private lands), Lower Klamath, Tule Lake, Sacramento, and Delevan NWRs; and Grizzly Island SWMA. The obvious exception is Redoubt Bay.

There have been intermittent attempts to classify Redoubt Bay as a State Game Refuge since 1977. In 1980, an administration-sponsored bill did not leave subcommittee, and the bill will probably meet a similar fate in the near future. Public displeasure in Alaska over passage of the 1980 Alaska National Interest Lands

Conservation Act will not soon wane, and this displeasure has influenced consideration of Redoubt Bay for refuge status. Complicating the issue is the future status of privately owned cabins that have been built illegally on State lands. The Alaska Department of Fish and Game is, however, pursuing refuge classification for Redoubt Bay.

Cook Inlet has Alaska's largest producing natural gas field and the State's second largest producing oil field. The Alaska Department of Natural Resources, in response to requests from the Department of Fish and Game and the National Audubon Society, recently withdrew Redoubt Bay from two oil and gas lease sales. Redoubt Bay will be excluded from additional sales through 1983, when sufficient information should be available to protect the birds from exploratory and possible developmental activities.

An underground oil pipeline parallels the east side of Redoubt Bay about 3 miles (4.8 km) inland. The line carries oil from 14 platforms in Cook Inlet, located 17 to 50 miles (27.2 to 80 km) northwest of Big River, to the Drift River storage and tanker loading facility 5 miles (8 km) south of Big River (Figure 1). There has not been a major on or offshore oil spill since this field was opened in the mid-1960s. However, oil companies have been notified of the concern for tule geese, and they will afford special protection to Redoubt Bay if a spill occurs (A. Cline, personal communication).

No further surface entry for oil and gas drilling or permanent roads will be allowed in the Seeley Lake area of Susitna Flats where tule geese occur. Minimum aircraft altitude and other restrictions are also required during oil and gas exploration activities. However, nesting locations there and up the Big River remain unidentified.

The west side of Cook Inlet will experience extensive development in the future, including agriculture, coal and gold mining, new roads, timber harvest, oil and gas, hydroelectric projects, and conversion of State lands to private ownership. However, if all key lands are placed in refuge status or otherwise protected, we believe that the tule goose in Cook Inlet will not suffer a significant population decline. Long-term habitat protection for Redoubt Bay is, however, a paramount need.

Although tule geese concentrate on protected areas in California during the hunting season, pre- and post- season use of private lands is substantial. Gilmer et al. (1982) discussed concerns for tule geese and other waterfowl wintering in California's Central Valley.

Challenges

Obvious management and research challenges include better assessment of tule goose population size and distribution during migration, summering, and wintering periods; protection of key use areas; and resolution of the *Anser albifrons* taxonomic enigma. Other complicating factors include hunting and potential designation of tule geese under endangered or threatened species status.

In response to a suspected Pacific whitefront population decline exceeding 50 percent the past 10 years (O'Neill 1979, Timm and Dau 1979), the Pacific Flyway Council recommended in 1979, and the States of California and Oregon adopted, certain restrictive hunting regulations that resulted in harvest reductions of over

50 percent in California (California Department of Fish and Game, unpublished data; U.S. Fish and Wildlife Service, unpublished data). A concomitant decrease of at least that magnitude occurred in harvest of tule geese. Although it was desirable to increase the number of tule geese, future challenges of harvest management may occur when either whitefront population requires independent actions to meet population objectives.

In 1981, the International Council for Bird Preservation petitioned the U.S. Fish and Wildlife Service to list the tule goose as an endangered species. Although the Service requested public comment on the petition, they do not plan to list the birds (J. Sheppard, personal communication). The International Union for the Conservation of Nature lists the tule goose in their *Red Book* as a subspecies of concern.

If tule geese were classified as endangered, hunting of whitefronts in California and Cook Inlet would essentially cease. Declining goose populations, restrictive seasons, and shrinking habitat have all contributed to a more than 30 percent reduction in waterfowl hunters during the past 10 years in California. The loss of whitefront hunting would be a major blow to wetland preservation in California, which is supported by the sale of duck stamps and hunting licenses. Incentives to retain privately-owned wetlands, which comprise the bulk of Central Valley waterfowl habitat (Gilmer et al. 1982), would also diminish.

Endangered status would essentially place land management and development of most coastal marshes in Cook Inlet and key tule goose areas elsewhere under Federal purview, in view of the Endangered Species Act and Section 404 of the Clean Water Act. Clearly, it is in the best interest of all concerns to insure the birds' welfare. Endangered or threatened status would limit management flexibility and do little that is not already being done to protect the subspecies.

Examination of Trading Bay in 1981 indicated that tule geese could potentially nest there. Range extension from natural expansion or by transplants is an exciting challenge for the future.

Recommendations

The Pacific Flyway Waterfowl Technical Committee has drafted a Tule Goose Management Plan that is under agency review. Recommendations include a prehunting season population of 5,000 birds, surveys to better define range and population size, and actions to insure habitat protection for Redoubt Bay. We believe that adoption of that Plan is desirable for coordinated and effective management.

Locating unknown major spring staging areas, and nesting areas in Susitna Flats and Redoubt Bay, is imperative. Continuation and expansion of fall and midsummer surveys is desirable to monitor population size and to better define the summer distribution of tule geese in Alaska. Harvest should be monitored, and a technique developed for in-hand field identification of tule geese. Banding in Alaska should continue at least until all major use areas are identified. Research in California should continue at least until habitat use and movements by tule geese are quantified and behaviorial differences between whitefront subspecies are determined. Beyond direct management applications the tule goose presents a unique opportunity to investigate life history and population dynamics of whitefronts.

Although taxonomy of Canada geese is still argued, taxonomy of white-fronted geese is presently far more obscure. A compilation and analysis of morphology and migration information for North American whitefronts is long overdue. Where data are inadequate, examination and marking of adults with young may be necessary before final judgement can be made on whitefront taxonomy.

Acknowledgements

There are many people—both government and public volunteers—who helped with all aspects of tule goose research the past three years. For their help in the northern areas, we particularly thank D. Bynon, B. Campbell, J. Hawkings, D. Herter, R. King, B. Overway, M. Petersen, T. Pogson, D. Rosenberg, R. Sellers, L. Smith, K. Timm, N. Wrocklage, and cabin owners; for help in southern areas, B. Buyer, J. Day, S. Denney, C. Ely, B. Gray, S. Lawry, D. Johnson, G. Kramer, M. Miller, T. Moser, D. Orthmeyer, J. Romero, and S. Thompson. We thank J. C. Bartonek, D. P. Connelly, D. E. McKnight, H. W. Miller, and P. F. Springer for critically reviewing the manuscript. Special recognition goes to Bob Elgas and Warren Hancock for their long and unwavering belief in, and work on, the tule goose.

References Cited

American Ornithologists' Union. 1957. Checklist of North American birds. The Lord Baltimore Press, Baltimore, Md. 691 pp.

Baldwin, S. P., H. C. Oberholser, and L. G. Worley. 1931. Measurements of birds. Vol. II. Sci. Publ. Cleveland Mus. Natu. Hist., Cleveland.

Bauer, R. D. 1979. Historical and status report of the tule white-fronted goose. Pages 44–55 *in* R. L Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Book Stores, Corvallis.

Delacour, J., and S. D. Ripley. 1975. Description of a new subspecies of the white-fronted goose *Anser albifrons*. Amer. Mus. Novitates 2656. 4 pp.

Elgas, B. 1970. Breeding populations of tule white-fronted geese in northwestern Canada. Wilson Bull. 82 (4):420–426.

Ely, C. R. 1979. Breeding biology of the white-fronted goose (*Anser albifrons frontalis*) on the Yukon-Kuskokwim Delta, Alaska. Thesis. Univ. of California, Davis. 110 pp.

Gabrielson, I. N., and F. C. Lincoln. 1959. The Birds of Alaska. The Stackpole Book Co., Harrisburg, Pa. 922 pp.

Gilmer, D. S., M. R. Miller, R. D. Bauer, and J. LeDonne. 1982. California's Central Valley wintering waterfowl; concerns and challenges. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 48:000–000.

Hartlaub, G. 1852. Descriptions de quelques nouvelles especes d'Oiseaux. Paris, Rev. Mag. 2, (4):3–9.

Krogman, B. D. 1979. A systematic study of *Anser albifrons* in California. Pages 22–43 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Book Stores, Corvallis.

O'Neill, E. J. 1979. Fourteen years of goose populations and trends at Klamath Basin Refuges. Pages 316–321 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Book Stores, Corvallis.

Ratti, J. T. 1980. The classification of avian species and subspecies. Amer. Birds 34(6):860–866.

Swarth, H. S., and H. C. Bryant. 1917. A study of the races of the white-fronted goose (*Anser albifrons*) occurring in California. Univ. Cal. Publ. Zool. 17(11):209–222.

Timm, D. E. 1980. Annual report of survey and inventory activities—waterfowl. Proj. Prog. Rep., Fed. Aid Wild. Restor. Proj. W-19-1, Job 10.0. Alaska Dep. Fish Game, Juneau. 35 pp.

———, and C. P. Dau. 1979. Productivity, mortality, distribution and population status of Pacific Flyway white-fronted geese. Pages 280–298 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Book Stores, Corvallis.

Constraints On Developments For Wildlife On Private Lands

L. Ross Shelton
Mississippi State University
Mississippi State, Mississippi

Resource conservation economics and policies as described by S. V. Ciriacy-Wantrup (1951) have not been effectively utilized and developed by wildlife professionals in the United States. Although Ciriacy-Wantrup focused his attention primarily upon the farmers and the general theme of conservation, the factors he described have great impact upon the development of wildlife on private lands in the United States. Factors involved in wildlife resource conservation and management will be discussed in the following order: (1) uncertainty, (2) property, (3) tenancy, (4) credit, (5) taxation, and (6) marketing arrangements.

Uncertainty

Farmers dread uncertainty, and uncertainty discourages conservation. Most habitat and wildlife improvement programs have deferred returns, and this extends the resource manager's planning period. An extended planning period tends to increase the amount of uncertainty and resultantly discourages the initial investments in land improvements. Farmers interested in deriving income from wildlife production have inadequate financial data and benefit/cost ratios for habitat improvement to allow them to properly evaluate the potential for wildlife recreational enterprises. The uncertainty of revenues, due to lack of interest and/or unwillingness to pay on the part of the sportsmen, and possible state, federal or private competition, is high in this relatively undeveloped field. The threat of public reaction to this "commercialization of the public's fish and game" and possible liability problems increase farmer uncertainty.

Farmer uncertainty is greatly increased when public policies and regulations are changing rapidly. This increased farmer uncertainty applies to rapidly changing state and federal wildlife regulations also. For example, the Colorado Division of Wildlife decided in late spring of 1971 to change drastically their big game hunting seasons to reduce non-resident hunting pressure and to let the big game populations increase. Instead of the traditional three-week season allowing the harvesting of both deer and elk, the Division split the deer and elk season and prohibited big game hunting for five days between the two seasons. The Division also reduced the bag limit on deer and elk. The results were dramatic. The number of non-resident big game hunters dropped 45 percent over 1970 and resulted in a loss of income of over $2-million to the Division (Feltner 1972). There were 89 percent fewer non-resident sportsmen licenses and 53 percent fewer non-resident deer licenses sold. The number of non-resident clients reported by guides and outfitters to the Division of Wildlife fell from 4,397 in 1970 to 3,629 in 1971. The number of guides and outfitters reporting non-resident clients decreased from 262 in 1970 to 233 in 1971 (Colorado Division of Wildlife 1972). At this particular time, I was conducting research with some cooperating Colorado ranchers who had big game hunting recreational enterprises. Three of these cooperating ranchers indicated in the summer of 1971 that their reservations were down by over 50 percent. One cooperator said that he had received 21 inquiries prior to the season being set and only two afterward. The potential effect on the income from big game to ranchers from a sudden change of seasons appears obvious. Not so obvious are the effects of uncertainty on the opportunity cost to the ranchers. A conversation with a certified public accountant in Grand Junction just after these season changes occurred revealed the following facts. A rancher client of his had been offered $25,000 by a non-resident for the hunting rights on his land for a lease period of ten years. The $25,000 was to be paid when the lease was signed. After the season changes were announced, the potential lessee was uncertain as to whether non-resident hunting would be prohibited in the future or an increase in specified permit only areas might limit his hunting to the luck of the draw. The non-resident wanted to put a clause in the contract that called for pro rata reimbursement of funds if, by reason of Colorado Division of Wildlife action, he could not hunt on the ranch. The landowner would not agree to the clause and he lost $25,000 in potential income. Some of this rancher's lands, prime winter range for mule deer, are now broken up into mini-ranches. The accountant also related that a local client wanted to buy a ranch and form an exclusive club with a $25,000 membership. This membership would be based on $10,000 down and $1,000 a year over fifteen years. The client reneged on the deal because of uncertainty over what Colorado Division of Wildlife might do in the future. Similar opportunity costs to landowners nationally, resulting from various state and federal rules and regulation changes, could be substantial.

Property

Property has been defined as a bundle of rights of control over resources. Indefinite property rights often lead to depletion. For some resources, property rights are not well defined, either by law or in other ways, causing the user to "reduce them to possession" before he has definite rights. These types of resources are called "fugitive resources," and the wildlife resource in the United States is an example of a fugitive resource. In the case of wildlife on open range, it is a matter of who gets there the "fustest with the mostest" that controls the resource rights. In the United States, wildlife is owned by the state and held in trust for the people, while most of the land is owned by individuals. The only way a landowner has greater interest or more stable rights to wildlife than anyone else is through the trespass law. Trespass laws to protect property rights vary among states and are often inconsistent. Because of these inconsistencies and the problems with protecting land rights, sportsmen or landowners are reluctant to make wildlife enhancement investments if they are not sure that they will reap the rewards of their efforts. Poaching and illegal trespass are serious deterrents to wildlife development on private lands. In an article in the January 1981 issue of *Outdoor Life*, George Laycock indicated that an incredible 2 million deer and countless moose, elk, ducks, rabbits and other game species are killed every year by poachers. This does not occur just on public land. Shelton (1969), in a survey of forest landowners owning 27,897,000 acres (11,300,000 ha) in the South, indicated that the greatest constraint on the development of wildlife on their properties was lack of control of property.

Landowners cannot be expected to make investments for wildlife enhancement if they cannot reasonably expect to harvest the benefits, either through personal enjoyment, enjoyment of friends, or income gained from recreational enterprises. No farmer will invest in a crop of corn, soybeans, or wheat if there is great uncertainty as to whether he, his neighbor, or someone else will put his combine in the field to harvest the crop. For a landowner interested in the area of wildlife recreation, the factors of production may be land, labor, capital, management, and more stable rights to harvest wildlife. More consistent and enforced trespass laws may be in the best interest of all.

Tenancy

Ciriacy-Wantrup indicated that long term farm leases tend to encourage conservation because lessees will have time to recover their investments in conservation practices. A similar parallel may be made with the length of hunting leases. The majority of hunting leases in the United States appear to be on an annual basis. Lewis (1965) found that the majority of hunting leases in Louisiana are on an annual basis. Goose and duck hunting areas in Illinois are normally leased on an annual basis (McCurdy and Echelberger 1968). Some landowners are reluctant to lease their property for hunting purposes. They feel that the hunting parties will interfere with their timber or agricultural operations, damage property or, in some cases, secure easements (utilities, etc.) that may prove difficult to remove in subsequent years. Some large landowners, in the initial stages of the leasing program, and particularly industrial firms, hesitate to sign long term leases because of (1) uneasiness of the success of such a program and (2) possible conflict with future land management programs. In the early stages of a leasing program, annual leases can be justified, but after a cooperative landowner-sportsman relationship has been established, longer leases will probably provide both parties with additional benefits. Many of the older hunting clubs in the South invest substantial sums of money in road building, equipment, fences, fire lanes, bridges, law enforcement, and wildlife enhancement projects that benefit the landowner as well as the sportsmen group. These investments will not be made if the sportsmen are not assured that they would get full benefit of their expenditures. A number of hunting clubs in Mississippi have become interested in quality deer management. This usually involves an increased harvest of antlerless animals, a reduced harvest of bucks, and implementation of habitat enhancement projects. These programs generally improve deer herd health and productivity. However, these programs may take three to five years to produce results. If sportsmen are uncertain as to how long they will have a lease, they may not attempt to manage for quality deer.

The preponderance of annual hunting leases may be a constraint on the development of wildlife on private lands by (1) encouraging uncertainty among sportsmen groups and inhibiting their investment for land improvements, and (2) masking the potential benefits of long term leases.

Credit

Banks and other lending institutions hesitate to make loans on wildlife recreational enterprises for the following reasons: (1) shortage of data on which to evaluate potential returns on recreational businesses and (2) the feeling that, in a recessionary period, recreation-based businesses may not be profitable (the marginal utility of recreation will be lower than that of food, clothing, etc.).

For a long time, the Farmers Home Administration would not make loans that were strictly for recreational development. Recreational type loans had to be supplemental to other farm type income. Funds were not available for those persons attempting to make recreation their primary business. In a new region and in new enterprises, e.g., wildlife enterprises, interest rates include a high allowance for uncertainty; and lenders may not reduce these rates as much as is justified when the region or the enterprise and economic conditions become more stable. Methods of appraising assets may be outdated in the field of wildlife recreational enterprises. Banks and other lending institution personnel are usually eager to learn about new enterprises, but we have failed as wildlife professionals to collect and present data to lending institutions to enable them to make more realistic evaluation of the potential of wildlife recreational enterprises.

Taxation

Several states have attempted to encourage conservation of lands for wildlife by reducing property taxes, either by zoning or a direct reduction of property taxes if particular pieces of property are placed in state programs designed to preserve wildlife land for the future. Peterson and Madsen (1981) indicated that Minnesota had initiated an innovative property tax credit program to preserve wetlands and native prairie. Property taxes are eliminated on lands placed in this program. In addition, tax credits are allowed on other taxable lands owned by the farmer based on the number of acres of wetland or prairie the landowner chooses to enroll in the program. Preliminary results indicate that the program is being well received by Minnesota landowners. Other state programs appear to have been moderately successful. Regardless, they are a step in the right direction. The property tax in general is thought to discourage conservation. Landowners generally feel that by developing their wildlife resources for income production they will raise their tax base and incur higher taxes on a development that may not return the expected revenue.

The landowner who manages his land solely to increase production of wildlife through wildlife practices and techniques and sells permits or memberships or leases his property for profit is not considered a farmer for tax purposes, according to an opinion offered by the review staff of the Jackson, Mississippi District, Internal Revenue Service. If this opinion is correct, landowners cannot qualify for certain expense deductions allowed to farmers. This opinion affects the development of wildlife enterprises very little at present because most of these developments are by persons already considered farmers for tax purposes. However, in the future, this could be a serious constraint for those interested solely in revenue derived from wildlife enhancement.

Tax laws have been generous in allowing the dues paid to social, sporting, or athletic clubs to be treated as entertainment facility expense if such expenses have approximate relationship to the taxpayer's business and can be reasonably expected to benefit the business. Recent changes in this law, however, have made it more difficult for companies to enhance habitat and develop wildlife properties for customer entertainment. This probably has dampened interest by various companies to develop such programs.

On October 14, 1980, the President signed into law two new tax incentives for virtually all persons who plant trees on their property. The maximum expenditure eligible with this new tax treatment is $10,000 per year.

It works like this: if a landowner spends $10,000 for tree planting costs, such as site preparation, seeds and seedlings, and labor, a 10 percent investment tax credit ($1,000) can be subtracted from the amount of taxes otherwise owed to the Federal Government. The owner can also deduct from yearly earnings the full $10,000 over a seven-year period (in general, $1,428 per year). This new tax incentive could benefit wildlife. However, it could be extended to be even more beneficial. Why not extend this tax incentive to things such as the construction of greentree reservoirs or fish ponds? The machinery for such a program is already in place. The Agricultural Stabilization Conservation Service (ASCS) oversees cost-share programs for wildlife. This national program could designate wildlife enhancement projects that qualify. The Soil Conservation Service (SCS) is already required to inspect and list specifications for wildlife enhancement projects. A landowner who received an approved project through the ASCS that was inspected upon completion by the SCS could receive a document to be filed with his income tax return, allowing for both a tax credit and depreciation for the project. Another possibility might be for expenditures for wildlife enhancements, approved by these two agencies on lands not held for income production, to be tax deductible if justified and inspected by these agencies. Thus, landowners holding property primarily for aesthetic or recreational reasons could employ enhancement practices benefiting wildlife and get a reasonable deduction up to some qualifying amount.

Marketing Arrangements

The absence of an orderly marketing arrangement is conspicuous in wildlife management (Davis 1964). Landowners interested in income producing recreational enterprises do not have effective channels through which to contact potential customers, particularly those landowners interested only in leasing the hunting rights on their property. This constraint could be eased somewhat by the Cooperative Extension Service of each state. This agency has personnel in almost every county in the nation, and it would be a simple matter to compile a list of landowners wishing to lease their hunting rights along with such pertinent data as: (1) the amount of acreage, (2) type of habitat, (3) principal huntable species, (4) any hunting restrictions, (5) cost per man or acre, and (6) maximum allowable club members or hunters. Any sportsman's group could then locate these landowners and negotiate for a place to hunt. Orderly marketing arrangements are a requirement if an efficient distribution of hunters is to be accomplished.

Conclusion

This paper has attempted to illustrate that the elements of the Ciriacy-Wantrup framework affect the development of wildlife resources in this nation. Examples have been given to substantiate each element's contribution or lack of it. Until the problems and constraints associated with each of these elements are understood by the governing bodies, including federal and state wildlife regulatory organizations, substantial gains in wildlife enhancement on private lands will be difficult at best.

It appears we have not come very far since 1940, when Aldo Leopold wrote: "We find that we cannot produce much to shoot until the landowner changes his way of using land and he, in turn, cannot change his way until teachers, bankers, customers, editors, governors, and trespassers change their idea of what land is for."

Literature Cited

Ciriacy-Wantrup, S. V. 1951. Dollars and sense in conservation. Calif. Agric. Exp. Sta., Circ. 402. 51 pp.

Colorado Division of Wildlife. 1972. Summary of guides and outfitters and clients, 1970 and 1971. Unpubl. Rep.

Davis, R. K. 1964. The value of big game hunting in a private forest. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 29:393–403.

Feltner, G. 1972. Non-resident hunting down almost in half in '71. Colorado Outdoors (July–August):22.

Laycock, G. 1981. Socking it to the poachers. Outdoor Life (January):54–56.

Leopold, A. 1940. The state of the profession. J. Wildl. Manage. 4(3):343–346.

Lewis, J. H. 1965. The role of large private forest ownership in outdoor recreation in Louisiana. M.S. Thesis. Louisiana State University, Baton Rouge. 144 pp.

McCurdy, D. R., and H. Echelberger. 1968. The hunting lease in Illinois. J. Forest. 66(2):124–127.

Peterson, C. C., and Carl R. Madsen. 1981. Property tax credits to preserve wetlands and native prairie. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:125–129.

Shelton, L. R. 1969. Economic aspects of wildlife management programs on large private land holdings in the Southeast. M.S. Thesis. Mississippi State Univ., Starkville. 88 pp.

Rationale and Options for Management in Grizzly Bear Sanctuaries

C. J. Martinka
National Park Service
Glacier National Park
West Glacier, Montana

Introduction

Grizzly bears (*Ursus arctos*) currently inhabit less than half of their original range in North America. Range recession most likely began with early exploration of western regions (Lewis 1961) and accelerated as humans subsequently occupied, developed, and exploited desirable areas and resources (Storer and Trevis 1955). Protection of human life, depredation control, sport hunting, and habitat deterioration have each contributed to diminishing bear populations south of Canada. The extinction process has continued unabated for nearly 200 years, and there is little evidence to suggest a dramatic change in that trend.

Grizzlies generally require large areas of relatively remote habitat for maintenance of maximum population densities. The unbroken tract of western wilderness which once provided this requirement no longer exists. In its place, a dispersed system of legislatively designated sanctuaries is emerging as the focal point for conservation of wilderness wildlife. The significance of sanctuaries is readily apparent near the southern extreme of grizzly bear habitat where they have played an important role in arresting further range recession.

Various kinds and sizes of protective sanctuaries have been established throughout grizzly bear range. National parks and monuments generally grant full protection to grizzlies as part of an effort to maintain the integrity of natural ecosystems. Designated wilderness areas also provide ecosystem protection, but may permit humans to play a functional role involving the harvest of wildlife. In contrast, refuges and preserves are frequently managed to benefit selected species and/or habitats. Where grizzlies are concerned, sanctuaries have the common goal of species conservation although the manner in which the goal is accomplished and the benefits derived by the public may be substantially different.

The presence and management of grizzlies in sanctuaries present unique problems. The species possesses a proclivity for aggressive encounters with humans, behavior which occasionally leads to both human injuries (or deaths) and bear removals. In sanctuaries where sport hunting is considered appropriate, the additional population mortality must be balanced with a low recruitment potential of about five percent (Sidorowicz and Gilbert 1981). Where full protection is granted, sanctuaries tend to attract a visiting public, a situation which also enhances the potential for bear deaths (Martinka 1982). In the heavily visited national parks, the issue and its ramifications have become especially apparent during the past decade.

This paper examines the relationship between grizzly bears and human visitors in Glacier National Park, Montana. Time series analyses are used as a basis for documenting trends in this relationship and predicting the level of future interactions. Results provide background for developing a rationale and determining management strategies in protected sanctuaries.

Background Information

Glacier National Park encompasses 4,100 km^2 of mountainous terrain near the southern extreme of occupied grizzly bear range in North America. The park is inhabited by a relatively stable and reproductively healthy population of approximately 200 grizzlies (Martinka 1974, 1981). Proximity to wilderness sanctuaries fosters gene flow through a regional population of grizzlies in northwestern Montana, southeastern British Columbia, and southwestern Alberta (Joslin and Kapler 1977). The park has experienced insidious shifts toward status as an ecological island during recent decades (Martinka 1982).

Interactions between grizzly bears and park visitors were analyzed using travel statistics, confrontation reports, and management records. Trends in visitation were determined from total annual visits adjusted to exclude travel on transient roadways. Confrontations between bears and visitors that resulted in injury or death to the visitors were used as the most reliable measure of interactions. Procedures that resulted in permanent removal of grizzlies from the population were considered to be the best indicator of management activity levels. Data were analyzed on a microprocessor using prepared software for linear correlation, temporal regression, and tests of significance. The period of analysis was from 1951–80 with data grouped into decade categories.

Grizzly bears have been involved in 24 visitor confrontations resulting in 27 injuries and six deaths over the 72 year history of the park (1910–82). Twenty confrontations (83 percent), resulting in 23 injuries and six deaths, occurred during the 1951–80 study period (Table 1). Confrontations correlated perfectly with visitation ($r = 1.00$; $Y' = -2.90 + 1.02X$), and both factors exhibited significant increases since the 1950s (Table 2). These data suggest a *fundamental relationship* between numbers of park visitors (*cause*) and numbers of confrontations (*effect*).

Management activities resulted in removal of 44 grizzlies from the park population over the same period. Correlations between bears removed and visitation ($R = 1.00$; $Y' = -4.99 + 0.98X$) as well as bears removed and confrontations ($r = 1.00$; $Y' -8.00 + 1.00X$) were also perfect. It was therefore expected and demonstrated that bear removals would closely track the trends set by both visitation and confrontations (Table 2).

Table 1. Interactions between grizzly bears and visitors in Glacier National Park from 1951–80 and projections for the 1981–90 period.

Decade	Million visits	Number of confrontations	Number of bear removals
1951–60	6.7	4	12
1961–70	8.8	6	14
1970–81	12.6	10	18
1981–90[a]	15.3	13	21

[a]Predicted from trend line equations shown in Table 2.

Table 2. Time series analyses for visitation, confrontations, and grizzly bear removals over a three decade period from 1951–80 in Glacier National Park.

Factor	Trend line equation	Variance accounted for by trend (%)	Test statistic (Z)
Visitation	$Y' = 6.42 + 2.95X$	97.31	2.45**
Confrontations	$Y' = 3.67 + 3.00X$	96.43	2.45**
Bear removals	$Y' = 11.67 + 3.00X$	96.43	2.45**

Table 3. Grizzly bear management removals in Glacier National Park from 1951–80.

Decade	Number of bears transplanted	Number of losses		
		After transplant	Direct disposal	Total
1951–60	1	0	12	12
1961–70	2	2	12	14
1971–80	18	10	8	18
Totals	21	12	32	44

The relative magnitude and manner in which bear removals occurred changed over three decades. An extrapolation from Table 1 shows that removals per confrontation declined from 3.0 in the 1950s to 1.8 in the 1970s. At the same time, efforts to transplant problem bears increased, especially during the 1970s (Table 3). These data suggest that relocation efforts were helpful in reducing the need for permanent removal. One grizzly that was transplanted in a preventative management action subsequently caused the death of a backcountry visitor.

Changing removal characteristics reflect an even more significant shift in general management activities for grizzlies. Prior to 1968, management efforts were largely sporadic and in response to obvious problem situations. More recently, a comprehensive program involving both bears and visitors has been implemented, with an emphasis on preventing development of seroius problems. It seems reasonable to assume that management activities have prevented an acceleration of conflicts between grizzlies and visitors. At the same time, it must be concluded that effects on the *fundamental relationship* between visitation and confrontations have been negligible.

Toward a Management Rationale

Public interest in grizzlies expanded and intensified as confrontations increased during recent decades. One result was that changing attitudes frequently led to expressions of need for more active management. In response, traditional programs were strengthened, and field activity was generally able to keep pace with rising visitation. In contrast, development and implementation of innovative techniques received only passing attention. Therefore, *fundamental relationships* have remained essentially unchanged and the pattern of increasing confrontations and bear removals is expected to continue.

Trend projections of future interactions between park visitors and grizzly bears are shown in Table 1. During the 1980s, mean annual visits of 1.5 million are expected, along with confrontations and bear removals averaging 1.3 and 2.1, respectively. Park records indicate that each category was equalled or exceeded in 1981, the first year of the predictive decade. Visits reached 1.5 million while three confrontations and three bear removals were recorded.

Traditional management has stressed the aggressive treatment of problem bears. Bear removals have been justified on the basis of behavior and remain well within biologically acceptable limits. However, trends point to removal rates that could approach allowable limits in the coming decades, especially if the additive effect of mortality adjacent to the park is considered. The significance of reaching that point is manifold. First, current evidence indicates that the low removal rate within the park may be mediating a substantially higher rate of regional losses (Martinka 1982). Second, the grizzly is listed as a threatened species and added mortality will probably jeopardize that status. Third, increasing losses are in conflict with a legislated mandate to preserve the park's natural integrity. Beyond these issues, there is little evidence to suggest that increasing removals will benefit visitor safety, the principal reason for removing grizzlies.

An alteration of current trends requires that the *fundamental relationship* be viewed in mathematical perspective. With this in mind, numbers of visitors and grizzlies are seen to act as independent variables (*cause*), upon which confrontations and bear removals are dependent (*effect*). Grizzly bear densities have been relatively stable during recent decades, causing that factor to act largely as a constant. Moreover, it now appears that manipulation of bear densities does not represent a viable option for future management if legislative and moral mandates are considered. It follows that visitor management, as an independent variable, holds the key to reducing future confrontations and bear removals in the park environment.

Options For Managing Visitors

Park visitation is characterized by both the number of visits and their distribution in time and space. The *fundamental relationship* recognizes only the magnitude of visitation, but does demonstrate that its manipulation offers opportunity for reducing confrontations and bear removals. Unfortunately, a substantial reduction in visits is required to effect a relatively modest shift in the dependent variables. Moreover, it seems doubtful that proposals to reduce visitation would engender widespread public support, especially if viable options are available. The results of several studies reveal that visitor distribution management may provide potentially effective alternatives to numbers control.

Visitors and grizzlies interact within a park access system which has remained essentially unchanged since the late 1930s (Martinka 1982). The human activity patterns dictated by this system, in combination with the ecological behavior of grizzlies, determine the innate contact rate. As one means of altering this rate, Riggs and Armour (1981) proposed changing the habitat use patterns of visitors. The rerouting of trails and/or the relocation of campsites to avoid important bear habitats was suggested as one possible technique. A second approach was to locally restrict activity on the current system to time periods when grizzlies were least likely to be present. Implementation of an activity management concept requires a data base on grizzly bear habits that is not currently available.

An alternative method for changing visitor travel patterns was explored through use of computer models (Stuart 1977, 1978). The study demonstrated that changing the backcountry activity patterns of hikers and campers precipitated a response in the number of potentially dangerous contacts with grizzlies. These results led to a recommendation that contact rates be determined for the various components of the access system, followed by an adjustment in visitor use to reduce the possibility of dangerous contacts. A partial data base currently exists on trail travel, campsite use, and contacts with bears.

During recent years, it has been postulated that habituation of grizzlies to human presence may be an important contributor to dangerous contacts (McArthur 1979, 1980). The likelihood of this occurrence within at least a part of the bear population strengthens support for visitor activity management. However, the goal here is to prevent an acceleration in contact rate with what is now a predominantly wild grizzly population. In contrast to distributional management, local manipulation of visitor numbers assumes a more important role in treating the habituation process. Studies are currently being conducted to more fully document the nature of habituation and its effects in the park.

Available information points to visitor management as a realistic approach to reducing confrontations and bear removals. At the same time, the exploratory nature of recent research and weakness in the existing data bank demand the cautious implementation of new plans. It therefore seems appropriate to move into experimental field management packages, coupled with intensive monitoring, to assure the early identification of success or failure.

Discussion

Sanctuaries provide a unique and favorable environment for the conservation of grizzly bears. Management to perpetuate indigenous grizzlies has been successful where sanctuaries were established prior to local population extinction. Unfortunately, evidence now points to a potential for mutually detrimental interactions between humans and grizzlies in protected areas. The fundamental cause of these interactions is the increasing presence of people, a trend readily apparent in parks and soon likely to be felt in other types of sanctuaries. Since contact rates are determined by the number, distribution, and activity of humans, mitigative techniques that control human use are considered appropriate and in the best interest of both bears and people.

Grizzlies occupy large home ranges that frequently extend across sanctuary boundaries. Protected populations may therefore be subjected to stresses beyond the control of sanctuary managers. Where populations are relatively small and/or isolated, peripheral stresses may reach significance from a mortality standpoint. In these situations, implementation of a regional management concept based on overall mortality levels is required. Mortality control through human activity management holds the greatest promise for success on a regional basis.

In conclusion, sanctuaries and their management will continue to play a critical role in the conservation of grizzlies. Management of surrounding lands will help to assure successful conservation well into the future. Guidance of human activities represents an effective means of reaching a management goal to conserve grizzly bears.

Literature Cited

Joslin, G., and J. Kapler. 1980. A computerized system for recording and recalling grizzly bear reports. Pages 33–36 *in* C. J. Martinka and K. L. McArthur, eds. Bears—their biology and management. Bear Biology Assn. Conf. Ser. 3. U.S. Government Printing Office, Washington, D.C.

Lewis, M. 1961. The Lewis and Clark expedition. J. B. Lippincott Company, New York and Philadelphia. Pp. 1–889.

Martinka, C. J. 1974. Population characteristics of grizzly bears in Glacier National Park, Montana. J. Mammal. 55(1):21–29.

———. 1981. Statement for U.S. House of Representatives subcommittee on public lands and national parks. U.S. Government Printing Office, Washington, D.C. 97-8(II):1–285.

———. 1982. Effects of conterminous land use of grizzly bears in Glacier National Park. AAAS Symposium on External Threats to Ecosystems of National Parks. (In press).

McArthur, K. L. 1979. Methods in the study of grizzly bear behavior in relation to people in Glacier National Park. Proc. 2nd Conf. on Scientific Research in the National Parks. U.S. Dep. Commerce, National Technical Information Service, Springfield, Va. (Microfilm)

———. 1980. Habituation of grizzly bears to people: a hypothesis. *In* E. C. Meslow, ed. Bears—their biology and management. Bear Biology Assn. Conf. Ser. 4. (In press).

Riggs, R. A., and C. Armour. 1981. A hypothesis for predicting grizzly bear habitat use in spring floodplain habitat mosaics with special reference to reducing human-bear contact rates. Compl. Rep. 1-43. National Park Service, Glacier Nat. Park. W. Glacier, Mt.

Sidorowicz, G. A., and F. F. Gilbert. 1981. The management of grizzly bears in the Yukon, Canada. Wildl. Soc. Bull. 9(2):125–135.

Storer, T. I., and L. P. Trevis. 1955. California grizzly. University of California Press, Berkeley. 355 pp.

Stuart, T. W. 1977. Exploration of optimal backcountry travel patterns in grizzly bear habitat. Pages 25–32 *in* C. J. Martinka and K. L. McArthur, eds. Bears—their biology and management. Bear Biology Assn. Conf. Ser. 3. U.S. Government Printing Office, Washington, D.C.

———. 1978. Management models for human use of grizzly bear habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43:434–441.

Let's Tell The Truth About Predation

Bart W. O'Gara
Montana Cooperative Wildlife Research Unit[1]
University of Montana, Missoula

Introduction

Environmental groups and livestock producers share many common interests, but they often clash over predator damage control. A rancher who finds his livestock killed or maimed by predators suffers emotional trauma as well as financial loss. Many people, including some biologists, have no direct interest in livestock and tend to regard these animals as statistical entities valued only in dollars. These people feel frustration and anger when tax dollars are spent on what they consider to be inhumane treatment of interesting and valuable wildlife by Animal Damage Control (ADC) agents. Neither group can identify with the other's feelings.

Each group contains individuals with radically differing viewpoints on predators and ADC, which further complicates an already difficult situation. I know ranchers who are blindly anti-predator and others who show almost unbelievable tolerance and concern for predators. Similarly, other groups and individuals concerned with predators vary from those who live in a television world, where predators can do no harm, to those with more realistic viewpoints. Unfortunately, some environmental advocates, some biologists, and some ranchers have been less than objective, allowing emotions to influence their viewpoints and statements. The unfortunate but very human tendency is for each "side" of the predator issue to associate the most extreme viewpoint with all members of the "opposition." Hence, the ludicrous claims about predators commonly made by animal protection groups tend to become associated with all environmental interests, and rabid anti-predator sentiment associated with all ranchers.

Disagreements are common between special interest groups, but adversaries can often stand eye-to-eye, disagree, and reach compromises that are at least partially satisfactory to both parties. Such is seldom true in the emotional predator issue; polarization and confrontation are far more common than compromise and cooperation. This unfortunate situation has prevented a united front in many environmental controversies in which both groups could have gained by cooperation.

Historical Perspective

The pendulum of public opinion concerning predators and predator management has swung to both extremes within a human lifetime, but has never stopped, or even slowed down, near dead center. Early in the twentieth century, predators were considered competitors with man for game and livestock—vermin to be extirpated. Hornaday's (1914:142) opinion of how wolves (*Canis lupus*) should be

[1]The U.S. Fish and Wildlife Service; Montana Department of Fish, Wildlife and Parks; University of Montana; and the Wildlife Management Institute cooperating.

managed exemplified attitudes of his day: "Wherever found, the proper course with a wild gray wolf is to kill it as quickly as possible."

During settlement of the West, large predators were killed by stockmen and "wolfers" employed by the U.S. Bureau of Biological Survey. Most farm boys trapped, keeping the lesser predators in comparatively low numbers at least around farmsteads. When wolves were nearly exterminated, attention shifted to coyotes (*C. latrans*). Unlike wolves, coyotes extended their range despite persecution, and government agents, now members of the U.S. Fish and Wildlife Service's ADC program, still control or attempt to control damage caused by them. Control has been mostly for the protection of livestock, but predators were sometimes removed to benefit game animals.

By the early 1930s researchers found that predators played a valuable role in wildlife communities. The idea took hold that habitat conditions ultimately determined how many animals could survive. Studies led to acceptance of the concept that populations "become vulnerable to predation in proportion to their *surplus*, seemingly irrespective of the kinds and numbers of predators ordinarily present" (Errington 1935:231). This study, along with numerous others, led to reduced control of predators for the sake of game, undoubtedly saving many dollars, and probably making little difference to game populations.

As appreciation for the role of predators grew in the scientific community, attempts were made to educate the public, especially sportsmen. Almost simultaneously, the Great Depression and World War II led to the urbanization of the United States, so fewer and fewer Americans were in a position to observe livestock predation firsthand. Findings on predator-wildlife interactions seemed equally applicable to predator-livestock situations in the minds of people not associated with the predator problem. Many biologists, who had little or no experience with livestock predation because ADC agents dealt with it, followed the same line of reasoning. Many urbanites longed for simpler, more natural, rural lives. Everything natural became good; predators were not only natural, they had been unjustly persecuted. Thus, predators were judged always good. In fact, many people reached a point where they automatically denied all allegations that predators could be anything but beneficial.

Meanwhile, back at the ranch, livestock producers and ADC agents were still killing predators. Evidence indicated that Compound 1080 (sodium monofluoroacetate) had drastically reduced the number of coyotes in the West, and most urbanites did not like it. In the early 1960s, Secretary of the Interior Udall asked his five-man Advisory Board on Wildlife Management to evaluate predator control. The subsequent report recommended that the basic governmental policy should be husbandry of all forms of wildlife, but that local population control was an essential part of management where a species was causing significant damage. The Advisory Board concluded that: "In open areas of the Western United States, by far the most efficient control method for coyotes is the 1080 bait station. . . . When properly applied, according to regulations, 1080 stations of this sort do an effective and humane job of controlling coyotes and have very little damaging effect on other wildlife" (Leopold et al. 1964:35).

Admiration for predators grew with environmental concerns of the 1960s. In response to increasing complaints about the toxic chemicals used for predator control, the Department of the Interior and the Council on Environmental Quality sponsored a 1971 study of the predator damage situation. The resulting report concluded that: "Today's society places as high a value on prairie dogs, eagles, and coyotes as does the grazing leasee on public lands or the owner of a ranch on his flock of sheep" (Cain et al. 1972:6). They recommended that predator control be made selective for the individual predators causing livestock depredations, and that toxicants be banned.

A combination of public pressure and the Cain report influenced President Nixon to issue an executive order in 1972, banning the use of toxicants for predator control on federal lands and by federal agencies. Subsequent action by the U.S. Environmental Protection Agency severely limited the availability of chemical toxicants for state and private predator control.

These events were followed by complaints from stockmen, especially sheep ranchers. Politicians, who had felt pressure to protect predators because they were deemed ecologically beneficial, were confronted by sheepmen who maintained that predators had little value in sheep grazing areas and should be controlled. In turn, members of some groups, aided by some biologists, disputed stockmen's claims concerning the extent of the problem, and maintained that losses were being exaggerated for political and monetary reasons. Still other biologists felt as Howard (1974) did when he wrote: "These federal regulations have merely transferred much of the responsibility of coyote control from trained officials to landowners. . . . As if that would improve the quality of the environment! Bad laws are unenforceable. . . ." Thus, the pendulum was on the side "favoring" predators, polarization between environmental interests and stockmen was nearly universal, and predator control continued. The U.S. Fish and Wildlife Service (1978) estimated that ADC was attempting to control coyotes on about 11 percent of the species' range, killing about 4 percent of the population annually.

The Problem

A need, or lack of it, for increased predator damage control or better methods of control are not at issue here, although those questions also need attention. Two issues are paramount. First, the environmental community and livestock producers are both being hurt by lack of understanding, and false or misused information. These two groups should be working together for an improved land ethic, but they seldom join together on land-use planning or other environmental issues that would benefit both groups and the ecosystems they both cherish. Second, when serious predator problems threaten the livelihood of some sheep raisers, other ranchers feel that they too may soon have similar problems, and can expect public opposition to dealing with those problems. Thus peer support increases and the stage is set for illegal and sometimes indiscriminate control that is certain to be more harmful than sound predator management programs would be.

The following are some of the commonly heard statements that infuriate stockmen and polarize them against "environmentalists," along with attempts to put these statements in perspective.

Stockmen Exaggerate Predator Problems

Hardly anyone, except other ranchers, seems to place any credence in stockmen's estimates of losses to predators. Amory (1974:348) exemplifies this attitude.

"I said that any man who would swear under oath that he had lost three hundred sheep or goats to coyotes in one year was a man to whom, at the very least, I'd like to address a few questions. The first of these is how many sets of books he keeps. I presume, like some ranchers, he keeps one for himself and another for the coyotes."

Am I using Mr. Amory as a "straw man?" The prestigious Cain Committee seemed to use similar logic in their evaluation of Reynolds and Gustad's (1971) study, which was based on questionnaires sent to a random sample of ranchers. The study concluded that annual predator losses averaged about 5 percent of the total sheep inventory in the West. Cain et al. (1972:25) stated that "similar and even more inflated figures have been arrived at in calculations by the National Wool Growers Association. While there is no basis for accepting these figures, there is no accurate source of information on which to make an objective evaluation."

Hindsight is always 20:20, but subsequent field studies conducted on ranches with normal levels of predator control in effect have documented minimum losses ranging from 3.36 to 5.8 percent (Shelton 1972, Klebenow and McAdoo 1976, Taylor et al. 1979).

I do not contend that the predator loss rates mentioned here are applicable throughout the West, or that anyone should have known the results before the studies were completed. However, the conclusion seems inescapable that concerned citizens, group spokesmen, and biologists must be extremely cautious about implying that all ranchers are liars.

Ranchers Believe that Every Animal Fed Upon Is a Kill

Naturally, ranchers vary in ability to judge actual kills, but during my research on ranches where predation on livestock was occurring, the ranchers were quite astute in judging kills by location of hemorrhages and bite or talon punctures. Furthermore, the ranchers relied on externally visible wounds or blood to identify kills, and from 5 to 10 percent of the coyote-killed sheep I have examined showed no external signs of predation.

Coyotes and eagles regularly scavenge sheep carcasses during the winter when the meat stays reasonably fresh, but carcasses usually disappear quickly during lambing because of decomposition and scavenging by corvids and insects. Henne (1975) and Munoz (1977) left 128 lamb carcasses in pastures on the Cook Ranch where coyotes were killing almost daily; only four were subsequently fed upon by coyotes, although a fresh kill was made within 10 yards (10 m) of a day-old carcass. O'Gara (1981) documented 76 lambs that had been killed by golden eagles (*Aquila chrysaetos*) but only one carcass that had been fed upon but not killed by eagles. In that study, attempts to attract eagles to traps baited with jackrabbit (*Lepus townsendii*) and lamb carcasses were unsuccessful until live decoy eagles were tethered at the carcass. The most logical implication was that the eagles preferred freshly killed prey, whether they killed it themselves or forced another bird from a kill it had made.

Thus, the hard-to-recognize instances of predation, and the small likelihood of finding lambs that were fed upon but not killed by predators, often outweigh the instances where ranchers identify carrion feeding as predation.

Ranchers with Predator Problems Simply Do Not Know How to Manage Livestock

The most predictable thing that I have learned about predators is that they are unpredictable. During the Cook Ranch studies, another ranch about 10 miles south was also experiencing heavy predation, even though the rancher was spending considerable time with his flocks and was doing everything legal to control predation. Another sheep ranch was located about midway between the two with heavy predation. The rancher was running a similar operation to the other two, coyotes were mousing in the pastures near his sheep, and no lambs were being lost to predation.

Another example of the unpredictability of coyote predation on sheep came to light near Lolo, Montana, where a rancher was keeping about two hundred ewes, mostly for weed control. The sheep were corralled every night for protection from coyotes, but, during the summer of 1975, coyotes took about 30 percent of the lambs during daylight despite extensive control with traps, snares, and helicopter gunning. The remaining lambs were sold about 30 pounds (14 kg) light, a substantial loss in addition to kills.

The Denver Wildlife Research Center was looking for a place to test guard dogs, and this situation appeared right for the test. We negotiated with the rancher to stop coyote control in 1976 and to call us as soon as coyotes started taking lambs. The plan was to pay for the predator kills, document the level of predation for several weeks, introduce the guard dogs, and document the level of predation with the dogs present. In 1976, coyotes were common on the ranch but no lambs were killed.

The preferences of individual predators, density of buffer species, and probably some things we do not even suspect make predation unpredictable. Yet the suggestion is often made that a rancher does not know how to manage his livestock because he suffers predation while his neighbor does not; it is enough to alienate anyone.

Predators Kill Only the Sick and the Weak

Anyone who watches television has heard this line again and again. It has, of course, basis in fact. When wild prey animals are large and formidable relative to their predators, and especially when the predator relies on extended pursuit, prime-age, healthy prey are seldom killed. Although the scientific literature is reasonably clear on the limitations and exceptions to the sick-and-weak syndrome, any semblance of a balanced viewpoint dissolves when the popular media and newsletters of some groups are involved. Hornocker (1970) showed clearly that physical condition of the prey species was not a significant factor determining the incidence of the kill of either elk (*Cervus elaphus*) or mule deer (*Odocoileus hemionus*) by mountain lions (*Felis concolor*) on his study area. Then, although citing Hornocker as a lion expert, Regenstein (1975:241) turned around, chapter and verse, "lions feed disproportionately (although not exclusively) on the lame, the weak, those wounded by hunters, the very young, and the old."

A recent, highly acclaimed film on predators vividly depicted a mountain lion relentlessly pursuing a band of bighorn sheep (*Ovis canadensis*) until a congenitally malformed yearling fell behind and was almost altruistically dipped from the otherwise threatened gene pool. The lion, of course, is above all else a stalk-and-wait predator, and is fully capable of taking full grown, healthy elk.

I have necropsied healthy adult deer and antelope (*Antilocapra americana*) killed by eagles and coyotes, and have watched both of these superbly adapted predators chase and capture speedy jackrabbits. Consequently, it is difficult for me to discuss seriously the idea that only sick and weak baby lambs can be taken. Yet, during my livestock-predator studies in Montana and Texas, I was contacted by officials of four major environmental groups and one federal agency. All of these people suggested that mainly sick or weak lambs were being taken, and two of them stated that the ranchers should be thankful that the spread of disease was being checked by the predators!

Determining the health of animals killed by predators is seldom easy. Organs are often missing, and the carcasses are sometimes not discovered before autolysis and decay confuse analyses. During the first year of the Cook Ranch study, health at time of death could be established reliably for 271 sheep (Henne 1975:27). Of these kills, 75 percent were judged healthy, 19 percent had minor health problems, and 6 percent had major disorders. Of 15 sheep shot randomly for comparison, 73 percent were healthy, 20 percent had minor abnormalities, and 7 percent had severe disorders. The Cook Ranch was very well managed, pregnant ewes were fed grain, range conditions were excellent, and parasite loads in the sheep were very light. Thus, coyotes were taking a heavy toll on generally healthy sheep. O'Gara (1982) noted that during and soon after lambing, the largest, most playful lambs were most apt to be killed by golden eagles.

Those of us in the scientific community who write about predators and predation must be especially careful. Ranchers, bombarded by tales of predators always benefitting their prey populations, react quickly to apparent slips by biologists. For instance, the prestigious Cain Committee wrote: "Bears, lions, wolves, coyotes, and eagles became the enemies of pioneers' livestock, especially of kids, lambs, and calves, as well as sick, injured, and strayed animals" (Cain et al. 1972:1). Before I received my copy of the report, an official of the Wool Growers Association called me saying he had received the report, and on the first page the committee said predators couldn't take adult, healthy sheep from a flock. He professed little interest in reading further. I could only say I doubted that any of the committee members were naive enough to make such a statement. When I received my copy, I realized that the *especially* was ignored in this sensitive and emotional issue. Since that time, I have heard representatives of animal protection groups cite the same passage, saying the committee of experts did not believe that predators take healthy domestic animals.

ADC Is Inefficient and Ineffective

Most ranchers I know are fairly satisfied with ADC field personnel. In fact, many ranchers view the control agents as the only people involved in the predator-livestock controversy who are not bent on frustrating any real solution. Thus, statements aimed at discrediting ADC are seen by some ranchers as just one more facet of the conspiracy. Comments like those by Nelson (1981a:22) that, "the agency spent about $144 for every dead predator . . . but the cost of private trapping, per coyote, is nowhere near $144" do seem unfair. The very segments of society who campaign for selective control if there must be control apparently cannot understand that it costs more to kill one particular depredating coyote than it does to kill several coyotes indiscriminately. Aerial gunning may well be the most selective control method, but most of us realize that Cessnas and helicopters don't come cheap these days.

Assessing the effectiveness of ADC operations is indeed difficult, but it should be done objectively. Nelson (1981a) pointed out that less livestock predation was being reported from four counties in Wyoming with private predator control than from the Wyoming counties where ADC was in operation. She did not consider the possibility of illegal methods of private control, even though she reported extensive use in the Dakotas of 1080 smuggled from Canada (Nelson 1981b).

Recent intensive field studies on ranches with ADC operations have documented predator losses of ewes at 0.2 to 1.6 percent and lambs at 2.9 to 3.2 percent (Nass 1977, Tigner and Larson 1977). Predator losses on ranches without ADC ranged from 0 to 8.4 percent on ewes and 12.1 to 29.3 percent on lambs (Henne 1975, Delorenzo and Howard 1977, Munoz 1977). These studies reflect conditions on an extremely small proportion of all sheep ranches in the West. Thus, they should not be extrapolated to estimate the overall effectiveness of ADC. Neither, however, should ranchers be told offhand that their only recognizable support in the predator problem is worthless.

Compound 1080 Is the Worst Poison Known

The delisting of 1080 will be considered during hearings this spring, and the compound may again become legal for predator damage control. Judging from experience during the 1960s and early 1970s, a great deal of misinformation about 1080 will flood the popular media as public interest in the issue peaks. As in the past, many characteristics of the chlorinated hydrocarbons will be attributed to 1080 by those who know virtually nothing about the compound except that it is horrible.

The general public understanding of 1080 was typified and reinforced by Amory (1974:340) when he wrote: "Even strychnine, horrible as it is, is as nothing compared to the dread compound 1080, or sodium monofluoroacetate. This is a poison so lethal that there is no known antidote. It is chain reacting—thus, when a meadow mouse eats it and is in turn eaten by a larger animal who is in turn eaten by a coyote who is in turn eaten by a mountain lion—well 1080 will have poisoned them all." Such exaggerations would be laughable except that many people seem to believe them carte blanche. A biologist with a federal agency once assured me that he knew of a dog that died from eating a rat that had been killed by 1080 a year earlier. I asked him how the dead rat was preserved for a year, who saw the dog eat the rat, and how the cause of death was diagnosed. He subsequently admitted that he had only heard the story, but believed it because "everyone knows" how potent and persistent 1080 is.

I do not have space here for a detailed account on the properties of 1080, but proponents and opponents should know the facts. A very short description follows, along with citations that will help anyone interested in learning more about the compound.

Compound 1080 is tasteless and highly toxic, especially to rodents and canids.

Unlike the chlorinated hydrocarbons, 1080 is water rather than fat soluble, hence it is not subject to bio-accumulation in food chains. Acute toxicity of 1080 varies widely between species (Atzert 1971). Effects of 1080 poisoning do not appear to be cumulative, and victims of sublethal doses recover within a few days as residues disappear (Robinson 1948, Foss 1948).

David and Gardiner (1966) reported that 50 ppm concentrations of 1080 (properly prepared coyote baits are about 33 ppm) were biodegraded in soil to glycolate and inorganic fluoride ions within 11 weeks. Goldman and Milne (1966) observed that self-degradation occurred in water, resulting in loss of toxicity.

Whether or not we believe that government and environmental interests owe stockmen the right to use 1080 legally in coyote control, we do owe them the right to have the issue considered on reason and fact rather than on emotion and hearsay.

Conclusions

Statements and attitudes of some scientists, resource managers, and members of the environmental community have created a deep sense of distrust among ranchers who have experienced heavy losses of livestock to predators. Further polarization will continue until the predator-livestock problem is acknowledged, and resource interests join with ranchers to find and apply management techniques that are effective and still compatible with sound management of predator populations.

Undesirable effects of the alienation of stockmen include:

1. Stockmen generally refuse to cooperate in land-use planning and other environmental issues with groups they feel have accused them of everything from ignorance to fraud.
2. Peer support increases, and illegal control activities can occur. These activities may be more damaging to predator populations, and are almost certain to be less selective than sensible, effective, legal control programs.
3. The credibility of resource interests in general is eroded whenever ridiculous statements or insinuations concerning predators and livestock surface.

References Cited

Amory, C. 1974. Man kind? Harper and Row, New York. 372 pp.

Atzert, P. 1971. A review of sodium monofluoroacetate (compound 1080), its properties, toxicology, and use in predator and rodent control. Spec. Sci. Rep. Wildl. No. 146. U.S. Fish and Wildl. Serv., Washington, D.C. 34 pp.

Cain, S. A., J. A. Kadlec, D. L. Allen, R. A. Cooley, M. G. Hornocker, A. S. Leopold, and F. H. Wagner. 1972. Predator control—1971. Report to the Council on Environmental Quality and the Department of the Interior by the Advisory Committee on Predator Control. Univ. Michigan Press, Ann Arbor. 207 pp.

David, W. A. L., and B. O. C. Gardiner. 1966. Persistence of fluoroacetate and fluoroacetamide in soil. Nature 209:1367–1368.

Delorenzo, D. G., and V. W. Howard, Jr. 1977. Evaluation of sheep losses on a range lambing operation in southeastern New Mexico. New Mexico State Univ. Agric. Exp. Sta. Res. Rep. 341. 13 pp.

Errington, P. L. 1935. Over-populations and predation: a research field of singular promise. Condor 37:230–232.

Foss, G. L. 1948. The toxicology and pharmacology of methyl fluoroacetate (MFA) in animals, with some notes on experimental therapy. Brit. J. Pharmacol. 3:118.

Goldman, P., and G. W. A. Milne. 1966. Carbon-fluorine bond cleavage. J. Biol. Chem. 241:5557–5559.
Henne, D. R. 1975. Domestic sheep mortality on a western Montana ranch. M. S. Thesis. Univ. Montana, Missoula. 53 pp.
Hornaday, W. T. 1914. Wild life conservation in theory and practice. Yale Univ. Press, New Haven, Conn. 240 pp.
Hornocker, M. G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho primitive area. Wildl. Monogr. 21. The Wildlife Society, Washington, D.C. 39 pp.
Howard, W. E. 1974. Predator control: whose responsibility? BioScience 24(6):360–363.
Klebenow, D. A., and K. McAdoo. 1976. Predation on domestic sheep in northwestern Nevada. J. Range Manage. 29(2):96–100.
Leopold, A. S., S. A. Cain, C. M. Cottam, I. N. Gabrielson, and T. L. Kimball. 1964. Predator and rodent control in the United States. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 29:27–49.
Munoz, J. R. 1977. Causes of sheep mortality at the Cook Ranch, Florence, Montana, 1975–76. M.S. Thesis. Univ. Montana, Missoula. 55 pp.
Nass, R. D. 1977. Mortality associated with sheep operations in Idaho. J. Range Manage. 30:253–258.
Nelson, M. 1981a. Animal damage control: is it worth the price? The Farmer 99(13):22–23.
———. 1981b. Despite ban, 1080 still being used by some ranchers. The Farmer 99(13):23.
O'Gara, B. W. 1982. Predation by golden eagles on domestic lambs in Montana. Pages 345–358 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock symposium: Proc. 10. Univ. Idaho, Moscow.
Regenstein, L. 1975. The politics of extinction. Macmillan Publishing Co., Inc., New York. 280 pp.
Reynolds, R. N., and O. C. Gustad. 1971. Analysis of statistical data on sheep losses caused by predation in four western states during 1966–69. U.S. Bur. Sport Fisheries Wildl., Washington, D.C. Mimeo. 20 pp.
Robinson, W. B. 1948. Thallium and compound 1080 impregnated stations in coyote control. J. Wildl. Manage. 12:279–295.
Shelton, M. 1972. Predator losses in 1 flock of sheep and goats. Natl. Wool Growers 62:20–21, 36–37.
Taylor, R. G., J. P. Workman, and J. E. Bowns. 1979. The economics of sheep predation in southwestern Utah. J. Range Manage. 32:317–321.
Tigner, J. R., and G. E. Larson. 1977. Sheep losses on selected ranches in southern Wyoming. J. Range Manage. 30:244–252.
U.S. Fish and Wildlife Service. 1978. Predator damage in the West. U.S. Fish and Wildl. Serv. USDI, Washington, D.C. 168 pp.

Western Riparian Habitats and Wetlands

Chairman:
WILLIAM SANVILLE
Team Leader
Wetland Research Program
U.S. Environmental Protection Agency
Corvallis, Oregon
Cochairman:
JAMES GOSSELINK
Chairman
Center for Wetland Resources
Louisiana State University
Baton Rouge

Vegetative Delineation of Coastal Salt Marsh Boundaries

H. Peter Eilers
California State University, Fullerton

Alan Taylor
Oregon State University, Corvallis

William Sanville
United States Environmental Protection Agency, Corvallis, Oregon

Introduction

Two decades of intensive research following the suggestions of Odum (1961) and the work of Teal (1962) have firmly established positive values for undisturbed coastal salt marshes. These intertidal wetlands are noted for high macrophyte production and for export of energy-rich organic detritus and dissolved organic carbon to estuarine waters. They serve as juvenile fish and wildlife habitats, water purifiers, and buffers to erosion of sediment.

Concurrent with increased awareness of salt marsh values and potentials, however, has been the rapid conversion of coastal marsh to urban, industrial, and agricultural uses through diking, filling, and construction activities (Darnell 1976). Recent federal legislation is designed to retard these alterations and thereby protect the nation's remaining wetland resources. Most notable are the Federal Water Pollution Control Act Amendments of 1972 and 1977 (Water Act) which, in Section 404, establish a permit review process to regulate dredge and fill projects.

This paper also has been published, in a somewhat different form, in *Environmental Management*

To implement Section 404 requires that those involved in the permit review: (1) identify wetland, and (2) determine wetland boundaries. Yet, while wetland may frequently be identified by noting the presence of standing water and plants adapted to saturated soil conditions, the determination of the upper limit is often difficult. Instead of exhibiting a sharp break, the characteristics of wetland are more likely to gradually shift to those of upland along a transition. In salt marsh, the influence of the tide diminishes with increasing surface elevation, soils become better drained, and vegetation gradually changes. An ecotone with interdigitation of marsh and upland species occurs between the two systems (Figure 1).

To better understand the nature of the marsh-upland ecotone and to develop methods of delineating a legally defensible intertidal salt marsh boundary, the U.S. Environmental Protection Agency, in conjunction with the U.S. Army Corps of Engineers, began a major research effort in 1975. After three pilot projects were completed (National Ocean Survey 1975, Frenkel and Eilers 1976, Jefferson 1976), four groups were funded to investigate transition zones and upper limits. They covered salt marshes along the coasts of California (Harvey et al. 1978); Oregon and Washington (Frenkel et al. 1978); Alaska (Batten et al. 1978); Delaware, Maryland, Virginia, and North Carolina (Boon et al. 1978). The reports provide a floristic description of marsh-upland ecotones and identify approaches to boundary determination based on vegetation.

The purpose of this paper is to: (1) evaluate the methods used by these researchers, (2) present alternative methods, and (3) recommend approaches to wetland boundary delineation based on vegetation. The methods presented are applicable to wetland-upland boundary determination in general, not exclusively to salt marshes. However, we do acknowledge that vegetation should not be the only criteria considered. The best approach will likely incorporate an analysis of vegetation, soil, and hydrology. The methods considered here are a first approximation, but, as our knowledge of physical factors across the wetland-upland ecotone increases, methods for defining boundaries will be refined.

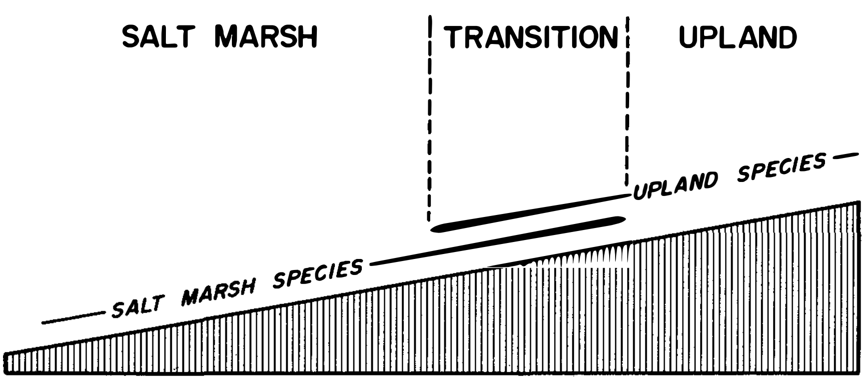


Figure 1. The transition from salt marsh to upland is often a zone of variable width with salt marsh and upland plant species.

Methods For Boundary Determination

The methods of determining wetland boundaries to be evaluated range from those that have little quantitative data and emphasize indicator species to those that require classification of all plant species recorded and intensive quantitative treatment. First, we consider the less quantitative approach favored by Batten et al. (1978); then the more quantitative methods of other researchers. To this we add other quantitative approaches.

Indicator Species

Batten et al. (1978) investigated Alaska coastal salt marshes and collected information on plant species percent cover from quadrats located along the elevation gradient between marsh and upland. Based on these data and knowledge of plant species habitat preference, they developed lists of indicator species that signal the shift from salt marsh to terrestrial upland or freshwater marsh. The lower limit of the transition zone (LTZ) was established at the point where species "abundant" in upland or freshwater wetland first become "abundant" in the marsh. The upper limit of marsh (ULM) was set at the point where all the species characteristic of the vegetation type bordering the marsh were present in "appropriate amounts." No definition of "abundant" or "appropriate amounts" is given and, thus, establishing an actual boundary in the field using this approach would be subjective and ill-suited to situations involving legal scrutiny.

Five Percent

The initial approach of Boon et al. (1978) and Harvey et al. (1978) was similar to that above but included boundary delineation. Following acquisition of plant cover estimates from marsh to upland, a "five percent" method was used to define the upper limit of the transition zone as the point at which the amount of ground coverage by upland plants is at least five percent and is contiguous with the upland proper (Boon et al. 1978). The lower transition limit was defined similarly—upland plant coverage less than five percent. Plants were classified as to marsh, transition, upland (Boon et al. 1978) or marsh, upland, non-indicator (Harvey et al. 1978), and results were presented graphically. Harvey et al. used the following procedure: (1) when a five percent cover of the appropriate type (either marsh or upland) occurred in a quadrat with no trace in the adjacent, more distal quadrat, the quadrat with five percent cover was marked as the transition; (2) if the adjacent quadrat distal to the five percent cover plot had a trace of the vegetation type in question, the adjacent quadrat was marked as the transition limit; (3) if two plots in sequence had a trace of either vegetation type, the more distal quadrat was marked as the limit; (4) if the five percent cover level fell between two quadrats, the limit was located by interpolation; (5) if no overlap of upland and marsh species occurred either due to bare ground and/or cover by non-indicator species, a point midway between quadrats in which each type was represented was chosen (Figure 2).

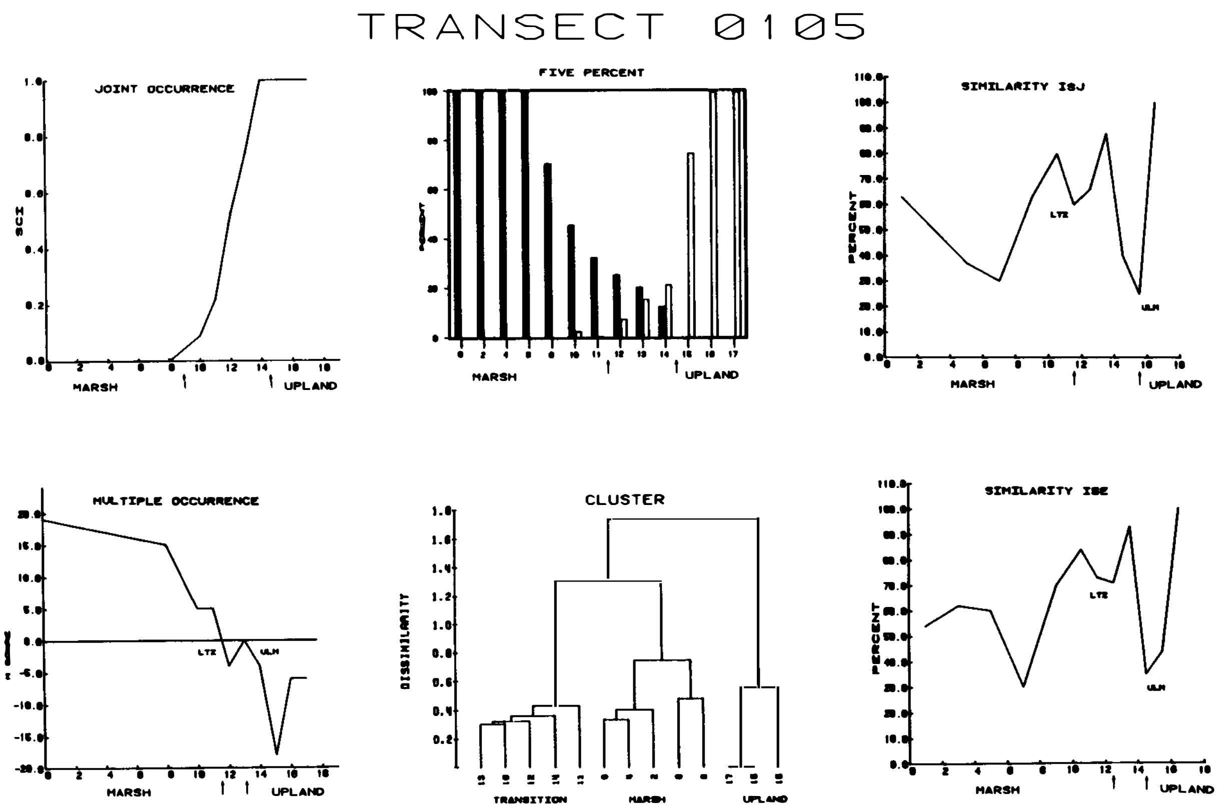


Figure 2. Lower limit of the transition zone (LTZ) and upper limit of marsh (ULM) for transect 0105 (Coquille Estuary, Oregon) as determined by six methods. Data from Frenkel et al. (1978).

Joint Occurrence

After applying the five percent method, Harvey et al. (1978) sought a "quicker, easier, but equally accurate approach." Their choice was a modification of Fager's (1957) measure of joint occurrence,

$$I_{MU} = \frac{2J}{nM + nU},$$

where, for any single quadrat, J is the number of joint occurrences of marsh and upland species, nM is the number of marsh species, and nU is the number of upland species. Non-indicator species were disregarded.

Plotting I_{MU} for quadrats along a transect shows a series of zeros for pure wetland, because there are no joint occurrences, followed by a rise to a peak in the transition and a fall to zero again in pure upland. In practice, however, Harvey et al. (1978) found it difficult to interpret such a graph when natural or man-made "patchiness" was present. This problem was largely eliminated by computing a standardized index (SI) then a standardized cumulative index (SCI) for each quadrat:

$$\text{SI}i = \frac{I_{MU_i}}{\sum_{i=1}^{n} I_{MU_i}} \text{ and } \text{SCI}_i = \sum_{i=1}^{Q} SI_i,$$

where n is the total number of quadrats and Q is the quadrat for which SCI is computed. After plotting SCI values, Harvey et al. (1978) identified the lower and upper limits of the transition as 0.5 m above the rise of the data line from the abscissa and 0.5 m above SCI = 1.0, respectively (given 1 m distance between sample quadrats or one-half the distance if greater than 1 m) (Figure 2). Close agreement between the SCI and the five percent method transition boundaries was observed.

Multiple Occurrence

Frenkel et al. (1978) analyzed species distribution patterns to develop four species categories—low marsh, high marsh, non-indicator, and upland—and computed a score for quadrant data collected along transects between marsh and upland. The "multiple occurrence method" (MOM) score (M) required the assignment of a weighting coefficient:

Species Type	*Weighting Coefficient*
Low marsh	2
High marsh	1
Upland	−2
Non-indicator	0

The quadrat score was calculated as:

$$M = \sum_{i=1}^{n} W_i C_i,$$

where W_i is the weighting coefficient for species i, C_i is cover value for species i, and n is total number of species in the quadrat sample. Cover values were after Daubenmire (1959): 0–5 percent = 1, 5–25 percent = 2, 25–50 percent = 3, 50–75 percent = 4, 75–95 percent = 5, 95–100 percent = 6. Species present but with negligible cover were disregarded.

Positive M values were interpreted as marsh, the upper limit of marsh was defined as M = 0, and M < 0 denoted upland. However, further interpretation was necessary because M values did not always descend to a single M = 0 and thereafter remain negative. Two additional cases were noted. One contained more than one M = 0 in succession, and the other M scores alternated above and below zero. In both cases, the portion of the transect between first and last M = 0 were considered the transition zone and the upper limit of marsh was placed midway through this zone. In our interpretation of this method we assigned the upper limit of the transition zone as the ULM and combined high and low marsh with a weighting coefficient of 2. The latter modification was considered to more accurately differentiate marsh and upland (Figure 2).

Cluster

If marsh and upland are floristically different, cluster analysis (Boesch 1977) of quadrat data collected along transects between the two systems might be used to identify wetland limits. Such an approach would have the advantage of not requiring preclassification of plant species into "marsh," "upland," "non-indicator." We chose the Bray-Curtis dissimilarity measure (Clifford and Stephenson 1975),

$$Djk = \frac{\sum_{i=1}^{n} x_{ij} - x_{ik}}{\sum_{i=1}^{n} (x_{ij} + x_{ik})},$$

where x is cover value for species i in quadrats j and k, and n is the total number of species. A "flexible" fusion strategy with Beta = −0.25 (Boesch 1977) was utilized and the results displayed in a dendrogram with quadrat clusters forming at decreasing levels of dissimilarity (Figure 2). The upland cluster was identified as that containing the highest numbered quadrats (when quadrats were numbered from wetland to upland). The upper limit of marsh was interpreted as being half the distance on the transect between the lowest numbered member of the upland cluster and the highest numbered member of the lowest group of quadrats. This second group was identified as "transition" if three or more clusters were present.

Similarity ISJ and ISE

By computing the level of similarity in species content of adjacent quadrat samples along a transect and graphing these values, we expected to observe a decrease in similarity at the marsh-upland border. In this case, two measures were chosen. One was Jaccard's index (Mueller-Dombois and Ellenberg 1974) which requires binary data (presence-absence):

$$\text{ISJ} = \frac{c}{a + b + c} \times 100,$$

where c is the number of species common to both quadrats, a is the number of species unique to the first quadrat, and b is the number of species unique to the second quadrat. The second was Ellenberg's (1956 in Mueller-Dombois and Ellenberg 1974) modification of Jaccard's index which accepts species quantities:

$$\text{ISE} = \frac{Mc{:}2}{Ma + Mb + Mc{:}2} \times 100.$$

Here, Mc is the sum of cover values of species common to both quadrats, Ma is the sum of the cover values of the species restricted to the first quadrat, and Mb is the corresponding sum for species restricted to a second quadrat. Species noted as present but with negligible cover were assigned a value of 0.25 to preserve their indicator value but minimize their influence.

Graphs of similarity values for adjacent quadrat pairs showed several peaks and troughs reflecting zonal patterns along the elevation gradient (Figure 2). The most elevated trough denoted by 40 percent or greater decrease in similarity, and the next lower trough, were interpreted as the ULM and LTZ, respectively.

Comparison of Methods

Each quantitative method was applied to a common data set. Twenty-two transects (12%) were chosen at random from the 190 sampled by Frenkel et al. (1978). The data were collected from 50 by 50 cm quadrats. Transects were located with one end well into wetland, the other well into upland, and the orientation parallel to the elevation gradient. Plant species in each quadrat were recorded as to cover class (Daubenmire 1959) except that those with negligible cover were assigned "present" status only. Categorization of plant species as to marsh, upland, etc., was not modified. As LTZ and ULM were calculated by each method, careful note was made of the time and ease of application. ULM identification was stressed because of its direct relationship to jurisdictional questions. ULM was considered to be synonymous with the upper limit of the transition zone.

Data presented in Table 1 reveal close agreement in LTZ and ULM positions obtained by the six methods. ULM for transects 0808 and 1606 was not identified by all methods, suggesting that the transects did not extend far enough to include both marsh and upland quadrats. ULM location agreed within 1.0 m on 9 of the remaining 20 transects (45%) and within 2.5 m on 13 transects (65%). The range of ULM estimates was greatest for transect 1703 (25.5 m), but cluster and similarity plots for this transect showed discontinuities at positions in agreement with other methods that could be interpreted as ULM. In general, methods using species classification (five percent, joint occurrence, and multiple occurrence) exhibited low intra-group variability, as did those without species classification.

All methods, with the exception of cluster, involved simple hand calculations. Cluster required a computer. Time differences were small, given basic field data and plant classifications, suggesting that the choice of method should be determined by time available for field work and availability of indicator species lists.

Perhaps the most important result of this comparative treatment was that use of species presence-absence yields ULM positions identical or nearly identical to those requiring species percent cover. Thus, the field effort required to obtain

Table 1. Lower transition zone limit (LTZ) and upper limit of marsh (ULM) as determined by 6 methods applied to 22 transects from Frenkel et al. (1978). Limits expressed as distance (*m*) along transect where distance increases from marsh to upland.

Transect number	Location	Five percent		Joint occurrence		Multiple occurrence		Cluster		Similarity ISJ		Similarity ISE		ULM Mean	ULM S.D.	ULM Range
		LTZ	ULM	LTZ	ULM	LTZ	ULM	LTZ	ULM	LTZ	ULM	LTZ	ULM			
	OREGON															
0105	Coquille Estuary	11.0	14.5	9.0	14.5	11.5	13.0	9.0	14.5	11.5	15.5	12.5	14.5	14.4	0.8	2.5
1208	Coos Bay	16.5	19.5	16.5	21.5	—	21.0	—	19.5	—	21.5	—	21.5	20.8	1.0	2.0
0301	Alsea Bay	9.0	15.5	—	15.5	10.0	15.0	9.0	15.5	9.0	15.5	9.0	15.5	15.4	0.2	0.5
0310	Alsea Bay	—	13.0	—	13.5	10.0	12.0	9.0	13.5	7.0	13.5	9.0	13.5	13.2	0.6	1.5
0402	Yaquina Bay	—	19.5	—	19.5	—	18.5	13.5	19.5	13.5	19.5	13.5	19.5	19.3	0.4	1.0
0407	Yaquina Bay	4.5	19.5	4.5	19.5	7.5	19.5	1.5	19.5	10.5	19.5	10.5	19.5	19.5	0.0	0.0
0704	Nehalem Bay	1.0	11.0	1.0	11.5	—	8.0	7.0	15.5	—	9.0	—	9.0	10.7	2.7	7.5
0706	Nahalem Bay	10.5	13.0	10.5	13.5	10.5	11.1	10.5	15.5	7.0	16.5	12.5	16.5	14.4	2.2	5.4
0710	Nahalem Bay	—	16.0	—	15.5	—	15.0	—	15.5	—	15.5	—	15.5	15.5	0.3	1.0
	WASHINGTON															
0804	Willapa Bay	14.5	15.5	14.5	16.5	11.0	15.0	9.0	15.5	9.0	15.5	9.0	15.5	15.6	0.5	1.5
0808	Willapa Bay	—	—	—	—	8.0	—	5.0	15.5	—	—	—	—	—	—	—
0809	Willapa Bay	15.0	22.5	—	22.5	15.0	22.0	19.0	22.5	20.5	22.5	19.0	22.5	22.4	0.2	0.5
0910	Willapa Bay	84.5	87.5	—	87.5	63.5	87.5	—	87.5	65.0	87.5	65.0	87.5	87.5	0.0	0.0
1001	Willapa Bay	256.0	265.0	—	265.0	248.0	259.0	—	259.0	—	249.0	—	249.0	257.7	7.2	16.0
1103	Grays Harbor	105.5	146.0	105.5	147.5	117.5	129.5	117.5	147.5	117.5	147.5	98.0	147.5	144.3	7.3	18.0
1201	Grays Harbor	18.5	19.5	—	19.5	—	19.0	17.0	19.5	17.0	19.5	17.0	19.5	19.4	0.2	0.5
1606	Thorndyke Bay	—	—	—	—	—	—	—	—	—	10.5	—	10.5	—	—	—
1610	Thorndyke Bay	—	6.0	3.5	7.5	—	3.0	—	10.5	—	10.5	—	10.5	8.0	3.1	7.5
1611	Thorndyke Bay	9.0	12.5	—	12.5	6.0	12.0	—	10.5	4.5	10.5	4.5	10.5	11.4	1.0	2.0
1612	Thorndyke Bay	—	21.5	—	21.5	1.0	20.0	12.0	23.5	—	12.0	12.0	23.5	20.3	4.3	11.5
1703	Snohomish Estuary	—	7.5	—	7.5	—	6.0	—	31.5	—	31.5	—	31.5	19.3	13.4	25.5
1802	Oak Bay	—	26.0	—	25.5	—	25.5	—	25.5	10.5	25.5	19.5	25.5	25.6	0.2	0.5

plant cover may not be necessary, and the greatest return might be from utilizing species occurrence only.

Discussion and Recommendations

The methods evaluated fall into two basic groups. The first comprises five percent, joint occurrence, and multiple occurrence and is characterized by reliance on pre-established lists of wetland and upland indicator species. Botanical expertise is required but, theoretically, a valid ULM determination could be made without in-depth knowledge of wetland ecology.

The second group—cluster, similarity ISJ and similarity ISE—does not require preclassification of plant species. Instead, it is assumed that species are distributed along elevation gradients in such a way as to form groups characteristic of wetland, transition, and upland, and that these groups can be identified objectively. This study suggests that this approach is viable and that results are comparable to those obtained by preclassification methods. Cluster and similarity methods are most sensitive to vegetation patterns and require interpretation based on ecological knowledge, as transect 1703 illustrates. A ULM of 31.5 m was chosen, but it is likely that a position closer to 7.0 m as indicated by five percent, joint occurrence, and multiple occurrence would have been the selected ULM, given on-site review. All six methods should be viewed as tools with strong indicator value and, whether classification of plant species is involved or not, the final boundary decision should involve sound ecological judgment.

A general vegetative approach to wetland boundary identification is outlined in Figure 3. If classification of plants is available, the joint occurrence method may be best because it reduces field time and yields results close to the five percent and multiple occurrence methods. If accepted plant classifications are unavailable, as is the present case for most freshwater wetlands, the cluster method or similarity ISJ applied to presence-absence data may provide defensible boundaries and have the added advantage of helping to establish a classification. Even if the requisite information needed to apply the joint occurrence method is available, it is still advisable to employ either cluster or similarity ISJ or both to support the initial decision.

Although a vegetative approach to ULM determination is likely to be satisfactory, in that plant distributions reflect environmental conditions, our present knowledge of physical factors, such as soils and hydrological regimes, across the transition is very limited. It is assumed that certain plants indicate physical conditions of wetland, transition, and upland; but we do not know tolerance limits for species so classified. Research underway at the U.S. Environmental Protection Agency and U.S. Army Corps of Engineers is designed to provide a more holistic treatment of the wetland boundary problem. Physical factors between wetland and upland are being intensively monitored at numerous wetland sites; greenhouse studies are testing species tolerance to various field conditions, such as inundation and soil saturation, and methods are being devised to incorporate both vegetation and physical factors in wetland boundary identification. In the near future, the ability to establish boundaries will be enhanced beyond the sole reliance on vegetation.

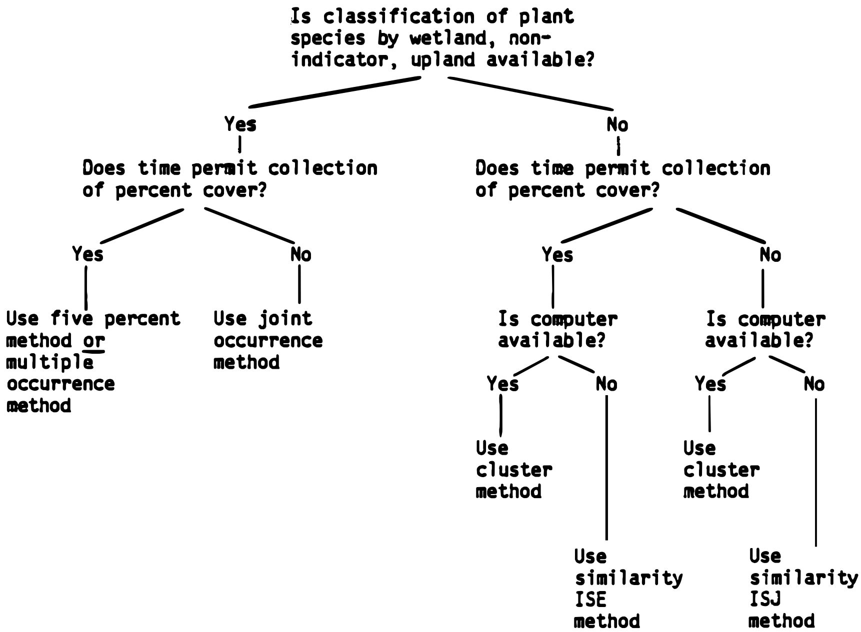


Figure 3. Flow diagram to facilitate choice of vegetation method to determine upper limit of wetland.

Acknowledgements

We thank Theodore Boss for comments and criticism; Jo Oshiro for help with computer graphics; and Brian Lightcap, Terry Huffman, Robert Frenkel, Porter Reid, David Peters, David Price, and William Sipple for critical review of the draft manuscript.

Literature Cited

Batten, A. R., S. Murphy, and D. F. Murray. 1978. Definition of Alaskan wetlands by floristic criteria. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Boesch, D. F. 1977. Application of numerical classification in ecological investigations of water pollution. Special Scientific Report No. 77, Virginia Institute of Marine Science, Gloucester Point, Va.

Boon, J. D., D. M. Ware, and G. M. Silberhorn. 1978. Survey of vegetation and elevational relationships within coastal marsh transition zones in the central Atlantic coastal region. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Clifford, H. T., and W. Stephenson. 1975. An introduction to numerical classification. Academic Press, New York.

Darnell, R. M. 1976. Impacts of construction activities in wetlands of the United States. Publ. No. EPA-600/3-76-045. U.S. Environmental Protection Agency, Corvallis, Oregon.

Daubenmire, R. F. 1959. Canopy coverage method of vegetation analysis. Northwest Sci. 33:43–64.

Fager, E. W. 1957. Determination and analysis of recurrent groups. Ecology 38:586–595.

Frenkel, R. E., and H. P. Eilers. 1976. Tidal datums and characteristics of the upper limits of coastal marshes in selected Oregon estuaries. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Frenkel, R. E., T. Boss, and S. R. Schuller. 1978. Transition zone vegetation between intertidal marsh and upland in Oregon and Washington. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Harvey, H. T., M. J. Kutilek, and K. M. DiVittorio. 1978. Determination of transition zone limits in coastal California wetlands. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Jefferson, C. A. 1976. Relationship of vegetation and elevation at upper and lower limits of the transition zone between wetland and upland in Oregon's estuaries. Report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and methods of vegetation ecology. John Wiley, New York.

National Ocean Survey (NOAA). 1975. The relationship between the upper limit of control marshes and tidal datums. Rockville, National Ocean Survey report to the U.S. Environmental Protection Agency, Corvallis, Oregon.

Odum, E. P. 1961. The role of tidal marshes in estuarine production. The Conservationist 15:12–13.

Teal, J. M. 1962. Energy flow in the salt marsh ecosystem of Georgia. Ecology 43:614–624.

Relationships Between Avifauna and Streamside Vegetation

Evelyn L. Bull and Jon M. Skovlin
U.S. Forest Service, Pacific Northwest Forest and Range Experiment Station, La Grande, Oregon

Introduction

Riparian microhabitats in coniferous forests in northeastern Oregon are sensitive to alteration. They have been used disproportionately by people, livestock, and wildlife. These uses have altered the habitats, specifically by reducing vegetative structure (Thomas 1979).

Land management agencies are revegetating depleted riparian zones to improve fish and wildlife habitat. Managers need information on the response of birds to kinds and structures of vegetation so that wildlife objectives can be met.

Several studies have dealt with the relationships of riparian vegetation and avifauna (Carothers and Johnson 1975, Ferguson et al. 1976, Stauffer 1978). Although these studies determined some of the habitat requirements of avian species and the consequences of habitat alteration, we need information on the relationship between occurrences of birds and structural components of riparian habitats.

The objectives of this study were to compare habitat use by birds with available riparian habitat, and to compare bird population characteristics among riparian habitats with different amounts of deciduous vegetation—high, moderate, and low.

Methods

Our study was conducted along streams dissecting coniferous forests in the Blue Mountains of northeastern Oregon. Six streams were selected with a maximum stream width of 66 feet (20 m), minimum riparian zone width of 230 feet (70 m), maximum slope gradient of 10°, and elevations of 2,800–4,500 feet (853–1,372 m).

Streams were stratified into one of three cover classes based on the percentage of riparian zone occupied by deciduous trees and shrubs: (1) high (> 40 percent), (2) moderate (15–30 percent), and (3) low (< 1 percent). Two streams occurred in each category.

A 2,624-foot (800-m) transect was placed parallel to and within 100 feet (30 m) of each stream. We used two survey techniques, the variable strip transect (Emlen 1971) and the variable circular-plot (Reynolds et al. 1980). Birds were recorded for 10 minutes at each of 10 equally spaced stations along the transect and while moving between stations.

Each transect was surveyed on three successive days within three hours after sunrise. Surveys commenced at the lowest elevation on May 15 and terminated at the highest elevation on June 21. Only birds seen were recorded because we wanted specific habitat locations. Data recorded were species, number, perpendicular distance to the transect, perching height of bird, and habitat characteristics in a 0.25-acre (0.1-ha) plot surrounding the bird. Habitat characteristics identified are shown in Table 1. The characteristics were estimated at the 10 stations along each transect to describe the available habitat.

Bird species were grouped by cluster analysis (Pimentel 1979) using mean habitat characteristics collected at sightings. We subjectively selected an amalgamation distance to define the level of clustering. Only species observed more than five times were included.

Performing further analysis on these clusters may not be appropriate because new data should be collected to distinguish among clusters and compare habitat used with that available. However, time and money restraints prohibited collecting new data. Chi square was used to test preferences between habitat available and habitat used by each bird cluster. Discriminant function analysis (Klecka 1975) was used to identify differences among clusters by comparing habitat characteristics at bird sightings. The analysis formed linear combinations (called discriminant functions) of the habitat variables and defined the degree to which the clusters were correctly classified. The variables explaining a significant amount of the variance among the groups were identified.

Species number, birds per survey by cluster, bird density (Caughley 1977:42), and bird diversity (Shannon and Weaver 1963) were compared among the deciduous cover classes with an analysis of variance. Least significant difference tests identified differences between pairs of classes (Steel and Torrie 1960). Cover classes were treatments and different streams were replicates.

Table 1. Average habitat characteristics of the study areas grouped into three deciduous vegetation cover classes; values for the two streams (replicates) in each class were averaged.

Habitat characteristic	Vegetation cover class		
	High	Moderate	Low
		Percent	
Grass cover	34	53	64
Shrub cover			
Short (<3 feet, 1 meter)	38	24	0
Medium (3–10 feet, 1–3 meters)	42	17	0
Tall (10–50 feet, 3–15 meters)	40	4	0
Deciduous tree cover	10	2	0
Total canopy cover	62	15	2
		Number	
Number snags/.25 acre (0.1 hectare)	0.2	0	0.2
Number shrubs/.25 acre (0.1 hectare)	15.6	4.8	0
Number deciduous trees/.25 acre (0.1 hectare)	1.2	0.05	0
Number conifers/.25 acre (0.1 hectare)	1.1	0.2	0.1
Height deciduous vegetation—feet (meters)	39.4 (12)	6.6 (2)	0
Height conifer tree—feet (meters)	19.7 (6)	9.8 (3)	6.6 (2)
Distance to clearing—feet (meters)	55.8 (17)	1.3 (.4)	0

Study Area

The high cover class of deciduous vegetation consisted of plots along two streams dissecting coniferous forests. The riparian zones averaged 210 feet (64 m) in width and were predominantly occupied by deciduous trees and shrubs (Table 1). Black cottonwood (*Populus trichocarpa*), alder (*Alnus incana*), and quaking aspen (*Populus tremuloides*) made up the tree component. Predominant medium and tall shrubs included hawthorn (*Crateagus douglassi*), willow (*Salix* sp.), red-osier dogwood (*Cornus stolonifera*), serviceberry (*Amelanchier alnifolia*), chokecherry (*Prunus virginiana*), and mockorange (*Philadelphus lewisii*). Short shrubs included currant (*Ribes cereum*), rose (*Rosa woodsii*), snowberry (*Symphoricarps alba*), thimbleberry (*Rubus parviflora*), and ninebark (*Physocarpus malvaceus*). The high density of shrubs eliminated open areas and made walking difficult. Despite the predominance of deciduous vegetation, scattered mature conifers occurred within these riparian zones. Deciduous and coniferous dead trees were present.

The moderate cover class consisted of two streams with deciduous vegetation cover intermediate between those with high and low cover classes. The zones averaged 207 feet (63 m) in width and were predominantly unwooded. All three shrub layers occurred, but with decreasing coverage as shrub height increased (see Table 1). Snowberry, rose, dogwood, alder, and willow were the principal shrubs. Black cottonwoods were present, but sparsely so and outnumbered by conifers. Dead trees occurred in such low densities that they did not occur in the habitat samples. This cover class was probably the most diverse structurally because all the vegetation cover classes, conifers, snags, and open areas, were present.

The lower cover class consisted of riparian habitats adjacent to two streams completely devoid of deciduous trees and shrubs. The riparian zones averaged 289 feet (88 m). A few conifers, predominantly short ones, provided the only vegetation structure other than grass and a few scattered dead trees. Conifer forests surrounded the riparian zones.

Results

We observed 983 birds representing 56 species. Species number ranged from 11 to 22 for any one survey. There were no significant differences ($\alpha \leq 0.10$) in species numbers among cover classes (Table 2).

Better visibility in study areas with less deciduous vegetation resulted in more birds actually seen per survey (Table 2); however, abundance was not significantly different among the vegetation classes.

Bird density considered detectability distances by species for each vegetation cover class and corrected for variable visibility among cover classes. Because we did not record birds heard, our density estimates were relatively low (Table 2). Density was highest in the high cover class but not significantly different from the low and moderate cover classes because of high variability in bird density between replicates.

Bird diversity was significantly ($\alpha \leq 0.10$) higher in the moderate cover class than the other two classes. The greatest number of species and highest abundance were observed here (Table 2).

We used a cluster analysis to group the species based on common habitat characteristics. Eight clusters were identified (amalgamation distance of 2.94) after

Table 2. Population characteristics (average) of birds observed in three deciduous vegetation cover classes in riparian habitats.

Population characteristic	Vegetation cover class		
	High	Moderate	Low
	Number		
Number species	15	17.5	17.2
Abundance (birds/survey)	47.3	60.7	55.8
Density (birds/2.5 acre or 1 hectare)	56.2	23	20.1
Diversity index[a]	2.42	2.58	2.48

[a]Significant difference ($\alpha \leq 0.10$) among cover classes.

eliminating clusters with small (<10) sample sizes (Figure 1). Eighty-nine percent of the birds observed were contained in the eight clusters identified by the analysis. Each cluster comprised various percentages of the total bird composition of each cover class (Table 3).

Bird abundance (number of birds/survey) of three clusters differed significantly (α <0.10) among the cover classes (see Table 3). Birds in cluster 3, deciduous-users, were more abundant in the high and moderate cover classes than in the low (see Figure 1). Birds in cluster 4, forest-dwellers, were more abundant in the low

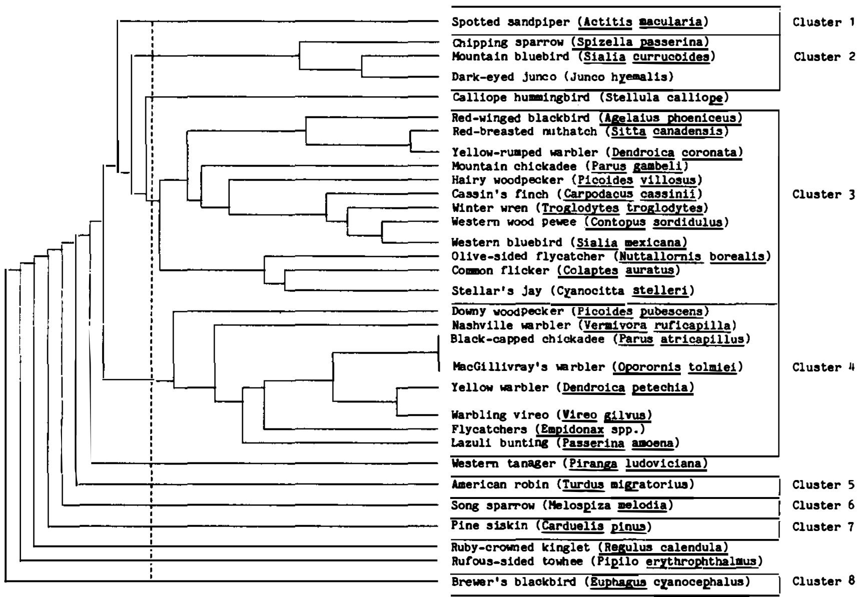


Figure 1. Bird species grouped by cluster analysis based on habitat use along streams. The dashed line identifies the clusters used.

Table 3. Bird composition (by cluster) comprising each of three deciduous vegetation cover classes.

Cluster	Vegetation cover class		
	High	Moderate	Low
	Percent		
Deciduous-users[a]	57	22	1
Forest-dwellers[a]	14	30	41
American robin	7	16	13
Ground-foragers	4	11	17
Song sparrow	3	2	4
Pine siskin[a]	2	0	10
Brewer's blackbird	1	6	1
Spotted sandpiper	0	2	2
Other[b]	13	10	11
Total	101	99	100

[a]Abundance (birds/survey) of this cluster significantly ($\alpha \leq 0.10$) different among cover classes.
[b]Birds not included in a cluster.

cover class than in the high. Birds in cluster 7, the pine siskin, were more abundant in the low cover class than the moderate or high.

The discriminant analysis correctly classified 42 percent of the cases into the proper cluster (Figure 2). The medium shrub component was the single variable best distinguished among clusters. Canopy closure, bird height, percentage of grass cover, conifer height, and shrub density further explained a significant amount of variance among the clusters.

The first discriminant function explained 68 percent of the variance among plots, and medium shrub cover and total canopy cover contributed the most to this function. An additional 17 percent of the variance was explained by the second discriminant function. Bird and conifer heights contributed most to the second function.

Discussion

The lack of significant differences in bird species, abundance, and density among cover classes resulted from several factors. Typically, species composition changes more than the number of species among similar habitats. Anderson et al. (1977) reported an increase in bird density as the vegetation density and height increased in salt cedar communities.

Densities should be regarded as relative because birds heard were not recorded. Density was highest in the high cover class, even though abundance was lowest here. Dense vegetation limited the number of birds seen, but detectability distances were short and resulted in a higher density. Variability between replicates detracted from differences among cover classes.

Bird diversity was highest in the moderate cover class because it contained the most diverse vegetation structure. Shrubs, conifers, and open grass areas were all

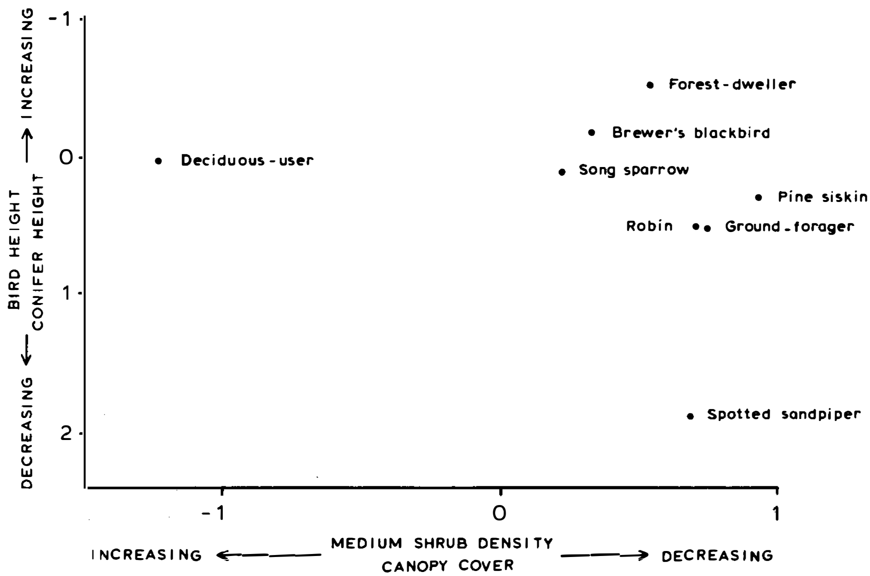


Figure 2. Group centroids of the first (x) and second (y) discrimination functions of birds observed in riparian habitats.

represented, while the high cover class lacked the open grass areas and the low cover class lacked the deciduous trees and shrubs (see Table 1). Fewer structural components provided fewer niches, thus less bird diversity. These findings are consistent with numerous papers that discussed the increase in species diversity with habitat diversity (MacArthur and MacArthur 1961, Balda 1975, Carothers and Johnson 1975, Anderson and Ohmart 1977, Meslow 1978).

Birds have traditionally been combined by foraging group or guild (Salt 1953, Root 1967). Lumping by guild combines species on the basis of similar niches (all feeding or nesting in the same manner), but not necessarily in the same type of habitat.

Because we wanted a combination of species that were observed in like habitats regardless of where or the manner in which they foraged and nested, we clustered them by habitat use. We selected an amalgamation distance on the basis of logical grouping and applicability for further statistical analysis, based primarily on sample sizes. A large number of species did not form clusters early, presumably because the habitat use of each was unique (see Figure 1). The clustering technique is a valuable tool for grouping species when habitat use is being considered and can be the basis of forming the "life forms" suggested by Haapanen (1965) and extrapolated in use by Thomas (1979).

The eight clusters characterized distinct groups. Cluster 1, the spotted sandpiper, was correctly classified 53 percent of the time. This cluster was particularly distinct because habitat with less than 25 percent grass cover, no shrubs, and no canopy closure was used and perching was on the ground (Table 4).

Table 4. Average habitat characteristics of 0.1-hectare plots where birds were observed in riparian habitats.

	Cluster							
Characteristic	Spotted sandpiper	Ground-forager	Forest-dweller	Deciduous-user	Robin	Song sparrow	Pine siskin	Brewer's blackbird
Height of bird (feet, meters)	0.3(0.1)	13.8 (4.2)	31.2(9.5)	20.7(6.3)	14.4(4.4)	12.1(3.7)	22.0(6.7)	28.5(8.7)
Percent								
Grass cover	9[a]	49[a]	50	39[a]	57	67[a]	46	52
Short shrub cover	0[a]	8[a]	16	40[a]	13[a]	24	3[a]	18
Medium shrub cover	0	5[a]	11[a]	43[a]	7[a]	24	4	18
Tall shrub cover	0	1[a]	8	42[a]	4[a]	14	2	18
Deciduous tree cover	0	0	5[a]	12	7	5	0	5
Total canopy closure	0[a]	22[a]	33[a]	63[a]	24	30	18	29
Number								
Snags/0.25 acre (0.1 hectare)	0	0.6[a]	0.8[a]	0.2	0.3	0.6[a]	0.5	0.1
Shrubs/0.25 acre (0.1 hectare)	0[a]	0.3[a]	2.0[a]	9.7[a]	0.9[a]	3.0	0.1	11.0[a]
Deciduous trees/0.25 acre (0.1 hectare)	0	0.03[a]	0.1[a]	0.9[a]	0.3	0.6	0	0
Conifers/0.25 acre (0.1 hectare)	0	1.0[a]	1.0[a]	0.7	0.7	0.4	1.0	0.3
Height deciduous vegetation—feet (meters)	0	3.0(0.9)[a]	8.9(2.7)	29.2(8.9)[a]	9.5(2.9)[a]	14.8(4.5)	1.6(0.5)	11.8(3.6)
Conifer—feet (meters)	0	32.1(9.8)[a]	46.9(14.3)[a]	18.4(5.6)	25.9(7.9)	24.3(7.4)	30.8(9.4)	27.9(8.5)
Distance to clearing—feet (meters)	0	5.6(1.7)	12.1(3.7)	20.7(6.3)	6.2(1.9)	8.9(2.7)	3.6(1.1)	3.3(1.0)
Number of plots	8	70	200	205	61	26	10	10

[a]Significant difference ($\alpha \leq 0.10$) between habitat used and that available.

Cluster 2, ground-foragers, consisted of three species that fed on the ground in open areas. Only 20 percent of the observations were correctly classified by the discriminant analysis; most overlap occurred with clusters 1, 3, and 5, all of which contained species with low perching heights. Preferred habitat included areas with more grass cover, snags, and tall conifers, but fewer shrubs and deciduous trees than if selected at random (Table 4). These birds preferred open stands with grassy areas for foraging and trees for perching.

Cluster 3, forest-dwellers, was made up of 12 species. Forty-six percent of the observations were correctly classified and defined a relatively distinct cluster. Habitats with more and taller conifers, more snags, but fewer shrubs were used disproportionately (see Table 4). The forest-dweller cluster comprised the largest percentage (41 percent) in the low vegetation class and decreased in abundance as deciduous vegetation increased. Most species in this cluster resided in conifer forests, half were cavity-nesters, and half foraged primarily in openings.

Cluster 4, deciduous-users, contained the highest percentage (55 percent) of correctly classified cases, and defined the most distinct cluster (see Figures 1 and 2). This cluster used habitats with more shrubs, deciduous trees, and canopy closure than any other (see Table 4). Areas with a low percentage of grass cover were used by deciduous-users more than if selected at random. These species typically nested and foraged in deciduous vegetation. The deciduous-user cluster comprised 57 percent of the birds in the high vegetation class, yet was almost absent from the low class. If deciduous vegetation is lacking, birds of this cluster will probably be absent.

Cluster 7, the pine siskin, was most abundant ($\alpha \leq 0.10$) in the low cover class. Only 13 percent of the observations were correctly classified. We think the difference in abundance was a function of their flocking behavior rather than a habitat preference.

The American robin, song sparrow, and Brewer's blackbird each comprised a cluster (5, 6, and 8, respectively). These species occurred in all cover classes and exhibited few habitat preferences.

Three clusters (forest-dweller, deciduous-user, and pine siskin) discussed above showed differences in abundance among cover classes. Of these, the deciduous-user cluster was the only group of birds highly dependent on deciduous vegetation in the riparian habitats considered. Therefore, removal of deciduous vegetation would be detrimental to at least 8 (deciduous-users) of 56 species occurring in riparian habitats in northeastern Oregon. The other clusters were either not affected by the amount of deciduous vegetation or were too scarce to detect differences.

In comparison, Stauffer and Best (1980) predicted that 11 of 41 species in riparian habitats in Iowa would be affected detrimentally if shrubs and saplings were removed. Carothers and Johnson (1975) reported that removal of 70 percent of the trees in riparian habitats in the southwestern United States reduced the total bird population density by at least 50 percent.

Management Implications

Before land managers can predict the effects of management decisions, they must understand how birds use different habitat components and how management practices affect plant succession and associated vegetation structure.

All plant communities evolve through seral stages of plant succession, each with specific plant species and structural components. As the structure of habitats becomes more complex, it provides more opportunities for nest sites and food resources, therefore additional birds can inhabit the area (Balda 1975, Meslow 1978). Structure takes a variety of forms: layers of vegetation, patchiness, interspersion of successional stages, edges, snags, or deciduous vegetation. Management activities advance or retard succession and change plant composition, vegetation structure, and edge effects. Changing the successional stage can be drastic, as with clearcut logging, or gradual, as with livestock grazing systems. In general, management activities that provide diversity in structure also provide greater bird diversity (MacArthur and MacArthur 1961).

Logging in the past 80 years removed many of the tall conifers from riparian zones and adjacent forested uplands in the Pacific Northwest interior. Heavy logging and excessive grazing converted many riparian zones from mixed conifer forests containing deciduous woody species to predominantly savannah herblands with scattered remnant conifers. A greater abundance of ground-foraging and forest-dwelling birds was associated with riparian zones lacking deciduous species in this study.

Clearcutting, overstory removal, regeneration cuts, and precommercial thinning in nearby forest uplands alter bird diversity in riparian zones. Forest practices that produce large-scale even-aged stands are less desirable than those providing even-aged stands on a smaller scale. The latter provide a greater variety of structures, successional stages, and edge. Highest bird diversity occurred in the moderate cover class that provided the greatest structural diversity.

Livestock grazing over the last century reduced the deciduous component of riparian zones. Repeated season-long cattle grazing reduced cottonwood, willow, and alder regeneration. Uncontrolled grazing depleted the mature stands through long-term attrition. Too many sheep removed the forb compliment of the herbaceous layer that probably reduced ground-foraging birds. The lack of deciduous woody vegetation was associated with low numbers of birds using deciduous cover in this study.

To reestablish deciduous vegetation where remnant seed stock exists, a grazing rest of several years or fencing streamsides encourages woody plant recovery. Hand and machine planting reestablish shrubs and trees where seed sources for the adapted genetic stock were eliminated locally.

In the homestead era, intensive forms of riparian zone agriculture such as irrigating and cropping for hay or grain reduced both the original deciduous trees and shrubs and conifers as well. Many old-field areas reverted to thick stands of sod-forming grasses that prevent reestablishment of woody plant regeneration. Hand or machine planting of shrubs in combination with grass reduction encourage reestablishment of these species.

Road construction altered original channel and streambank configuration and removed deciduous trees and shrubs from the old streambanks, roadbed, and right-of-way. If roads were constructed far enough above the floodplain to provide several hundred feet of upland vegetation, the buffer strips would enhance habitat for birds (Thomas 1979).

Unregulated use of campgrounds in riparian zones degraded vegetation through soil compaction and vegetation trampling. Removal of vegetation that reduces structural diversity also reduces bird diversity. Management by limited entry or closure during the spring nesting season may restore habitat and, as a result, maintain bird population.

The avifauna is influenced by the deciduous vegetation in riparian habitats. One group of birds, the deciduous-users, is particularly dependent on shrubs and deciduous trees for nesting and feeding. By understanding the associations between birds and habitat, management activities can be implemented to provide appropriate habitat for desired species.

Acknowledgements

H. Reed Sanderson, Aaron A. Skirvin, and Jack Ward Thomas reviewed the manuscript. Timothy A. Max and Fred L. Ramsey reviewed the statistical analyses.

References Cited

Anderson, B. W., A. Higgins, and R. D. Ohmart. 1977. Avian use of salt cedar communities in the lower Colorado River valley. Pages 128–136 *in* Importance, preservation and management of riparian habitat: a symposium. USDA For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta., Fort Collins, Colo.

Anderson, B. W., and R. D. Ohmart. 1977. Vegetation structure and bird use in the lower Colorado River valley. Pages 23–34 *in* Importance, preservation and management of riparian habitat: a symposium. USDA For. Serv. Gen. Tech. Rep. RM-43. Rocky Mt. For. and Range Exp. Sta., Fort Collins, Colo.

Balda, R. 1975. Vegetation structure and breeding bird diversity. Pages 59–80 *in* Proceedings of symposium on management of forest and range habitats for nongame birds. Gen. Tech. Rep. WO-1. USDA For. Serv., Washington, D.C.

Carothers, S. W., and R. R. Johnson. 1975. The effects of stream channel modification on birds in the southwestern United States. Pages 60–76 *in* Proceedings, symposium on stream channel modification. Harrisonburg, Va.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, New York. 234 pp.

Emlen, J. T. 1971. Population densities of birds derived from transect counts. Auk 88(2):323–342.

Ferguson, H. L., R. W. Ellis, and J. B. Whelan. 1976. Effects of stream channelization on avian diversity and density in Piedmont, Virginia. Proc. Southeast Assoc. Game and Fish Comm. 29:540–548.

Haapanen, Antti. 1965. Bird fauna of the Finnish forests in relation to forest succession. I. Ann. Zool. Fenn. 2(3):153–196.

Klecka, W. R. 1975. Discriminant analysis. Pages 434–467 *in* SSPP statistical package for the social sciences. 2nd ed. McGraw-Hill Book Co., New York.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42(3):594–598.

Meslow, E. C. 1978. The relationship of birds to habitat structure—plant communities and successional stages. Pages 12–18 *in* Proceedings of workshop on nongame bird habitat management in the coniferous forests of the western United States. USDA For. Serv. Gen. Tech. Rep. PNW-64. Pac. Northwest For. and Range Exp. Sta., Portland, Ore.

Pimentel, R. A. 1979. Morphometrics the multivariate analysis of biological data. Kendall/Hunt Publ. Co., Dubuque, Iowa. 276 pp.

Reynolds, R. T., J. M. Scott, and R. A. Nussbaum. 1980. A variable circular-plot method for estimating bird numbers. Condor 82(3):309–313.

Root, R. B. 1967. The niche exploitation pattern of the blue-jay gnatcatcher. Ecol. Monogr. 37(4):317–350.

Salt, G. W. 1953. An ecological analysis of three California avifauna. Condor 55(4):258–273.

Shannon, C. E., and W. Weaver. 1963. The mathematical theory of communication. Univ. Illinois Press, Urbana. 117 pp.

Stauffer, D. F. 1978. Habitat selection by birds of riparian communities: evaluating the effects of habitat selection. M.S. thesis. Iowa State Univ., Ames. 86 pp.

———, and L. B. Best. 1980. Habitat selection of birds of riparian communities: evaluating effects of habitat alternatives. J. Wildl. Manage. 44(1):1–15.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics with special reference to the biological sciences. McGraw-Hill Book Co., Inc., New York. 481 pp.

Thomas, J. W., tech. ed. 1979. Wildlife habitats in managed forests—the Blue Mountains of Oregon and Washington. Agric. Handb. 553. USDA For. Serv., Washington, D.C. 512 pp.

Livestock and Riparian-Fishery Interactions: What Are the Facts?

William S. Platts
U.S. Forest Service, U.S. Department of Agriculture
Intermountain Forest and *Range Experiment Station, Boise, Idaho*

Introduction

The riparian environment has become a key consideration in the planning and management of the public lands. This highly productive habitat receives many uses, some of which conflict with one another. Because there are conflicts that need immediate attention, range and fishery managers are making complicated, hurried decisions, often without the benefit of adequate knowledge or experience. In addition, interpretations emerging from riparian studies are often confusing and contradictory, inhibiting the manager's decision-making abilities.

Leopold (1974) stated that fish and wildlife habitat in western rangeland has experienced and is experiencing a steady deterioration under livestock grazing. The same year, Heady et al. (1974) stated that livestock grazing is being managed and integrated with other uses of federal lands and that there is no evidence that well-managed grazing of domestic livestock is incompatible with a high quality environment. Behnke and Zarn (1976), on the other hand, reported that degradation of streambanks by livestock is one of the principal factors contributing to the decline of native trout in the West. Two years later, Hayes (1978) concluded that, during spring runoff, streambank degradation occurred more often and to a greater extent along ungrazed streambanks than along grazed streambanks. Busby (1979) stated that range conditions today are far better than the denuded, deteriorated rangelands that existed in the early 1900s. A year later, Platts (1979) agreed with this interpretation, but pointed out that the improvement was based mainly on data collected from drier portions of the rangeland and did not take into account the still deteriorated condition of riparian areas. Kimbal and Savage (1977) reported that proper grazing management will restore degraded riparian-stream habitats, and Duff (1977), a year later, stated that trout numbers increased dramatically and the condition of the riparian habitat immediately improved when grazing was eliminated. Holechek (1981) in a recent issue of the *Journal of Range Management* went even further. He stated that livestock grazing controlled by the use of scientific principles is compatible with other public rangeland resources, and may be used for the enhancement of these resources.

Land managers are having a tough enough time trying to properly manage the riparian-stream habitats without the literature confusing their thinking. This report attempts to evaluate past findings and to place the facts in better perspective. Many articles in the literature discuss the effects of livestock grazing on riparian-fishery habitats, but most are either intuitively developed or are state-of-the-art reports that do not include actual data for analysis. Examples are Armour 1977, Bakke 1977, Behnke and Zarn 1976, Meehan and Platts 1978, Miller 1972, Platts 1978, 1981, and Platts and Martin 1980. These types of articles were ignored in this report; only those reports that provided actual data with interpretation were considered in determining the facts. Study evaluations were based on study design, sample size, statistical reliability and whether the area provided an unbiased place to do research.

Findings of the Fishery Profession

Effects on Fish Populations

One detailed research report was on Rock Creek, Montana, where Gunderson (1968) reported that brown trout (*Salmo trutta* [Linnaeus]) biomass was 31 percent greater per unit area in an ungrazed stream section than in an adjacent grazed section. Marcuson (1977) in a follow-up study, found brown trout biomass was 3.4 times greater per unit area in the ungrazed versus the grazed section. While the authors' conclusions may be true, there is the dangerous possibility that even if cattle had never grazed the area, one of the reaches could have contained 3.4 times more trout biomass than the other. Also, the stream had previously experienced a major flood that resulted in the grazed section being channelized and cleared of vegetation by the U.S. Army Corps of Engineers. The grazed section had also been burned over in the 1930s while the nongrazed area was not. Their conclusions concerning grazing effects, therefore, are difficult to defend.

Storch (1979) found that, after 10 years of rest inside an exclosure (an area rested from grazing), game fish made up 77 percent of the fish population on Camp Creek, Oregon, but only 24 percent of the population in the grazed areas outside the exclosure. Storch failed, however, to show that the areas were comparable and that the differences reported did not occur naturally. His conclusions, therefore, are also hard to defend.

Van Velson (1979) blames the past heavy livestock grazing in the Otter Creek, Nebraska, drainage for the elimination of trout spawning runs in the stream. The author stated that large spawning runs composed of sizable trout entered Otter Creek prior to grazing, and that, after grazing was begun, runs soon became insignificant. Later, when livestock was excluded from the upper 2 miles (3.2 km) of stream, rainbow trout spawning runs again developed. A confusing factor is that, with the exclusion of the livestock grazing, the Nebraska Game and Parks Commission initiated a rainbow trout fingerling stocking program. Furthermore, no fish population data were presented prior to the exclusion of grazing for valid comparisons. Therefore, it is difficult to distinguish the benefits derived from the fish-stocking program from those derived from reduced livestock grazing. The circumstantial evidence, however, infers that reduced livestock grazing was the main factor responsible for increasing trout populations.

Starostka (1979), studying Sevenmile Creek, Utah, found that trout numbers per unit area in an ungrazed 2-mile (3.2 km) section of stream were about the same as in adjacent grazed sections. The exclosure was constructed in 1961, but by 1970 was no longer functioning and the area had been returned to grazing. In 1974, the exclosures were refurbished and grazing was eliminated, but no changes in fish populations could be detected. This study contains the same problem that most studies contain; there were no pregrazing data, therefore bias can cloud the interpretations.

Platts (In press a) in his Horton Creek, Idaho, studies found that fish density in a lightly grazed or nongrazed meadow stream section was 10.9 times higher than the density in an adjacent heavily grazed stream section. The grazed portion of the meadow had been heavily grazed by sheep for 80 years under a continuous system, while the lightly grazed or nongrazed meadow had been rested during most of this time. Platts assumed that, prior to livestock grazing, the two stream reaches were similar and, therefore, fell into the same trap that occurred in most of the other fishery studies. Platts' conclusions, although they may be correct, are based on circumstantial evidence and are therefore suspect.

Platts (In press b), in studying a sheep rest rotation system in Frenchman Creek, Idaho, concluded that sheep grazing was having no detrimental effect on the fish population. Again, Platts had no pregrazing information to go on, but based his conclusions on results obtained by comparing a grazed section of Frenchman Creek with a presently ungrazed section (exclosure). The fact that the fish population in the area grazed by sheep was in good condition led him to his conclusion.

Platts (In press c), on the South Fork Salmon River, Idaho, studied a three-pasture, rest-rotation cattle grazing system initiated in 1979 in a previously ungrazed watershed. He concluded that the first cycle of the cattle rest-rotation system had no effect on the fish population. This conclusion was sound because the study design and methodology was sound. Pregrazing information was obtained and he used two controls to check the results of the treatment findings. As this study progresses through additional grazing cycles, changes in the fish population may take place.

Chapman and Knudsen (1980) compared pairs of grazed and ungrazed stream sections in the Puget Sound area of Washington and found that although livestock-altered reaches contained less total cutthroat trout biomass, young-of-the-year trout biomass was higher. The field crews used a visual analysis of the channel to determine if the channel had been altered by livestock or was still in a natural state. This, plus the fact that conditions prior to any supposed alteration are unknown, means that the results might have been the same without grazing.

Duff (1977) studied Big Creek, Utah, and found after three years that trout numbers within an ungrazed exclosure were 3.6 times greater than those in a downstream grazed area. However, an upstream grazed area that was influenced by beaver dams had 1.5 times as many trout as the ungrazed exclosure. Again, as in most studies, the author gives no supporting data to establish whether the areas are comparable. Also, the addition of 17 in-stream habitat structures inside and outside the exclosure in 1970, an additional 26 structures built solely within the exclosure in 1971, and the annual fish-stocking program could bias the study conclusions relating to fish populations.

Keller et al. (1979) studied the effects of exclosures closed to cattle grazing on Summit Creek, Idaho. Two miles of the stream below the headwater spring source were fenced to exclude cattle, and Keller reported a remarkable recovery in aquatic habitat conditions. A high variation in fish population estimates precluded statistically valid appraisals of what happened to the fish population. Also, the closer the fish population is to the spring source, the higher the population density; this bias could cause confusion. Again, the sites selected for comparison had no pretreatment information to determine whether they were truly comparable.

Effects on Riparian-Aquatic Habitat

All but one of the 20 studies conducted by the fishery specialists listed in Table 1 concluded that riparian-stream habitats had been degraded by livestock grazing. The same number reported that such habitats improved when grazing was prohibited. Platts (In press a) was the only author who found that conditions improved with grazing and this was on a well-managed sheep allotment using a rest-rotation system with effective herding that protected the riparian areas. Duff (1977) found that riparian vegetation biomass increased 63 percent in a Big Creek, Utah, exclosure after four years of rest. Marcuson (1977) found that ungrazed sections of Rock Creek, Montana, had 82 percent more vegetative cover per unit of stream than grazed areas. Van Velson (1979) found remarkable increases in the amount of riparian vegetation adjacent to Otter Creek, Nebraska, once cattle grazing was eliminated. Platts (In press c) found that an ungrazed stream reach on Horton Creek was only one-fourth as wide and five times as deep as the adjacent reach on a grazed section. Storch (1979) found in Camp Creek, Oregon, that 10 years of rest from grazing stabilized the streambanks and dramatically increased the shade over the stream. Even though most of these studies have much the same biases as

Table 1. Fishery or fishery related authors' findings of riparian-stream habitat and fish population conditions influenced by livestock grazing.

	Riparian condition			Fish populations			Soundness of conclusions		
Author	Improved	No change	Degraded	Increased	No change	Decreased	Good	Fair	Poor
Berry and Goebel (1978)			X			X		X	
Chapman and Knudsen (1980)			X			X		X	
Clair and Storch (1977)			X			X			X
Crispin (Unpublished)			X			X			X
Dahlem(1979)			X	—	—	—		X	
Duff (1977)			X			X			X
Gunderson (1968)			X			X			X
Keller et al. (1979)			X			X			X
Kennedy (1977)			X			X			X
Lorz (1974)			X			X		X	
Marcuson (1977)			X			X			X
Platts (In press a)			X			X		X	
Platts (In press c)	X				X			X	
Platts (In press b)			X		X		X		
Platts (1978)			X			X			X
Starostka (1979)			X		X				X
Storch (1979)			X			X			X
Van Velson (1979)			X			X		X	
Wineger (1977)			X	—	—	—		X	
Winget and Reichert (1976)			X			X		X	

discussed earlier, there is concensus among authors that improper livestock grazing degrades the riparian-aquatic habitat.

Findings of the Range Profession

Range and watershed specialists have concentrated their studies on the upland part of the watershed and few studies center on riparian-stream systems. Most range specialists agree that the poorest rangeland conditions occurred between 1885 and 1935 and that they have been improving since that time (Busby 1979). A few range specialists feel that serious and extensive environmental degradation has taken place and is continuing to take place (Meiners 1974). Specialists with either viewpoint rely mainly on intuitive thinking rather than actual data analysis to reach their conclusions.

Sediment Effects

Busby and Gifford (unpublished) and Branson and Owen (1970) found that grazing may be altering water quality by affecting the hydrologic conditions within a given watershed (Table 2). Wood and Blackburn (1981), working in the rolling plains of Texas, found that sediment production in grazed shrub canopy areas was the same as in ungrazed areas. Lusby (1970), studying the effects of grazing on watershed hydrology in Colorado, found that ungrazed watersheds produced only 71 to 76 percent as much sediment as did grazed watersheds. These studies were all well designed and their conclusions sound. They show that the likelihood of livestock grazing altering a watershed and increasing the amount of sediment deposition in streams depends on such things as landform, grazing strategy, climate, condition of the vegetation, and grazing intensity.

Table 2. Range and watershed authors's findings on riparian-stream habitat conditions under grazed conditions.

	Riparian condition			Stream condition			Soundness of conclusions		
Author	Improved	No change	Degraded	Improved	No change	Degraded	Good	Fair	Poor
Buckhouse et al. (1977)[a]		—			X		X		
Buckhouse et al. (1981)		—			X			X	
Busby and Gifford (Unpublished)		—				X	X		
Gifford and Hawkins (1976)[a]		X		—	—	—	X		
Hayes (1978)		—		X					X
Kimbal and Savage (1977)	X			X					X
Lusby (1970[a]		—				X	X		
USDI-BLM (1974)			X			X			X
Wood and Blackburn (1981)[a]		—			X		X		

[a]A study that presents watershed data interpreted by William S. Platts as to effects of livestock grazing on riparian-stream systems.

Riparian-Aquatic Habitat Effects

Hayes (1978) studied a series of high elevation meadows and their associated streams in central Idaho. Ungrazed meadows were compared with meadows that were being grazed by cattle under a three-pasture, rest-rotation system. After only one field season of observation, Hayes reported that rest-rotation grazing by cattle did not significantly alter channel movement and that soil erosion on the ungrazed streambanks was significantly greater than the erosion on the grazed streambanks. Hayes did attribute some bank erosion to livestock during the vegetative growing season.

Hayes' conclusion that streambank erosion was greater on ungrazed watersheds than on grazed watersheds is biased because of improper study design. Hayes selected a study stream for the ungrazed meadow sites that naturally had less stable streambanks, greater stream power, four times greater channel gradient, higher stream velocities, larger channel substrate, and greater distance from the stream bottom to the top of the bank than the streams selected to represent grazed conditions. The grazed sites were also higher in elevation. The sites were in no way comparable and so the conclusions of the study cannot be accepted.

Kimbal and Savage (1977) suggested that in time proper grazing management will restore degraded riparian habitats. Under a reduced cattle stocking program, with watershed revegetation, a stream rehabilitation program, and a rest-rotation grazing system, these authors showed that the standing crop of fish in the Diamond Fork, Utah, study site increased 400 percent over the 10-year range improvement program. Armour (Unpublished) in a critique of the Kimbal and Savage Diamond Fork Aquatic study demonstrated, however, that their study design was technically deficient and that there was no way in which to determine whether the stated recovery actually happened. Their conclusions, therefore, cannot be accepted as fact.

Buckhouse et al. (1981) studied different grazing strategies on Meadow Creek, Oregon, and discovered that the relative stability of Meadow Creek was not significantly changed ($P>0.10$) after two years of cattle grazing. Although they found that the grazed streambanks experienced more sloughing of cutbanks (average of 15 cm per year) than the ungrazed banks (average of 9.5 cm per year), they concluded that the difference between the means was not significant. The study design was solid and the sampling data were of high caliber, but the confounding factors are that the Meadow Creek riparian areas have been grazed for the past 100 years, logging has eliminated 50 percent of the riparian overstory, and, at one time, logs were driven down the stream during high flows with the aid of splash dams. Furthermore, a railroad and road were constructed along some areas of the stream. This stream, therefore, may not lend itself to a study of this type.

Conclusions

About 85 percent of the fishery-range studies found in the literature, with a study design and data base for interpretations, concluded that livestock grazing degraded stream-riparian environments. However, it is possible that many of these study sites were chosen in the most degraded areas and do not represent the overall range condition. Also, the studies do not identify whether the grazing strategy and intensity of use being studied were being properly or improperly managed. This classification presents a problem because "proper grazing" is in the mind of the beholder and changes from person to person and from discipline to discipline.

A bias exists in most of the livestock-fishery interaction studies because of poor study design, poor data collection, or erroneous interpretations, and seldom have authors known the exact condition of their study area prior to the grazed conditions. Also, those studies confounded by stream improvement structures, other land uses, or fish-stocking programs may have just as much bias. Regardless of the biases in the studies, when the findings of all studies are considered together, there is evidence indicating that past livestock grazing has degraded riparian-stream habitats and decreased fish populations.

The future calls for range and fishery professionals to work closely together to build solidly designed studies that will continue the management goal of building good compatibility between fisheries and livestock grazing.

References Cited

Armour, C. L. 1981 Critique of the Diamond Fork aquatic study. *In* Bureau of Land Management Water Resources Workshop Proceedings, Unpublished, copies on file Idaho State Office, Boise.

______. 1977. Effect of deteriorated range streams on trout. Bureau of Land Management, Idaho State Office, Boise, Idaho. 7 pp.

Bakke, B. M. 1977. Grazing is destroying our fish. Action Line, Trout Unlimited, Portland, Ore. (July):7–9.

Behnke, R. J., and M. Zarn. 1976. Biology and management of threatened and endangered western trouts. USDA Forest Service, General Technical Report RM-28. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo. 45 pp.

Berry, C., and P. Goebel. 1978. The use of livestock exclosures as a fishery management tool. (Abstract). Encyclia: J. Utah Acad. Sci., Arts and Lett. 55:97. (Utah State University, Logan.)

Branson, F. A., and J. B. Owen. 1970. Plant cover, runoff, and sediment yield relationships on Mancos Shale in western Colorado. Water Resour. Res. 6(3):783–790.

Buckhouse, J. C., R. W. Knight, and J. M. Skovlin. 1977. Some erosional and water quality responses to selected animal grazing in northeastern Oregon. Proc. Oreg. Acad. Sci. 15:13–22.

Buckhouse, J. C., J. M.,Skovlin and R. W. Knight 1981. Streambank erosion and ungulate grazing relationships. J.Range Manage. 34(4):339–340.

Busby, F. E. 1979. Riparian and stream ecosystems, livestock grazing, and multiple use management. Pages 6–12 *in* Grazing and riparian/stream ecosystem forum proc. Trout Unlimited, Vienna, Va.

______, and G. F. Gifford. Unpublished. Impact of management on watershed values. Presented at the sagebrush ecosystem symposium. Utah State University, College of Natural Resources, Logan, Utah.

Chapman, D. W., and E. Knudsen. 1980. Trans. Amer. Fish. Soc. 109:357–363.

Claire, E., and R. Storch. Unpublished. Streamside management and livestock grazing: An objective look at the situation. Paper presented at symposium on livestock interactions with wildlife, fish and their environments, Sparks, Nevada, May 1977. On file at University of California, Davis.

Crispin, V. A. Unpublished. Stream rehabilitation of the West Fork Deer Creek, Nevada. U.S. Department of Interior, Bureau of Land Management, Elko District, Nevada.

Dahlem, E. A. 1979. The Mahogany Creek watershed—with and without grazing. Pages 31–34 *in* Grazing and riparian/stream ecosystem forum proc. Trout Unlimited, Vienna, Va.

Duff, D. A. Unpublished. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. Paper presented at symposium on livestock interactions with wildlife, fisheries and their environments, Sparks, Nevada, May 1977. On file at University of California, Davis.

Gifford, G. F., and R. H. Hawkins. 1976. Grazing systems and watershed management: A look at the record. J. Soil and Water Conserv. 31(6):281–283.
Gunderson, D. R. 1968. Floodplain use related to stream morphology and fish populations. J. Wildl. Manage. 32(3):507–514.
Hayes, F. 1978. Streambank stability and meadow condition in relation to livestock grazing in mountain meadows of central Idaho. M.S. thesis. University of Idaho, Moscow. 91 pp.
Heady, H., T. W. Box, J. E. Butcher and others. 1974. Livestock grazing on federal lands in eleven western states. J. Range Manage. 27(3):174–181.
Holechek, J. L. 1981. Livestock grazing impacts on public lands: A viewpoint. J. Range Manage. 34(3):251–254.
Keller, C., L. Anderson, and P. Tappel. 1979. Fish habitat changes in Summit Creek, Idaho after fencing. Pages 39–45 *in* A forum on grazing and riparian/stream ecosystems. Trout Unlimited Inc., Denver, Colo.
Kennedy, C. 1977. Wildlife conflicts in riparian management: water. Pages 52–48 *in* Importance, preservation and management of riparian habitat symposium. USDA Forest Service, General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.
Kimbal, J., and F. Savage. 1977. Diamond Fork aquatic and range habitat improvements. U.S. Department of Agriculture, Forest Service, Intermountain Region, Ogden, Utah. 19 pp.
Leopold, A. S. 1974. Ecosystem deterioration under multiple use. Pages 96–98 *in* Wild trout management: symposium proceedings. U.S. Department of Interior, Fish and Wildlife Service, and Trout Unlimited, Denver, Colo.
Lorz, H. W. 1974. Ecology and management of brown trout in Little Deschutes River. Fish. Res. Rep. 8. Oreg. Dep. Fish and Wildl., Portland. 49 pp.
Lusby, G. 1970. Hydrologic and biotic effects of grazing vs. nongrazing near Grand Junction, Colorado. J. Range Manage. 23(4):256–260.
Marcuson, P. E. 1977. The effect of cattle grazing on brown trout in Rock Creek, Montana. Special Proj. Report F-20-R-21-11-a. Montana Department of Fish and Game, Helena, Mont. 26 pp.
Meehan, W. R., and W. S. Platts. 1978. Livestock grazing and the aquatic environment. J. Soil and Water Conserv. 33(6):274–278.
Meiners, W. R. 1974. Rest rotation grazing—a bummer. Presented at the Society for Range Management 27th Annual Meeting, Tucson, Ariz.
Miller, J. N. 1972. Nibbling away of the west. Readers Digest (December 1972):107–111.
Platts, W. S. 1978. Livestock interaction with fish and aquatic environments: problems in evaluation. Trans. N. Amer. Wildl. Natur. Resour. Conf. 43:498–504.
———. 1979. Livestock grazing and riparian/stream ecosystems an overview. Pages 39–45 *in* Grazing and riparian/stream ecosystems forum proc. Trout Unlimited, Vienna, Va.
———. 1981. Effects of livestock grazing, USDA, Forest Service, General Technical Report PNW-124. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Portland Ore. 25 pp.
———. In press a. Riparian-habitat-livestock grazing interaction research in the Intermountain West. Paper presented at the California riparian systems conference at Davis California, 1981. On file at the University of California, Davis.
———. In press b. Sheep and cattle grazing strategies on riparian-stream environments. Paper presented at wildlife-livestock relationships symposium at Coeur d'Alene, Idaho, 1981. On file at the University of Idaho, Moscow.
———. In press c. Impairment, protection, and rehabilitation of Pacific salmonid habitats on sheep and cattle ranges. Paper presented at the symposium on protection, enhancement, and rehabilitation of pacific salmonid habitat, Arcata, California, 1981. On file at Humboldt State University, Arcata, Calif.
———, and Martin, S. B. 1980. Livestock grazing and logging effects on trout. Pages 34–46 *in* Proceedings of Wild Trout II. Trout Unlimited, Denver, Colo.
Starostka, V. J. 1979. Some effects of rest rotation grazing on the aquatic habitat of Sevenmile Creek, Utah. Pages 61–73 *in* Transactions of the Bonneville Chapter of the American Fisheries Society. Salt Lake City, Utah.

Storch, R. L. 1979. Livestock/streamside management programs in eastern Oregon. Pages 56–59 *in* A forum—grazing and riparian/stream ecosystems, Denver, Colorado. Trout Unlimited, Denver, Colo.

U.S. Department of the Interior, Bureau of Land Management. 1974. The effects of livestock grazing on wildlife, watershed, recreation and other resource values in Nevada. U.S. Dep. of the Interior, Bureau of Land Management, Washington, D.C. 58 pp.

Van Velson, R. 1979. Effects of livestock grazing upon rainbow trout in Otter Creek, Nebraska. Pages 53–55 *in* Grazing and riparian/stream ecosystems forum. Trout Unlimited Inc., Vienna, Va.

Winget, R., and M. Reichert. 1976. Aquatic survey of selected streams with critical habitats on NRL affected by livestock and recreation. Unpublished final report. U.S. Bureau of Land Management, Utah State Office, Salt Lake City. 109 pp.

Wineger, H. H. 1977. Camp Creek channel fencing plant, wildlife, soil and water response. Rangeman's J. 4(1):10–12.

Wood, M. K., and W. H. Blackburn. 1981. Sediment production as influenced by livestock grazing in the Texas rolling plains. J. Range Manage. 34(3):228–231

Characterization of Playas of the North-Central Llano Estacado in Texas

Fred S. Guthery and Jean M. Pates
Department of Range and Wildlife Management
Texas Tech University
Lubbock

Fred A. Stormer
Rocky Mountain Forest and Range Experiment Station
Great Plains Wildlife Research Laboratory
Lubbock, Texas

Introduction

Playas, or undrained basins, are prominent features of the Llano Estacado, a large tableland in western Texas and eastern New Mexico (Bell and Sechrist 1972). The importance of these habitats to waterfowl and other migratory birds has been documented by Bellrose (1976), Bolen et al. (1979), and Simpson et al. (1981). These areas are also important to resident wildlife because they provide the only stable cover in an intensively and extensively farmed region (Bolen et al. 1979, Guthery 1981). Guthery et al. (1980) thought that without playas, substantially fewer ring-necked pheasants (*Phasianus colchicus*) would persist in west Texas.

Although research has focused on playa wildlife, little attention has been paid to physical and floristic variation among playa habitats; also, knowledge of the effects of land-use practices on playa habitat is inadequate (Stormer et al. 1981).

The purpose of this study was to characterize playas in the north-central Llano Estacado by describing their physical features, identifying the physiognomic plant communities present, determining extent and type of land-use practices, and examining the effects of land use on physiognomic communities and floristics.

Study Area and Methods

The study was conducted during June–August 1980 in Bailey, Lamb, and Castro counties, Texas, an area with fine- and medium-textured soils (Lotspeich and Coover 1962). The three counties comprise more than 2,730 square miles (7,000 km^2) of the north-central portion of the Llano Estacado, which is 32,000 square miles (81,920 km^2) in total area. The sample of 101 playas included 37 in Lamb County and 31 in Bailey County, selected randomly from soil maps. In Castro County, 33 playas were selected randomly from 50 whose vertebrate communities were being studied by Texas Tech University. Annual precipitation averages about 19 inches (48 cm) in the study area. About 1,130 square miles (2,900 km^2) of croplands are irrigated with ground water from the Ogallala aquifer (Texas Crop and Livestock Reporting Service 1980). Major crops are cotton, winter wheat, sorghum, and corn.

Playas, as defined here, are the basins occupied by Randall clay or Randall fine sandy loam (a surface layer of fine sandy loam, deposited by wind, covers the Randall clay), as determined from U.S. Soil Conservation Service soil maps. Randall clays form from alternate wetting and drying and, therefore, circumscribe the area of hydric influence. Playas were defined as modified if there had been soil excavation in the Randall zone.

Percent slopes of watersheds and areas of watersheds and Randall soil zones were measured from U.S. Geological Survey topographic maps and soil maps, as appropriate. Percent slope of each basin was calculated as the average of measurements made along the four cardinal compass directions from the center of the playa to the perimeter of the watershed.

Physiognomic types occupied by Randall soils were identified from nearly vertical, false-color infrared aerial photographs. Dark Randall soils were easily distinguished from the surrounding, lighter colored soils on photographs. Identity of the physiognomic types was verified by field reconnaissance. Because the aerial photographs lacked horizontal control, the following method was used to determine areas in each physiognomic type. The proportion of the Randall soil zone in each type, estimated from the aerial photographs, was multiplied by the area in Randall soil, estimated from U.S. Soil Conservation Service soil maps.

Aerial photographs also were used to obtain an index of interspersion of physiognomic types for each playa. Two perpendicular lines, oriented in cardinal compass directions, were drawn through the center of the Randall soil zone, and the number of type interfaces along each line was determined. The average count for the two lines was divided by the diameter of a circle whose area equaled the hectares in Randall soil, because playas are approximately circular. This index of interspersion, the number of interfaces per 200 m, is applicable to all sizes of playas.

For each playa, the presence or absence of 33 plant taxa (24 of which were used in the analysis) was noted. Also recorded were the estimated cubic meters of soil excavated for modification, number of irrigation pumps present, percentage of the Randall soils disked or cropped (estimated from aerial photographs or from ground inspection), and presence of irrigation tailwater recovery and of grazing.

Factor analysis with orthogonal rotation (Helwig and Council 1979) was used to identify groups of intercorrelated variables that measured playa attributes and land use. This was done to determine which biological variables were associated with a given land use practice. Factors were generated only as long as correlation matrix eigenvalues were ·1.0 (Lawlis and Chatfield 1974). Interpretation of factors was made using variables with absolute loading values greater than 0.35.

Two sets of data were factor analyzed. Variables in the first set were areas in physiognomic types, cubic meters of soil excavated, and area of Randall soil. Variables in the second set were presence or absence of 24 plant taxa, modification, tailwater, and open water; size classes of Randall soil zone (1 if $\leq$9 ha, 2 if $>$9 ha) (9 ha was the median size of playas in this sample); and extent of disking of the Randall soils (1 if none, 2 if some, 3 if all). Each analysis resulted in six factors that accounted for at least 60 percent of the total variance.

Results and Discussion

Physical Features

Playa watershed areas varied from 2.0 acres (0.8 ha) to 668 acres (267 ha), with an average ($\pm$ standard error) of 138.5 $\pm$ 22.5 acres (55.5 $\pm$ 9.0 ha); area of the

Randall soil averaged 17.0 ± 1.5 acres (6.8 ± 0.6 ha) and ranged from 1 acre (0.4 ha) to 68 acres (27 ha). There was a significant ($P < 0.01$) but relatively weak ($r^2 = 0.35$) positive relationship between watershed size and Randall soil areas. Two playas with large watersheds (375.0 and 653.3 acres) (150.0 and 261.3 ha) and relatively small Randall soil zones (5.5 and 6.0 acres, respectively) (2.2 and 2.4 ha, respectively) contributed to the low coefficient of determination. Slopes on the watersheds of sample playas averaged 0.9 ± 0.6 percent and ranged between 0.0 and 2.3 percent.

Physiognomic Types

Fourteen physiognomic types were identified on playas in the study area (Table 1). Wet meadow and broad-leaved emergent types were most common. Because the summer of 1980 was dry, open water was present only on playas receiving irrigation tailwater.

Complete series of unbroken, concentric zones of different vegetation, a characteristic of undisturbed ponds and lakes in the glaciated prairie region (Steward and Kantrud 1972), were present consistently only on physically undisturbed basins. A sequence of community types that can occur from the center of the basin outward is wet meadow, mesic forb, and shortgrass. In drier playas, the wet meadow type is likely to be replaced by the mesic forb type. Some playas (probably those with more frequent and prolonged flooding) contain broad-leaved emergent or mudflat types in the center followed, going outward, by the wet meadow, mesic forb, and shortgrass or cultivation types. However, depending on a playa's moisture regime, as influenced by its physical characteristics, tailwater recovery, and modification, intermediate zones may be absent or portions broken and replaced by other types (e.g., the wet meadow zone may be absent in the latter sequence, or the mesic forb type could be replaced by the disturbed forb type).

Cultivation

Vegetative cover of playas is lost to cropping and/or disking for weed control. On sample playas, an average of 55.6 ± 4.6 percent of the Randall soil areas was disturbed. Cropping and/or disking of Randall soil occurred on 75 percent of the playas; 45 playas were entirely disked. Of the latter, 9 were Randall fine sandy loams and 36 were Randall clays.

The average size of playas with more than 75 percent of the Randall soil zone disked was smaller ($P < 0.01$) than playas with less than 75 percent of the Randall soil zone disked (8.3 ± 1.0 acres and 26.8 ± 2.0 acres, respectively) (3.3 ± 0.4 ha and 10.7 ± 0.8 ha, respectively). The percentage of the Randall soil zone disked decreased exponentially with hectares in Randall soil ($R^2 = 0.33$, $P > 0.0001$). Hence, a greater proportion of the potential habitat area of smaller playas is lost to disking than that of larger playas.

Grazing

Evidence of grazing (fences, livestock, livestock feces) was present on 25 percent of the sample. This is likely an underestimate of the prevalence of grazing on

Table 1. Names, attributes, and prevalence of physiognomic types on playas ($N = 101$) of the North-Central Llano Estacado of Texas.

Physiognomic type	Vegetation height (m)	Dominant taxa[a] (feature)	Secondary taxa[a] (feature)	Playas with type (%)
Open water		Pondweed (*Potamogeton* spp.)	Arrowhead (*Sagittaria longiloba*)	28
Broad-leaved emergent	0.5–1.2	Smartweeds (*Polygonum bicorne, P. lapathifolium*)	Barnyardgrass (*Echinochloa crusgalli*) Spikerush (*Eleocharis* spp.)	36
Narrow-leaved emergent	1.0–1.5	Cattail (*Typha domingensis*) Bulrush (*Scirpus* spp.)		13
Mesic forb	0.2–1.0	Devilweed (*Aster spinosus*) Gray ragweed (*Ambrosia Grayii*)	Smartweeds Barnyardgrass Spikerush	26
Wet meadow	0.2–1.0	Barnyardgrass Red sprangletop (*Leptochloa filiformis*)	Smartweeds Spikerush Devilweed	41
Johnsongrass	0.5–1.5	Johnsongrass (*Sorghum halepense*)		17
Disturbed forb	0.5–1.5	Kochia (*Kochia scoparia*) Blueweed sunflower (*Helianthus ciliaris*)	Horseweed (*Conyza canadensis*) Wild lettuce (*Lactuca* spp.	9
Cultivation	Variable	Crop		20
Mudflat	<0.5	Absence of vegetation	Barnyardgrass Water-hyssop (*Bacopa rotundifolia*)	16
Spoilbank		Kochia Camphor-weed (*Heterotheca* spp.)	Tumbleweed (*Salsola kali*)	1

Table 1. Continued.

Physiognomic type	Vegetation height (m)	Dominant taxa[a] (feature)	Secondary taxa[a] (feature)	Playas with type (%)
Midgrass	0.5	Western wheatgrass *(Agropyron smithii)* Vine-mesquite *(Panicum obtusum)*		
Shortgrass	<0.2	Buffalograss *(Buchloe dactyloides)*	Gray ragweed	13
Road-pit[b]	Variable	Absence of vegetation		12
Tree-shrub	Variable	Willow *(Salix nigra)* Saltcedar *(Tamarix gallica)* Siberian elm *(Ulmus pumila)*		21

[a]Dominant taxa were those that were most prevalent in terms of coverage; secondary taxa were those that commonly occurred in a type, but had lower coverage than the dominant taxa.
[b]The road-pit physiognomic type refers to calcareous spoil (caliche) deposited for road fill or excavated from borrow pits in the basin.

playas, because farmers commonly erect temporary fences after harvest of crops to graze livestock on both cropland and playas.

In this study, the effect of grazing on playa habitat was examined in relation to the presence or absence of key taxa and other land uses. Grazing (0.85) loaded highest on a factor that accounted for 9.8 percent of the total variance. (Varimax loadings are given in parentheses.) Buffalograss (*Buchloe dayctyloides*) (0.77), cocklebur (*Xanthium* sp.) (0.61), and gray ragweed (*Ambrosia grayii*) (0.50), a shortgrass associate of buffalograss (Table 1), also loaded high on this factor.

Grazing of playas may promote buffalograss and shortgrass associates at the expense of western wheatgrass (*Agropyron smithii*). Two ungrazed playas were observed with western wheatgrass in the outer vegetational zone where the shortgrass type commonly occurs. On heavily grazed midgrass ranges, buffalograss increases, while western wheatgrass decreases if heavily grazed, particularly during spring months (Phillips Petroleum Company 1963).

Modification

Forty percent of the sample playas were modified. Previously, Bolen et al. (1979) estimated that 85 percent of "larger" playas were modified. The volume of soil excavated from modified playas ranged between 15 and 45,375 cubic yards (12 and 37,500 m^3) and averaged about 8,712 cubic yards (7,200 m^3). Peripheral pits, some with entering ditches, represented 63 percent of the modification types.

Bolen et al. (1979) and Simpson et al. (1981) pointed out that, because of their tenacity for holding water in dry years, modified playas provide an open-water habitat, whereas they would be dry if unmodified. However, without a supply of irrigation tailwater, most modified playas likely would be dry during drought as severe as that prevailing in 1980. Ninety-five percent of the modified playas received irrigation tailwater, whereas only 36 percent of the unmodified playas received tailwater.

Effects of modification vary with physical and biological characteristics of playas and with those other land uses to which they are subjected. A major problem of ascribing effects to modification is that it is a poorly defined term. There is variation in design, volume, and purpose of excavation. Playas are modified to collect precipitation for irrigation, collect tailwater for recirculation onto crops (pumps were present on 25 percent of the playas in our sample), reclaim cropland, reduce mosquito breeding habitat, and recharge the Ogallala aquifer.

The factor analysis of physiognomic communities identified a disturbance factor that accounted for 12.7 percent of the total variance and contained four variables: volume of soil excavated (-0.83) and areas of the cultivation (-0.71), road-pit (-0.58), and spoilbank (-0.56) physiognomic types (Table 1). (Varimax loadings are given in parentheses.) This factor probably indicated playas that had state or county roads crossing them. Soil excavated would be correlated with the road-pit type because of "borrow" needed to elevate the road above the flood zone.

On large playas with extensive modifications, concentric zones of vegetation were broken or discontinuous. Because soil was disturbed and the distribution of moisture within the basin was altered by excavation and location of tailwater runoff, various physiognomic types occurred in patches rather than in unbroken, concentric bands (Figure 1). Modified playas in which the broad-leaved emergent or, less commonly, the narrow-leaved emergent type dominated the Randall soil zone also were observed in this study.

In the analysis of taxa presence, modification (-0.68) appeared in a factor that accounted for 15.6 percent of the total variance and contained variables associated with wetland habitat. These included open water (-0.62), tailwater (-0.40), bulrush (*Scirpus* sp.) (-0.67), and cattail (*Typha* sp.) (-0.62). Woody species (-0.67), including either or both saltcedar (*Tamarix* sp.) and willow (*Salix* sp.), also loaded high on this factor. Early successional forbs that appeared in the factor were kochia (*Kochia scoparia*) (-0.39), horseweed (*Conyza canadensis*) (-0.47), blueweed sunflower (*Helianthus ciliaris*) (-0.39), and annual sunflower (*H. annuus*) (-0.74). Kochia is characteristic of the spoilbank type on modified playas. Sedimentation from tailwater runoff favors the presence of lower successional species, especially those that respond to more mesic conditions.

Bolen et al. (1979) reported that playa modification destroys the littoral zone, and submersed aquatics are absent from modified playas. This does not seem to be universally true as pondweed (*Potamogeton* sp.), present on 16 percent of the sample playas, occurred only with modification. If re-excavation is infrequent, pits and ditches are shallowed by slumping of banks and deposition of sediment carried in irrigation tailwater. Shallow, relatively persistent water with fluctuating levels prevails, providing conditions appropriate for the growth and/or spread of many submerged aquatics (Davis and Brinson 1980).

Figure 1. Modification (soil excavation) and the location of irrigation tailwater runoff may disrupt the concentricity of physiognomic communities on playas. Symbols for physiognomic communities are JG = Johnsongrass, MF = mesic forb, WM = wet meadow, and M = modification.

Tailwater Recovery

Sixty percent of the sample playas received irrigation tailwater, and 63 percent of the playas receiving tailwater were modified. Volumes of water varied from minute amounts entering at a single point to massive quantities entering at four points.

Although data on vegetation biomass or density were not collected, physiognomic differences between those playas receiving or not receiving tailwater were striking. The mean areas of the watershed and Randall soil zone of playas receiving irrigation runoff were two to three times larger, respectively, than those not receiving runoff (Table 2). With the exception of the shortgrass, Johnsongrass, and disturbed forb types, mean areas of the remaining types were larger ($P < 0.05$) on playas receiving tailwater.

Substantial differences in the size of basins with and without tailwater obviously explain differences in the size of associated physiognomic types. Nonetheless, the differences were striking on playas of similar dimensions. For example, playas 30 (Randall zone = 18.3 acres = 7.3 ha, watershed = 139.3 acres = 55.7 ha) and 52 (Randall zone = 18.3 acres = 7.3 ha, watershed = 120.0 acres = 48.0 ha) were physically similar. Playa 30, which lacked tailwater, had no physiognomic communities because the Randall clay was disked. The Randall clay in playa 52 was completely vegetated, with the broad-leaved emergent and wet meadow communities together occupying 70 percent of the Randall zone. If playa 30 had received tailwater, hydric conditions would have precluded disking.

In the analysis of presence of plant taxa and land uses, tailwater was intercorrelated with wetland taxa in four of six factors. Pondweed, water clover (*Marsilea* sp.), arrowhead (*Sagitarria* sp.), bulrush, cattail and a smartweed (*Polygonum lapathifolium*) were found only on playas that received tailwater. Guthery and Stormer (1980) previously suggested that tailwater artificially cultures marshland in playas of the Southern Great Plains.

Playas that received tailwater had a greater richness and interspersion of physiognomic types and, thus, more edge. The average index of community inter-

Table 2. Comparison of areas ($\bar{x}$ ± SE) in different physiognomic types on playas that do ($N = 60$) and do not ($N = 41$) receive tailwater.

	Receives tailwater		No tailwater	
Variable	Acres	Ha	Acres	Ha
Watershed	181.0 ± 17.0	72.4 ± 6.8	76.8 ± 12.5	30.7 ± 5.0
Randall soil	24.0 ± 1.8	9.6 ± 0.7	6.8 ± 1.0	2.7 ± 0.4
Broad-leaved emergent	2.5 ± 0.5	1.0 ± 0.2	0.0 ± 0.0	0.0 ± 0.0
Narrow-leaved emergent	0.8 ± 0.3	0.3 ± 0.1	0.0 ± 0.0	0.0 ± 0.0
Shortgrass	1.3 ± 0.5	0.5 ± 0.2	2.0 ± 0.3	0.8 ± 0.1
Johnsongrass	0.3 ± 0.0	0.1 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Open water	2.8 ± 0.8	1.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0
Mesic forb	2.5 ± 0.5	1.0 ± 0.2	0.0 ± 0.0	0.0 ± 0.0
Wet meadow	5.5 ± 1.0	2.2 ± 0.4	0.3 ± 0.3	0.1 ± 0.1
Disturbed forb	1.0 ± 0.5	0.4 ± 0.2	0.0 ± 0.0	0.0 ± 0.0

spersion was nearly 14 times higher on playas receiving tailwater (1.91 ± 0.14) than on playas not receiving tailwater (0.14 ± 0.07).

Implications

Because playa sizes vary geographically with soil texture, the descriptive data presented here do not apply throughout the Southern Great Plains. Interpretations of patterns and influences revealed in this study are not unequivocal. Moreover, rainfall during January–August 1980 was 31 to 66 percent below normal on different portions of the study area, so the impact of tailwater may have been accentuated. In spite of these limitations, we believe the data will be useful in management of playas and associated wildlife.

Immediate effects of heavy grazing were reduction in cover and changes in habitat physiognomy. Heavy grazing of playas reduces or eliminates ring-necked pheasant winter and nesting cover (Guthery et al. 1980, Taylor 1980). Waterfowl nesting on playas (Rhodes 1978, Bolen et al. 1979) may be negatively affected by intense grazing (Bue et al. 1952, Kirsch 1969, Whyte 1978). However, moderate grazing of dense emergent vegetation can improve breeding habitat of many marsh birds (Verner 1975).

Although modification can be associated with severe disturbance of playa habitats, as indicated by the factor analysis of physiognomic types, the practice is not without beneficial results. Modification of large basins that receive tailwater sometimes adds to interspersion by perpetuating open water and creating spoilbank communities; Taylor's (1980) data would indicate that the latter improves playas for ring-necked pheasant nesting.

Modification can dry basins by concentrating water or by precluding runoff. If cover is left intact, this may benefit terrestrial wildlife by increasing the amount of terrestrial habitat available (Guthery 1981). Taylor (1980) found that chick production per unit was higher in playa basins than in any habitat he examined in the Texas Panhandle. Modification could increase the amount of ring-necked pheasant nesting habitat because the area in open water would decrease.

Rhodes (1978) and Bolen et al. (1979) speculated that a "staircase" type of excavation of an otherwise vertical-sided pit might retain or create enough littoral zone to promote emergent vegetation and invertebrate productivity and, hence, improve the modification for wildlife. Pits and ditches also may be made more attractive to waterfowl by spreading spoil out rather than leaving it in high embankments around the excavation (Mickey Black, U.S. Soil Conservation Service, pers. comm.).

Placing a water control gate at the junction of a peripheral pit and ditch leading from the center of a playa would permit temporary flooding of a portion or all of a basin for habitat management. When the desired flooding is completed, water in the flooded basin could remain, or the gates could be opened, allowing drainage into the pit.

The practice could be used to attract waterfowl during the fall when tailwater from irrigation of winter wheat, supplemented with precipitation, could be used to flood the basin, and when water loss to evaporation would be less than during warmer months. Sale of trespass rights by landowners for waterfowl hunting may provide an incentive for this practice. However, economic feasibility of temporarily flooding basins has not, as yet, been demonstrated.

A major finding in this study was the powerful influence of irrigation tailwater recovery in creation and perpetuation of wetland habitats on playas. Personal observations lead us to believe that massive quantities of tailwater can mitigate the potential effects of other land uses such as grazing and modification.

Community interspersion was strongly associated with tailwater recovery. Since Leopold's (1933) "law of interspersion," floral and structural richness has been measure of habitat quality for many species. Baxter and Wolfe (1972) found their interspersion index highly correlated with bobwhite quail (*Colinus virginianus*) numbers. Vance (1976) found a decline in small game numbers corresponding to a decline in the Baxter and Wolfe interspersion index.

Diversity and number of nongame birds also increase with habitat complexity (Willson 1974). The occurrence of various avian species can be associated with horizontal patches of different vegetation (MacArthur et al. 1962). Ecotones are known to support a greater diversity of breeding birds than homogeneous communities (Balda 1975). Likewise, diversity is the key to heavy use of areas by migratory avifauna (Sprunt 1975).

Wildlife resources of the Llano Estacado are dependent on irrigated crop production and playas. Highest densities of ring-necked pheasants are found where irrigated crops are produced (Guthery et al. 1980), and without irrigation, they would probably decline. Irrigation of winter wheat ensures the presence of some open water for the second largest concentration of wintering waterfowl of the Central Flyway (Buller 1964); tailwater runoff from irrigation of warm-season crops provides waterfowl brood habitat. Wintering waterfowl are also dependent on irrigated crops for food; corn comprises 93 percent of their fall and early winter diet in the southern Texas Panhandle (Moore 1980).

However, the trend is toward a reduction in irrigation tailwater runoff into playas and to less acreage in irrigated grain crops that are important for ring-necked pheasants and wintering waterfowl. Depletion of underground water (Judd n.d.) and increased cost of energy for pumping are forcing a reduction of volume of water pumped per unit area and implementation of irrigation methods to reduce runoff and conserve water for crop production. In dryland agriculture, emphasis is also being placed on methods to hold water on the land. It appears that, unless water importation (Bolen et al. 1979) becomes a reality, the quality of playa habitats for wildlife on the Llano Estacado is likely to decline.

Literature Cited

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59–80 *in* D. R. Smith, tech. coordinator. Proceedings of the symposium on management of forest and range habitats for nongame birds. General Technical Report WO-1. U.S. Dep. of Agric., Forest Service, Washington, D.C.

Baxter, W. L., and C. W. Wolfe. 1972. The interspersion index as a technique for evaluation of bobwhite quail habitat. Pages 158–165 *in* J. A. Morrison and J. C. Lewis, eds. Proceedings of the first national bobwhite quail symposium. Oklahoma State Univ. Research Foundation, Stillwater.

Bell, A. E., A. W. Sechrist. 1972. Playas, Southern High Plains of Texas. Pages 35–40 *in* C. C. Reeves, ed. Playa lake symposium. International Center for Arid and Semi-arid Land Studies Publ. 4. Texas Tech Univ., Lubbock.

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pa. 543pp.

Bolen, E. G., C. D. Simpson, and F. A. Stormer. 1979. Playa lakes: threatened wetlands on the Southern Great Plains. Pages 12–30 *in* Riparian and wetland habitats of the Great Plains. Great Plains Agric. Counc. Publ. 91. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Bue, I. G., L. Blankenship, and W. H. Marshall. 1952. The relationship of grazing practices to waterflowl breeding populations and production on stock ponds in western South Dakota. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 17:396–414.

Buller, R. F. 1964. Central Flyway. Pages 209–323 *in* J. P. Linduska, ed. Waterfowl tomorrow. U.S. Dep. of the Int., Fish and Wildl. Serv., Washington, D.C.

Davis, G. J., and M. M. Brinson. 1980. Responses of submerged vascular plant communities to environmental change. FWS/OBS-79/33. U.S. Dep. of the Int., Fish and Wildl. Serv., Washington, D.C. 70pp.

Guthery, F. S. 1981. Playa basins and resident wildlife in the Texas Panhandle. Pages 47–51 *in* Proceedings of the playa lakes symposium. Office of Biol. Serv., U.S. Dep. of Int., Fish and Wildl. Serv. Washington, D.C.

———, J. Custer, and M. Owen. 1980. Texas Panhandle pheasants: their history, habitat needs, habitat development opportunities, and future. General Tech. Rep. RM-74. U.S. Dep. of Agric., Forest Serv., Fort Collins, Colo.

Guthery, F. S., and F. A. Stormer. 1980. Playa lake symposium. Wildl. Soc. Bull. 8:172

Helwig, J. T., and K. A. Council. 1979. SAS user's guide. SAS Institute, Inc., Raleigh, N.C. 494pp.

Judd, P. F. (n.d.) An introduction to water and water conservation with emphasis on the High Plains of Texas. High Plains Underground Water Cons. District No. 1, Lubbock, Tex. 47pp.

Kirsch, L. M. 1969. Waterfowl production in relation to grazing. J. Wildl. Manage. 33:821–828.

Lawlis, F. G., and D. Chatfield. 1974. Multivariate approaches for the behavioral sciences: a brief text. Texas Tech Univ. Press, Lubbock 153pp.

Leopold, A. 1933. Game management. Charles Scribner's Sons, New York, N.Y. 481pp.

Lotspeich, F. B., and J. R. Coover. 1962. Soil forming factors on the Llano Estacado: parent material, time and topography. Texas J. Sci. 14:7–17.

MacArthur, R. H., J. W. MacArthur, and J. Preer. 1962. On bird species diversity. II. Prediction of bird census from measurements. Amer. Natur. 96:167–174.

Moore, R. L. 1980. Aspects of the ecology and hunting economics of migratory waterfowl on the Texas High Plains. M.S. Thesis. Texas Tech Univ., Lubbock. 80pp.

Phillips Petroleum Company. 1963. Pasture and range plants. Phillips Petroleum Co., Bartlesville, Okla. 176pp.

Rhodes, M. J. 1978. Habitat preferences of breeding waterfowl on the Texas High Plains. M.S. Thesis. Texas Tech Univ., Lubbock. 46pp.

Simpson, C. D., F. A. Stormer, E. G. Bolen, and R. L. Moore. 1981. Significance of playas to migratory wildlife. Pages 35–41 *in* Proceedings of the playa lakes symposium. Office of Biol. Serv., U.S. Dep. of Int., Fish and Wildl. Serv., Washington, D.C.

Sprunt, A. 1975. Habitat management implications of migration. Pages 81–86, *in* D. R. Smith, tech. coordinator. Proceedings of the symposium on management of forest and range habitats for nongame birds. Gen. Tech. Rep. WO-1. U.S. Dep. of Agric., Forest Serv., Washington, D.C. 343pp.

Steward, R. E., and H. A. Kantrud. 1972. Vegetation of prairie potholes, North Dakota, in relation to quality of water and other environmental factors. Professional Pap. 585-D. U.S. Dep. of the Int., Geol. Surv., Reston, Va. 34pp.

Stormer, F. A., E. G. Bolen, and C. D. Simpson. 1981. Management of playas for migratory birds—information needs. Pages 52–61 *in* Proceedings of the playa lakes symposium. Office of Biol. Serv., U.S. Dep. of Int., Fish and Wildl. Serv., Washington, D.C.

Taylor, T. T. 1980. Nesting of ring-necked pheasants in the Texas Panhandle. M.S. Thesis. Texas Tech Univ., Lubbock. 35pp.

Texas Crop and Livestock Reporting Service. 1980. 1979 Texas county statistics. Texas Dep. of Agric. and U.S. Dep. of Agric., Austin, Tex. 277pp.

Vance, D. R. 1976. Changes in land use and wildlife populations in southeastern Illinois. Wildl. Soc. Bull. 4:11–15.

Verner, J. 1975. Avian behavior and habitat management. Pages 39–58 *in* D. R. Smith, tech.

coordinator. Proceedings of the symposium on management of forest and range habitats for nongame birds. Gen. Tech Rep. WO-1. U.S. Dep. of Agric., Forest Serv., Washington, D.C. 343pp.
Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017–1029.
Whyte, R. J. 1978. The effects of cattle on shoreline vegetation of ponds and tanks in south Texas. M.S. Thesis. Texas A&M Univ., College Station. 60pp.

Playas, Irrigation, and Wildlife in West Texas

Eric G. Bolen
Dean's Office, The Graduate School, and
Department of Range and Wildlife Management
Texas Tech University, Lubbock

Fred S. Guthery
Department of Range and Wildlife Management
Texas Tech University, Lubbock

Introduction

Geological forces during the late Tertiary shaped the latter-day fortunes of both men and wildlife throughout a large region of North America. By the end of Pliocene, the foundation of the vast Ogallala Aquifer was deposited over much of the continent's interior. A myriad of watercourses originating in the western cordillera traversed the region, depositing not only immense quantities of water but also a thick layer of calcareous sediments that trapped the water. Later, with the advent of the Quaternary, a mantle of fine aeolian sediments gradually covered the Ogallala during the Pleistocene, forming the landscape today known as the High Plains.

Subsequent geological events isolated the southern third of the High Plains. Drainage patterns were altered so that the flow of surface water was intercepted. To the west, the Pecos River diverted lesser streams southward, whereas to the north, the Canadian River captured and directed surface water eastward. These diversions created an isolated and streamless tableland known as the Southern High Plains (Figure 1)[1]. More importantly, the underlying Ogallala Aquifer simultaneously was denied any means of major recharge save for a minimum of precipitation permeating the aeolian mantle. Some 32,000 square miles (82,920km^2), covering much of the Texas Panhandle and the fringes of adjoining states, comprise the Southern High Plains, and it is to the northern one-third of this region that our remarks are directed.

The Playas

Some 25,000 playa basins represent the only prominent hydrographical feature on the Southern Great Plains (Guthery et al. 1981). About 17,000 to 18,000 of these occur in the Southern High Plains (Figure 1). Playas are best defined as circular basins of Randall clay interspersed among lighter soils in the Southern High Plains. (Playas have Ness or Lofton clays north of our study area; in New Mexico and Colorado, they are mapped as intermittent bodies of water with no specific soil designation.) The Randall clays are nearly impermeable soils that enable the

[1]Regionally, the area also is called the Llano Estacado, or Staked Plain, but the precise origin of this name is obscure although it is often—and erroneously—attributed to Francisco Coronado when he searched fruitlessly for the Seven Cities of Gold. The Ogallala Aquifer itself is the namesake derivative of the Oglala Indians, a tribe once occupying western Nebraska where the aquifer reaches its northernmost extension.

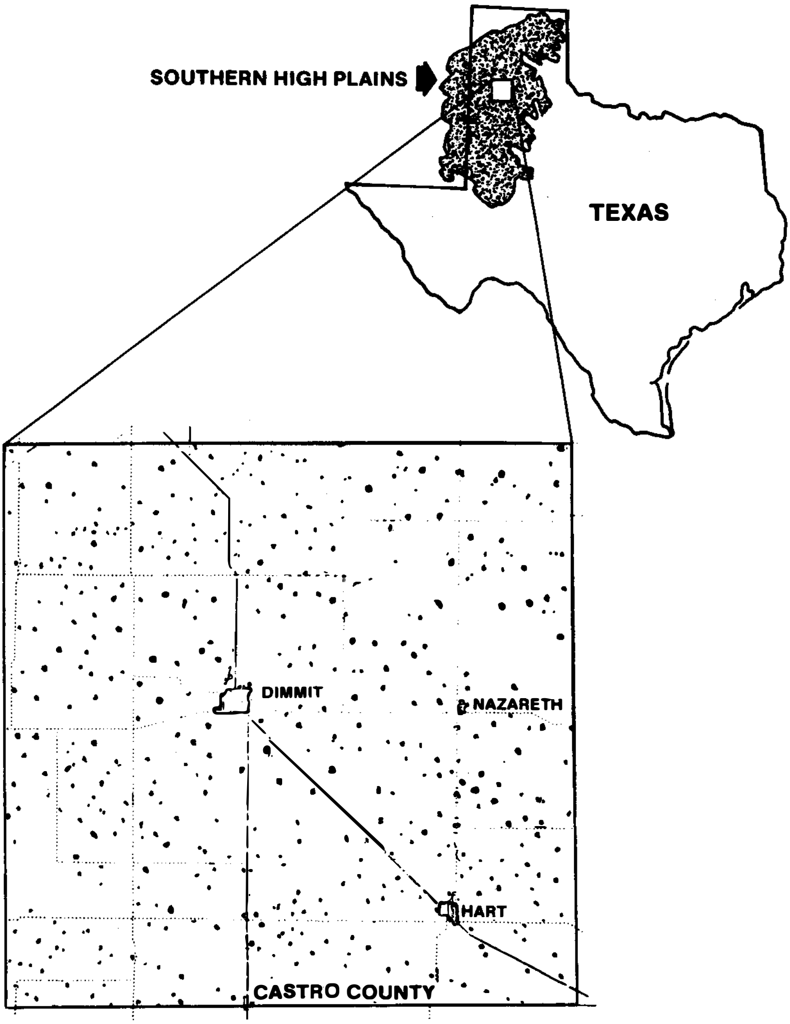


Figure 1. The Southern High Plains occupy an area of about 82,920 km² in the Texas Panhandle and adjacent New Mexico. Playa basins occur in densities of 0.6/km² throughout the region, here represented by more than 600 basins in Castro County. The basins represent "islands" of wildlife habitat in a region otherwise under heavy cultivation.

accumulation of surface run-off, often leading to the formation of aquatic or semi-aquatic environments in an otherwise semi-arid region. The depressions originated from a variety of natural causes, but wind deflation is the most common type of playa formation (Reeves 1966).

In pristine times, water retention in the basins remained a balance between precipitation and evaporation, but today factors associated with agriculture play an important role in the permanence of the playas' water. Under the current regime, playas now may be either ephemeral or relatively permanent in their water-holding capacities.

Waterfowl and Playas

As winter habitat in the Central Flyway, the playa region is second in importance only to the Texas Gulf Coast (Buller 1964). Mid-winter censuses for the region reflect boom or bust in waterfowl numbers dependent on the amount of available surface water. Vagaries in breeding success on northern wetlands also may influence the winter population, but the magnitude of this relationship is unknown. Nonetheless, winter populations typically exceed one million birds and may reach more than two million in favorable years (Curtis and Beierman 1980).

A variety of species are included, but the pintail (*Anas acuta*), green-winged teal (*A. crecca*), mallard (*A. platyrhynchos*) and wigeon (*A. americana*) dominate the population. Species of lesser numbers include northern shovelers (*A. clypeata*), gadwall (*A. strepera*) and some pochards (*Aythya* spp.); blue-winged teal (*Anas discors*) are common only as migrants.

According to data presented by Bellrose (1976), about 93 percent of the green-winged teal in the Central Flyway winter in Texas with more than half of these—nearly 100,000 birds—selecting playa environments. Soutiere et al. (1972) found that wigeon comprised about 22 percent of the winter population at Buffalo Lake National Wildlife Refuge; during a 9-year period, wigeon on the Refuge averaged 106,000 birds, with a peak of more than 200,000. Pintails are particularly abundant, and have reached peaks of 855,000 birds in the last decade (Texas Parks and Wildlife Department files).

Waterfowl wintering on the Southern High Plains are harvested lightly compared to other regions in the Central Flyway; duck stamp sales are lower per capita throughout this region (Funk et al. 1971). Because of high survival rates, the High Plains Mallard Management Unit was organized and more liberal shooting regulations were adopted for mallards and other ducks in the region.

Unfortunately, little is known about those features of playas that attract and regularly maintain sizable numbers of wintering ducks. Some lakes do, and some do not. Moore (1980) felt that mallards seem to prefer playas with well developed stands of emergent vegetation, whereas pintails concentrate on the larger, more open lakes, but no data support this contention. Bennett and Bolen (1978), in a study of winter stress in green-winged teal, suggested that shelter may be a component of winter habitat, especially when severe weather is accompanied by high winds. At present, food availability in the playas themselves does not seem a major factor in waterfowl use of these habitats. Ongoing studies, however, will determine if playa foods supply essential nutrients, such as proteins, to some species of ducks.

A second interaction between waterfowl and the playas concerns winter mortality. In addition to losses from winter stress (Bennett and Bolen 1978), the pathogens for fowl cholera (*Pasteurella multocida*) and botulism (*Clostridium botulinum*) often inflict large losses of ducks on playas.

Historically, the first documented incidence of fowl cholera in North American waterfowl occurred on the Southern High Plains in 1944 when 307 ducks died from the disease in Castro County (Quortrup et al. 1946). A second outbreak occurred during the winter of 1949–50 at Muleshoe National Wildlife Refuge in Bailey County; more than 4,000 waterfowl died in this epizootic (Petrides and Bryant 1951). Unfortunately, fowl cholera remains a constant threat to the waterfowl overwintering on the Southern High Plains, although year-to-year losses seem quite variable (i.e., the severity seems either of enzootic or epizootic proportions).

Losses from botulism seem to occur in late summer-early autumn, although rigorous laboratory methods are required to determine whether botulism or fowl cholera was the primary agent when a carcass is encountered. It is possible that both diseases may attack simultaneously.

Fowl cholera may be accentuated in playa environments. Large numbers of waterfowl are crowded on relatively small acreages of surface water, likely enhancing the transmission of the disease. Further, as the playas also are habitat for transient species (e.g., blue-winged teal) as well as the winter terminus for others, birds infected elsewhere in the flyway may easily reintroduce fowl cholera each winter. Resident species, such as common crows (*Corvus brachyrhynchos*), may be instrumental in maintaining fowl cholera in the Southern High Plains; crows regularly scavenge the many duck carcasses and thereafter may serve as reservoirs for subsequent infections (Taylor and Pence 1981).

Moore and Simpson (1980) estimated the magnitude of disease mortality in Castro County. Carcasses were censused, by species, on sample lakes and the results extrapolated for the county. An estimated 33,000 and 35,000 ducks died in each of two consecutive years. Such losses, probably restricted to four or five counties, were much higher than hunting mortality in those years. Moore and Simpson (1980) reported a harvest of about 800 ducks, whereas 2,345 birds were counted in their carcass surveys. Within the limits of these results, nearly three times as many ducks died from disease as from hunting. However, like fowl cholera, botulism severity varies greatly from year to year, so the relation between hunting and disease mortality is not constant.

A concurrent survey by the Texas Parks and Wildlife Department censused 165 playas; 66 of the lakes contained water and, of these, diseased ducks were found on 35 lakes (53 percent). More than 2,600 carcasses were tallied between September 15, 1977, and November 15, 1977; botulism was believed the primary mortality agent for these deaths.

A final ingredient in the mix of playa management is the local breeding population. Whereas the winter population of waterfowl is large, a comparatively smaller number of ducks breed in the playas. Several species are involved, including redheads (*Aythya americana*), pintails, cinnamon teal (*Anas cyanoptera*), blue-winged teal and northern shovelers, but mallards clearly are the most abundant breeding species.

Ducks apparently nested at greater densities in playa basins than in other available habitats during the summers of 1979 and 1980 in Castro County (Taylor and Guthery 1980). Playa cover had an estimated nest density of 2.0/acre (4.9/ha) and produced 5.0 ducklings/acre (12.4/ha). Roadside cover, wheat, and alfalfa had nest densities below 0.7/acre (1.7/ha) and produced fewer than 3.0 ducklings/acre (7.4/ha).

Rhodes and Garcia (1981) investigated features of playas that seemed associated with site preferences of duck broods. The three most significant ($P < 0.01$) habitat characteristics were (a) the area of emergent vegetation more than 1.5 feet (0.5 m) tall, (b) the height of emergent vegetation more than 1.5 feet (0.5m) tall, and (c) turbidity. Of these, the two vegetational features together accounted for 88 percent of the variation in brood utilization, and turbidity accounted for an additional 11 percent of the variation.

Traweek (1978) completed an extensive survey of waterfowl breeding on playas in 12 counties; 25 driving-walking transects were used to estimate brood production in June and July for each of 4 years (1974–1977, inclusive). During this period, the numbers of broods encountered varied between 136 (1975) and 53 (1976); 913 and 256 ducklings were counted in the same year, respectively. These data, when expanded for the 12-county study area, estimate that 13,754 and 3,872 duckling were produced in these years.

The production of ducks on the Southern High Plains is small compared to that elsewhere in the Central Flyway. Nonetheless, the results of Traweek's (1978) survey suggest that brood production can be sizable in some years, especially for mallards. The production of redheads in the study area also is notable, not so much for their numbers but instead because the species has declined nationally (Weller 1964). Thus, any redheads produced on the Southern High Plains to some extent help buoy their numbers. Rhodes (1979) commented further on redhead broods encountered in Castro County, noting that the species' propensity for late nesting matches well with current irrigation practices and the abundance of aquatic invertebrates available in July and August.

For waterfowl, the thrusts of playa ecology thus include the threefold subjects of wintering grounds, diseases, and breeding. Because the playas dotting the Southern High Plains represent virtually all of the wetland habitat available in a large geographical region, waterfowl necessarily rely on playas for many of the components essential for their existence (Bolen et al. 1979, Bolen 1980). Unfortunately, however, quantitative data generally are lacking that describe these functions.

Pheasants and Playas

Ring-necked pheasants became established in the Texas Panhandle about 1940 (Jones and Felts 1950) and subsequently colonized 33 counties (Guthery et al. 1980). The value of playas to these birds has become apparent in recent years. Succeeding data that pertain to habitat use are from Whiteside and Guthery (in prep.) and those that pertain to nesting are from Taylor (1980), unless otherwise indicated.

Playas are most critical to Texas pheasants in winter (December–February), because a lack of alternative cover forces the birds to mass in these habitats. Data from radio-tagged pheasants in Castro County suggest that they spend 70 to 90 percent of their time in playas during this season. Guthery (1981) reported a February concentration of 186 pheasants on a 30-acre (12-ha) playa, indicating a specific density of 6.2 birds/acre (15.5 birds/ha). Subsequently, Whiteside (unpubl. data) conducted drive counts on about 25 playas and determined minimum concentrations of more than 300 birds per lake on two occasions. Fall and winter concentrations of 75 to 150 birds per playa were common in Castro County.

During spring (March–May), pheasants begin dispersing from playas into alfalfa, if it is available, and winter wheat, but they still rely heavily on playas. Radiotelemetry data suggest that the birds spend about 70 percent of their time in playas during March; this figure decreases to about 20 percent in May when more cover from crops is available. There is a tendency for pheasants to use playas more heavily during mid-day than during morning and evening in spring.

Playas also provide important nesting cover during spring. Because these habitats have most of the residual cover, they attract the first hens that nest. Average clutch size, percentage nest success, and chick production per unit area tend to be higher in playas than in strip cover, alfalfa, or small grains. On three study areas in Castro County, playas produced an estimated 30 to 40 percent of the chicks during two nesting seasons even though they occupied only 3 to 4 percent of the areas.

Playas are least used by pheasants during summer (June–August). At this time, the birds fulfill most of their requirements in crops such as corn, wheat, sorghum, sunflowers, and alfalfa. Some birds apparently never use playas during the summer, except possibly in June, whereas others may use them lightly. The role of the playas in the ecology of broods has not been determined. These habitats often have lower successional communities that would seem to provide excellent feeding cover, but crops probably provide better loafing and escape cover.

Starting in September and continuing through November, pheasant use of playas increases steadily. This is associated with loss of crop cover to harvest and soil tillage. By winter, the birds again are essentially restricted to playas.

Clearly, playas should be the focal point for management of pheasant habitat in the Texas Panhandle. The birds already use these habitats, and management to produce more pheasants would not have excessive costs nor would it seriously disrupt prevailing rural traditions.

Guthery et al. (1980) first discussed the habitat development potential of playas. They suggested that if a suitable plant could be grown on small playas that occur in cropland, this would provide more cover for pheasants and possibly save money for farmers by cancelling the need for crop weed control. This same opportunity exists on the margins of many medium to large playas. Taylor and Guthery (unpubl. data) estimated that if tillage and grazing were removed from playas, pheasant cover in Castro County would increase by 7,500 to 10,000 acres (3,000 to 4,000 ha). Whiteside and Guthery (in press) developed a simple habitat management prescription for Panhandle pheasants. It required an ungrazed, untilled playa about 60 acres (24 ha) in size with wheat and corn grown in adjacent fields. They believe with no other management this prescription could result in more than 100 pheasants on the playa in fall.

Playas, Wildlife, and Irrigation

The Southern High Plains is one of the most intensively cultivated regions in the Western Hemisphere. Cotton and cereal grains comprise the bulk of these crops. Corn and wheat are important in the northern one-third of the region, coinciding with the area used by large numbers of waterfowl and pheasants. Agricultural production since World War II has depended heavily on irrigation water from the Ogallala Aquifer; more than 70,000 wells tap the formation (New

1979). Because the Ogallala essentially has no recharge, ground water steadily diminishes. Estimates of the High Plains Underground Water District project that recoverable ground water for the Southern High Plains (45 counties) will decline from 351,331,000 acre-feet in 1980 to 126,989,000 acre-feet by 2020. Increasing energy costs associated with increased pumping lifts as the aquifer declines also may reduce the area irrigated in the Southern High Plains (Coomer 1978). At some point, net profits from dryland agriculture may equal those from irrigated agriculture, and then it would be economically unfeasible to irrigate.

As ground water for irrigation becomes less available, the acreage devoted to cereal grains will decrease. Estimates by the Texas Department of Water Resources indicate that the 1.4 million acres (566,802 ha) of corn and irrigated wheat planted on the Southern High Plains in 1977 will diminish by 99 percent to 0.07 million acres (23,340 ha) by 2020; the acreage in cotton and dryland wheat will increase concurrently.

The shift in crop types could decrease carrying capacity for wildlife of the Southern High Plains because of the present dependence on food supplied by waste grains. Corn comprised fully 93 percent by volume of the winter foods consumed by a sample of 243 ducks of four major species collected in 1977–78 and 1978–79 (Moore 1980). Sell (1979) examined the autumn foods of teal on the Southern High Plains. Because the samples originated in September during the special hunting season, they illustrate the diets of these birds more than 6 weeks before Moore's (1980) data were collected. Nonetheless, corn comprised 71 percent of the total food volume, with barnyard grass (*Echinochloa crusgalli*) ranking second in importance at 22 percent. These data further confirm the importance of cultivated row crops, primarily corn, as the mainstay of diets of waterfowl overwintering in playa environments.

Likewise, waste corn and other grains are staples in the diet of pheasants (Edminister 1954). In a sample of 45 birds collected in the Southern High Plains, Guthery (unpubl. data) found that 98 percent (by weight) of the winter diet and 96 percent of the spring diet were composed of corn and sorghum. Areas of greatest pheasant density in the Southern High Plains (Guthery et al. 1980) coincide well with areas of greatest corn production (Texas Crop and Livestock Reporting Service 1980).

Forthcoming changes in management of irrigation run-off water will, like changes in crop composition, negatively affect wildlife. It is estimated that "almost 20 percent of the water pumped for irrigation may leave the farm as tailwater" (High Plains Underground Water Conservation District 1977:4). Because five to eight million acre-feet per year have been pumped from the Ogallala in recent years, about one to two million acre-feet enter tailwater recovery pits and playas.

Allowing tailwater to accumulate is wasteful of ground water, so management of tailwater is stressed (High Plains Underground Water Conservation District No. 1, 1977). Recommendations to reduce tailwater include reduction in the length of irrigation runs, shortening the time of irrigation sets, reducing field slopes, establishing earthen borders around fields, and converting to sprinkler irrigation. The low-energy-precision-application sprinkler system, now in the prototype stage of development, results in infiltration of more than 90 percent of the water applied to crops.

Tailwater may have a powerful influence on the playas that receive it (Guthery et al. 1982). It increases the interspersion of physiognomic communities and masks the effects of other playa uses such as grazing and modification. As the input of tailwater into playas decreases because of water conservation, playa habitat will become more sensitive to perturbations.

Agriculture in the Southern High Plains also has turned to natural run-off to help mitigate the irrigation water crisis. For example, an implement that creates dikes in cropland furrows and thereby increases infiltration rates is in wide use. The U.S. Soil Conservation Service cost-shares in contour terracing of playa basins to prevent run-off and soil erosion. These practices decrease the amount of water that enters playas.

Modification of playas is another practice, related to the water crisis, that impacts wildlife. Modification entails various methods that alter natural drainage patterns. In extensively irrigated portions of the Southern High Plains, tailwater and natural run-off are collected and stored, usually in steep-sided pits, for additional irrigation on surrounding cropland (Figure 2). Other reasons for modifying playas include reducing breeding habitat for mosquitos, the vectors of encephalitis (Huddleston et al. 1963), providing livestock water, reclaiming farmland, and potentially recharging the Ogallala aquifer (Guthery et al. 1981).

A recent survey suggested that the number of modified playas increased from 150 to 10,800 during the 15-year period ending in 1980; this represents 43 percent of the playas in a 52-county area surveyed by Guthery et al. (1981). However, no data were recorded on the volume of soil excavated; it should be recognized at the outset that the impact of modification on wildlife habitat varies with the size of the playa and the volume of soil excavated, and that some modified playas currently provide excellent wildlife habitat whereas others are essentially worthless.

Generally, the results of modification present waterfowl biologists with a management dilemma. First, drainage and consolidation of the water may vastly reduce, or even destroy, the lakes' littoral zones—areas of high biological productivity and the foundation for aquatic food webs. In pristine times, whatever foods wintering waterfowl may have eaten were surely dependent, directly or indirectly, on the littoral zones of the playas. With their reduction, by modification, and with the forthcoming changes in irrigation practices, it remains uncertain if the playas can sustain the productivity necessary to provide requirements for large numbers of waterfowl. Some indirect evidence, although not from a major corn-producing area, suggested that teal prefer unmodified playas for feeding (Rollo and Bolen 1969).

Second, modification increases the availability of some water even in the driest of years. At such times, irrigation is more frequent and the tailwater enters playas that might otherwise be dry. Thus, modification leads to a water supply that might not otherwise maintain the lakes as a modicum of aquatic habitat. During dry years, the modified lakes are refugia for waterfowl overwintering on the Southern High Plains.

Third, modification of playas may result in less frequent or severe outbreaks of botulism and fowl cholera (Pence 1981). To our knowledge, this premise has not been tested. However, if modification stopped or minimized fluctuation of water levels, it would appear to prevent one of the conditions necessary for botulism outbreaks (Enright 1971).

Based on a small sample (4 modified, 4 unmodified) of arbitrarily selected playas

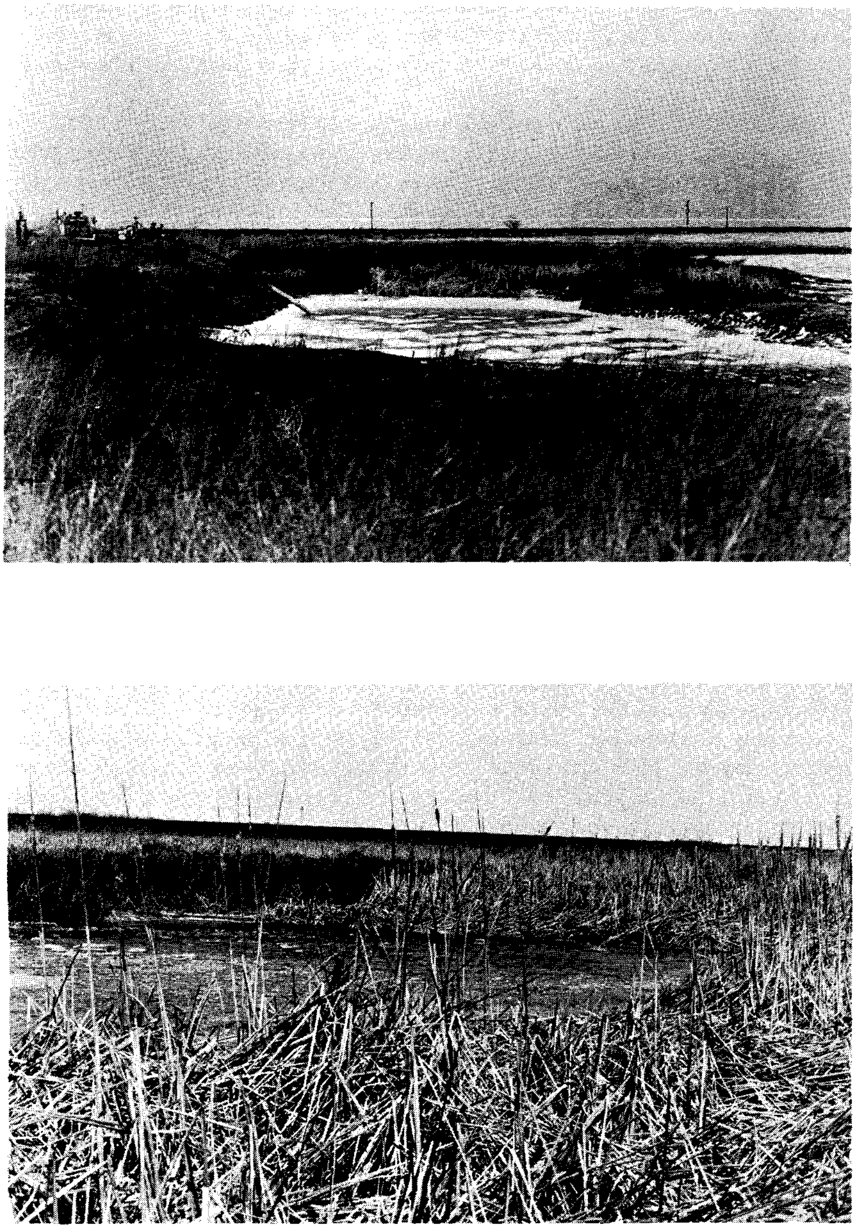


Figure 2. Tailwater recovery pit constructed in a playa basin (upper). About 70 percent of the playas of more than 4 ha are modified in this or other ways that concentrate water for irrigation. Many unmodified playas maintain littoral zones essential for high biological productivity (lower). Photo credit: Patricia A. Chamberlain.

studied during one summer, Rhodes and Garcia (1981) reported that unmodified playas had about 29 times more area of total cover than modified lakes with emergent vegetation following the same trend. Turbidity was three times greater on unmodified lakes, perhaps reflecting wave action on their littoral zones or more abundant plankton populations. Waterfowl broods and ducks without broods were significantly ($P < 0.01$) more common on unmodified playas than on modified playas during the summer. These results probably represent extreme comparisons between modified and unmodified playas because there is great variation in the design, purpose, and volume of excavation (Guthery et al. 1982).

Whereas Rhodes and Garcia (1981) collected few crustaceans from either modified or unmodified playas, the unmodified lakes contained significantly more ($P < 0.05$) insects (92 percent of the total) than modified playas (7 percent of the total); diversity was also greater, with eleven families of insects recorded in the unmodified playas versus six families in the modified lakes. However, Merickel and Wangberg (1981) found a greater diversity of macroinvertebrates in a modified playa in Lubbock County than in an unmodified playa.

The precise impact, then, of modification on the invertebrate populations of playas remains unresolved. It is clearly an important question because of the requirements of laying hens and broods for proteinaceous foods. On breeding marshes elsewhere, Krapu (1974), Swanson et al. (1974), and others have shown a major shift in the foods of laying hens from a diet largely of plant materials to one dominated by insects and other invertebrates. Mallard broods, among other species, initially are dependent solely on invertebrates, predominantly insects, for their foods, gradually shifting to seeds and other plant materials as the ducklings mature (Chura 1961).

The impact of modification on terrestrial wildlife may sometimes be positive. Playas are important to these species for the vegetative cover they provide rather than for the aquatic habitat. Because modification decreases the area of open water and thereby increases the area of vegetative cover, the practice may favor ring-necked pheasants and other species (Guthery 1981). This premise, like so many of our ideas about playas, has not been tested. However, Whiteside (unpubl. data) has observed exceptionally high pheasant populations on modified playas.

Management Strategies

Considering for present purposes only the game species of pheasants and waterfowl, we now contemplate the potentials of playas for management. The obvious first option is to do nothing. Many landowners will continue to manage their lands primarily for agricultural production with little regard for wildlife. Further modification of playas for water storage will continue in traditional ways (i.e., steep-sided pits, or with various ditching schemes). Demands for recycling irrigation water from the pits may gradually change as cropping practices follow lessening supplies of ground water and/or reduced feasibility of pumping. In any case, without regard for wildlife values, no premium is placed on the playas as wildlife habitat and their biological integrity is steadily reduced, given future trends in water use and management.

A second strategy, public ownership and management, initially would seem an attractive alternative. Two national wildlife refuges (Buffalo Lake and Muleshoe) already are located in the Southern High Plains. Whereas neither refuge includes typical playas, each harbors large numbers of waterfowl in years of sufficient rainfall. Recently, however, structural problems in the dam impounding a lake at Buffalo Lake National Wildlife Refuge pose some threat to the future usefulness of the site unless major repairs are forthcoming. The irregular spacing of playas clearly would preclude acquisition of a significant number of lakes in a single block of land for refuge management. As a rule of thumb, the lakes occur in a density of about 1.5/square mile ($0.6/km^2$) so that an immense financial commitment would be necessary even to acquire a token number in contiguous public ownership.

Management on individual playas or groups of playas might copy Wildlife Management Area programs established on similarly sized wetlands in the northern prairies. Wildlife Management Areas protect breeding habitat for a seasonally scattered waterfowl population whereas a much denser population relies on the playas. However, because wildlife use of playas is affected strongly by agricultural activities on surrounding lands, failure to simultaneously control these lands would limit effective wetland management. Nonetheless, a modicum of protection for some key playas might be possible with funding generated by sales of the Texas Waterfowl Stamp (initiated in 1981). At the very least, adding a few unmodified lakes to the national inventory of ecological types would seem wise, as would obtaining playas to test modification designs for providing multiple benefits.

A third strategy is to develop an economic base for wildlife harvests. Wildlife without corresponding dollar values at hand quite simply does not carry much worth to the Southern High Plains agricultural community on a purely aesthetic basis. Pheasants already command fees for lease-hunting, but the scale currently is limited to only one or two counties where civic clubs have gained the cooperation of local farmers. Elsewhere in Texas, the lease system for geese (mainly *Anser* spp.) and particularly white-tailed deer (*Odocoileus virginianus*) is well-established and generates substantial income for landowners in large regions of the state (Teer and Forrest 1968). The fees generated for waterfowl hunting in other states set an empirical goal for the Southern High Plains; blinds in California regularly command $500 each season with deluxe settings bringing $10,000 per blind (Teague 1971). However, the attractive economic situation potentially available for waterfowl and pheasants requires development of options for landowners based on "hard-dollar" evaluations. In short, what are the economic trade-offs between water storage as now practiced and the income from hunting fees? How much income from crops is offset by hunting leases when playas remain unfarmed? What are the returns if habitat and/or hunting management is practiced (e.g., leaving playas unburned, unplowed, or undrained; altering pumping schedules to enhance drawdown management; construction of blinds and provision of other accommodations)?

The potential importance of income derived from hunting fees seems clear when the impact of diminished irrigation is assessed against future returns from crops alone. On a per-hectare basis, returns from irrigated production on the Southern High Plains in 2020 are estimated as $267 (in 1977 dollars). By comparison, the estimated income from dryland farming in 2020 is only $86 (Texas Department of Water Development). Accordingly, each hectare of irrigated land that reverts to dryland farming will realize a potential loss of $181 by 2020. If such estimates prove accurate, then the stage is set for supplemental sources of income (i.e., hunting fees) to assume a greater percentage of total farm revenues in a regime of dryland farming. Other economic assessments of waterfowl hunting on the Southern Great Plains noted that larger fees could be commanded where emergent vegetation contributed to the aesthetic setting (Moore 1980).

The fourth strategy is not unrelated to the third, namely, development of methods for habitat management that are feasible on privately owned land. Guthery et al. (1980) have described some of these for pheasants but little else is known, especially for waterfowl. Whether altered or unaltered, some playas attract large numbers of ducks whereas others remain under-used. One scheme under current investigation supposes that artificial littoral zones can be incorporated into either existing or new pits in anticipation that aquatic productivity might be partially maintained while accommodating water storage.

The overall strategy for playa management undoubtedly must incorporate elements of both hunting economics and habitat enrichment. We underscore here that government regulation of these privately owned wetlands likely will meet with considerable resistance, perhaps to the point that it becomes counterproductive in the long-run (e.g., landowners denying access for hunting). Instead, we believe that incentives are needed that encourage the private sector to accept a form of wildlife management fully integrated with agricultural production. To do less will be to ignore the uniqueness of a major wetland system and its importance as a natural resource. Like the inspired creation of multi-faceted diamonds, the playas of the Southern High Plains offer the potential of emanating brilliance from many viewpoints. Indeed, as these ecological diamonds are cut, let us be sure we enhance their value.

Acknowledgments

We gratefully acknowledge the review of this manuscript by F. A. Stormer, R. J. Whyte, and R. W. Whiteside and the support that the Caesar Kleberg Foundation for Wildlife Conservation and the USDA Forest Service (Rocky Mountain Forest and Range Experiment Station) provided for our research, both past and present, on playas and wildlife on the Southern High Plains. This is contribution T-9-286, College of Agricultural Sciences, Texas Tech University.

Literature Cited

Bellrose, F. C. 1976. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, Pa. 543 pp.

Bennett, J. W., and E. G. Bolen 1978. Stress response in wintering green-winged teal. J. Wildl. Manage. 42(1):81–86.

Bolen, E. G. 1980. Playa wetlands of the U. S. Southern High Plains: Their wildlife values and challenges for management. Paper presented at the International Wetlands Conference, New Delhi, India, September 13, 1980.

———, C. D. Simpson, and F. A. Stormer. 1979. Playa lakes: threatened wetlands of the southern Great Plains. Pages 23–30 *in* Riparian and wetland habitats of the Great Plains. Pub. 91, Great Plains Agric. Council. USDA Forest Serv., Fort Collins, Colo. 88 pp.

Buller, R. F. 1964. Central Flyway. Pages 209–232 *in* J. P. Linduska, ed. Waterfowl tomorrow. U.S. Govt. Printing Off., Washington, D.C. 770 pp.

Chura, N. J. 1961. Food availability and preferences of juvenile mallards. Trans. N. Amer. Wildl. Conf. 26:121–134.

Coomer, J. M. 1978. Projected irrigation adjustments to increasing natural gas prices in the Texas High Plains, 1976–2025. M.S. Thesis. Texas Tech Univ., Lubbock. 98 pp.

Curtis, D., and H. Beierman. 1980. The playa lakes characterization study. U.S. Fish and Wildl. Serv., Austin, Texas. 55 pp.

Edminister, F. C. 1954. American game birds of field and forest. Charles Scribner's Sons, New York. 490 pp.

Enright, C. A. 1971. A review of research on type C botulism among water birds. U.S. Bur. Sport Fish. and Wildl. and Colorado Coop. Wildl. Res. Unit., Fort Collins, Colo. 22 pp.

Funk, H. D., J. R. Grieb, D. Witt, G. F. Wrakestraw, G. W. Merrill, T. Kuck, D. Timm, T. Logan, and C. D. Stutzenbaker. 1971. Justification of the Central Flyway High Plains Mallard Management Unit. Central Flyway Tech. Comm. Rep. 48 pp.

Guthery, F. S. 1981. Playa basins and resident wildlife in the Texas Panhandle. Pages 47–51 *in* Proc. Playa Lakes Symposium. FWS/OBS-81/07. U.S. Dep. Int., Fish and Wildl. Serv., Washington, D.C.

______, F. C. Bryant, B. Kramer, A. Stoecker, and M. Dvoracek. 1981. Playa assessment study. Rep. submitted to Water and Power Res. Serv., Amarillo, Texas. 182 pp.

Guthery, F. S., J. Custer, and M. Owen. 1980. Texas Panhandle pheasants: their history, habitat needs, habitat development opportunities, and future. Gen. Tech. Rep. RM-74. U.S. Dep. Agric., For. Serv., Fort Collins, Colo. 11 pp.

Guthery, F. S., F. A. Stormer, and J. M. Pates. 1982. Characterization of playas of the north-central Llano Estacado in Texas. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 47:516–527

High Plains Underground Water Conservation District No. 1. 1977. Guide to irrigation tailwater recovery. Rep. 77-01. High Plains Underground Water Conservation District No. 1, Lubbock, Tex. 78 pp.

Huddleston, E. W., C. R. Ward, and D. Ashdown. 1963. Biology and ecology of playa lakes. Pages 1–27 *in* Multipurpose modification of playa sinks. Proj. No. 29. Div. Water Supply and Pollution Control, U.S. Public Health Service, Lubbock Texas. 68 pp.

Jones, P. V., Jr., and J. Felts. 1950. Pheasants in the Panhandle? Texas Game and Fish 8(11):4–7.

Krapu, G. L. 1974. Foods of breeding pintails in North Dakota. J. Wildl. Manage. 38(3):408–417.

Merickel, F. W., and J. W. Wangberg. 1981. Species composition and diversity of macroinvertebrates in two playa lakes on the Southern High Plains, Texas. Southwestern Natur. 26(2):153–158.

Moore, R. L. 1980. Aspects of the ecology and hunting economics of migratory waterfowl on the Texas High Plains. M.S. Thesis. Texas Tech Univ., Lubbock. 80 pp.

______, and C. Simpson. 1980. Disease mortality of waterfowl on Texas playa lakes. Southwestern Natur. 25(4):566–568.

New, L. 1979. 1977 High Plains irrigation survey. Texas Agric. Ext. Serv., College Station, Texas. 23 pp.

Pence, D. B. 1981. The effects of modification and environmental contamination of playa lakes on wildlife morbidity and mortality. Pages 83–93 *in* Proc. Playa Lake Symposium. FWS/OBS-81/07. U.S. Dept. Int., Fish and Wildl. Serv., Washington, D.C.

Petrides, G. A., and C. R. Bryant. 1951. An analysis of the 1949–50 fowl cholera epizootic in Texas Panhandle waterfowl. Trans. N. Amer. Wildl. Conf. 16:193–216.

Quortrup, E. R., F. B. Queen, and L. J. Merovka. 1946. An outbreak of pasteurellosis in wild ducks. J. Amer. Vet. Med. Assoc. 108(827):94–100.

Reeves, C. C., Jr. 1966. Pluvial lake basins of west Texas. J. Geol. 74(3):269–291.

Rhodes, M. J. 1979. Redheads breeding in the Texas Panhandle. Southwestern Natur. 24(4):691–692.

Rhodes, M. J., and J. D. Garcia. 1981. Characteristics of playa lakes related to summer waterfowl use. Southwestern Natur. 26(3):231–235.

Rollo, J. D., and E. G. Bolen. 1969. Ecological relationships of blue and green-winged teal on the High Plains of Texas in early fall. Southwestern Natur. 14(2):171–188.

Sell, D. L. 1979. Fall foods of teal on the Texas High Plains. Southwestern Natur. 24(2):373–375.

Soutiere, E. C., H. S. Myrick, and E. G. Bolen. 1972. Chronology and behavior of American widgeon wintering in Texas. J. Wildl. Manage. 36(3):752–758.

Swanson, G. A., G. L. Krapu, J. C. Bartonek, J. R. Serie, and D. H. Johnson. 1974.

Advantages in mathematically weighing waterfowl food habits data. J. Wildl. Manage. 38:302–307.
Taylor, T. T. 1980. Nesting of ring-necked pheasants in the Texas Panhandle. M. S. Thesis. Texas Tech Univ., Lubbock. 35 pp.
———, and F. S. Guthery. 1980 Use of playa lakes and surrounding cover types for duck nesting. Page 54 *in* R. E. Sosebee and F. S. Guthery, eds. Research Highlights Vol. 11. Dep. of Range and Wildl. Manage., Texas Tech Univ. Lubbock.
Taylor, T. T., and D. B. Pence. 1981. Avian cholera in common crows (*Corvus brachyrhynchos*) from the central Texas Panhandle. J. Wildl. Dis., in press.
Teague, R. D. 1971. Wildlife enterprises on private land. *In* R. D. Teague, ed. A Manual of wildlife conservation. The Wildlife Society, Washington, D.C. 206 pp.
Teer, J. G., and N. K. Forrest. 1968. Bionomic and ethical implications of commercial game harvest programs. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 33:192–204.
Texas Crop and Livestock Reporting Service. 1980. 1979 Texas county statistics. Texas Dep. of Agric. and U.S. Dep of Agri., Austin, Tex. 277 pp.
Traweek, M. S., Jr. 1978. Texas Waterfowl. Waterfowl Production Rep. No. 5, Texas Parks and Wildl, Dep., Austin, Texas. 16 pp.
Weller, M. W. 1964. Distribution and migration of the redhead. J. Wildl. Manage. 28(1):64–103.
Whiteside, R. W., and F. S. Guthery. In press. Movement, ranges, and habitat use of pheasants in northwest Texas. J. Wildl. Manage. 47:(1983).

Sandhill Cranes and the Platte River

Gary L. Krapu, Kenneth J. Reinecke[1], and Charles R. Frith[2]
U.S. Fish and Wildlife Service,
Northern Prairie Wildlife Research Center,
Jamestown, North Dakota

Introduction

The waters of many western rivers have been diverted by man for irrigation and other consumptive uses (Ohmart et al. 1977, Johnson 1978). As flows in certain rivers diminished precipitously during this century, numerous conflicts have arisen brought on by changes affecting various interests. The Platte River is such an example. With approximately 69 percent of the annual flows destined for the Platte now removed upstream (Kroonemeyer 1979) and additional projects proposed that would utilize remaining flows, intense competition and widespread concern have developed among the factions relying on the river's flows to meet their needs.

One effect of the growing water shortage in the Platte River Basin has been alteration of riparian habitats in the Big Bend reach of the Platte River, an area of major importance to populations of several species of migratory birds (Figure 1). Foremost among the biological concerns has been the impact of habitat alteration on the midcontinent population of sandhill cranes (*Grus canadensis*) (Frith 1974, Lewis 1977, Krapu 1979). The cranes gather along the Platte and North Platte Rivers from late February to mid-April each year, reaching a peak population of approximately a half-million birds during late March (U.S. Fish and Wildlife Service 1981). Upon departure, the birds stop briefly on the Canadian prairies and then disperse to breeding grounds in central and arctic Canada, Alaska, and Siberia.

The U.S. Fish and Wildlife Service (FWS), recognizing the need to protect riparian habitats suitable for the cranes, attempted in the early 1970s to establish a 14,993-acre (6070-ha) national wildlife refuge along the Platte River near Grand Island. This plan met with strong opposition from landowners who feared condemnation of their properties (Wallenstrom 1976); local resistance culminated in political opposition to the plan within the State. In the debate that followed announcement of FWS plans, numerous questions were raised concerning the need for a refuge in the Big Bend reach of the Platte River to satisfy the requirements of cranes and other migratory birds. To acquire the necessary information to answer these questions, FWS began a 3-year investigation in 1978. The study was part of an Interior-directed project also involving research by the U.S. Geological Survey and U.S. Bureau of Reclamation. The purpose of this paper is threefold: (1) to describe changes in riparian habitats along the Platte during modern times and identify underlying causes of habitat alteration, (2) to describe effects of habitat alteration on the staging sandhill crane population, and (3) to consider alternatives for maintaining the habitat base needed to support the crane population during the stopover period.

[1]Present address: USFWS, c/o WES, Env. Lab., Box 631, Vicksburg, MS 39180
[2]Present address: USFWS, 1811 W. 2nd. St., Grand Island, NE 68801

The Platte River Basin

The Platte River Basin extends across about 90,000 square miles (233,100 km^2) of Colorado, Wyoming, and Nebraska. The Platte begins near North Platte, Nebraska, at the confluence of the North and South Platte Rivers (Figure 1). The River loops southeastward to form the Big Bend reach before crossing eastern Nebraska and joining the Missouri River near Omaha. The headwaters of the North Platte River are in north central Colorado, about 90 miles (145 km) northwest of Denver, and those of the South Platte about 60 miles (97 km) southwest of Denver (Figure 1). Both rivers begin as snowmelt in the Rocky Mountains. Our studies were limited primarily to the 203-mile (327-km) reach of river in Nebraska lying between Kingsley Dam and Chapman.

The hydrology of the Platte River and its major tributaries is complicated by the massive alteration of flows that has accompanied water resource development. After leaving the Rocky Mountains, both the North and South Platte Rivers flow across hundreds of miles of semi-arid plains before converging to form the Platte. To compensate for the dry climate, water development was initiated shortly after settlement of the Valley began in the late 1850s. Irrigation was first recorded on lands adjacent to the South Platte River in 1863 and, following some initial setbacks, began to expand rapidly (McKinley 1935). By 1894, canals served 364,200 acres (147,449 ha) and 1,442,000 additional acres (575,709 ha) were under survey in the Platte Valley. Irrigation development has continued to expand along the Platte and throughout much of the State during the twentieth century. By 1979, Nebraska had 7,445,200 irrigated acres (3,014,251 ha) and ranked third in the Nation in total lands under irrigation (Anonymous 1979).

Much of the impact of upstream water resource development in the Big Bend reach of the Platte River has come from massive irrigation projects along the major tributaries. Reservoirs built to impound flows for irrigation include Pathfinder Reservoir completed in 1909; Guernsey Reservoir, 1927; Alcova Reservoir, 1938; Seminoe Reservoir, 1939; Lake McConaughy, 1941; Kortes Reservoir, 1950; Glendo Reservoir, 1957; and Gray Reef Reservoir, 1961 (Missouri River Basin Commission 1975). Storage capacity of these facilities totals approximately 5.0 million acre-feet (6,200 million m^3). Small offstream reservoirs raise the capacity to about 5.4 million acre-feet (6,700 million m^3). Another 1.3 million acre-feet (1,600 million m^3) of flows are impounded along the South Platte River. In recent times, the growth of center pivot irrigation, energy development, and an expanding human population, particularly in Colorado, have placed additional demands on the water resources of the Platte River Basin.

The Big Bend Reach—A Historical Perspective

The channel of the Platte River between North Platte and Grand Island was originally very wide, and characterized by braided channels and a shifting streambed. In 1842, the explorer John C. Fremont recorded a channel width of 5,350 feet (1,630 m) just below the confluence of the North and South Platte Rivers (Williams 1978). Before development, annual flows at Overton, Nebraska, were variable but probably averaged about 2.9 million acre-feet (3,600 million m^3) (G. Miller, pers. comm.); the highest annual flow recorded at the Overton gauging station in the

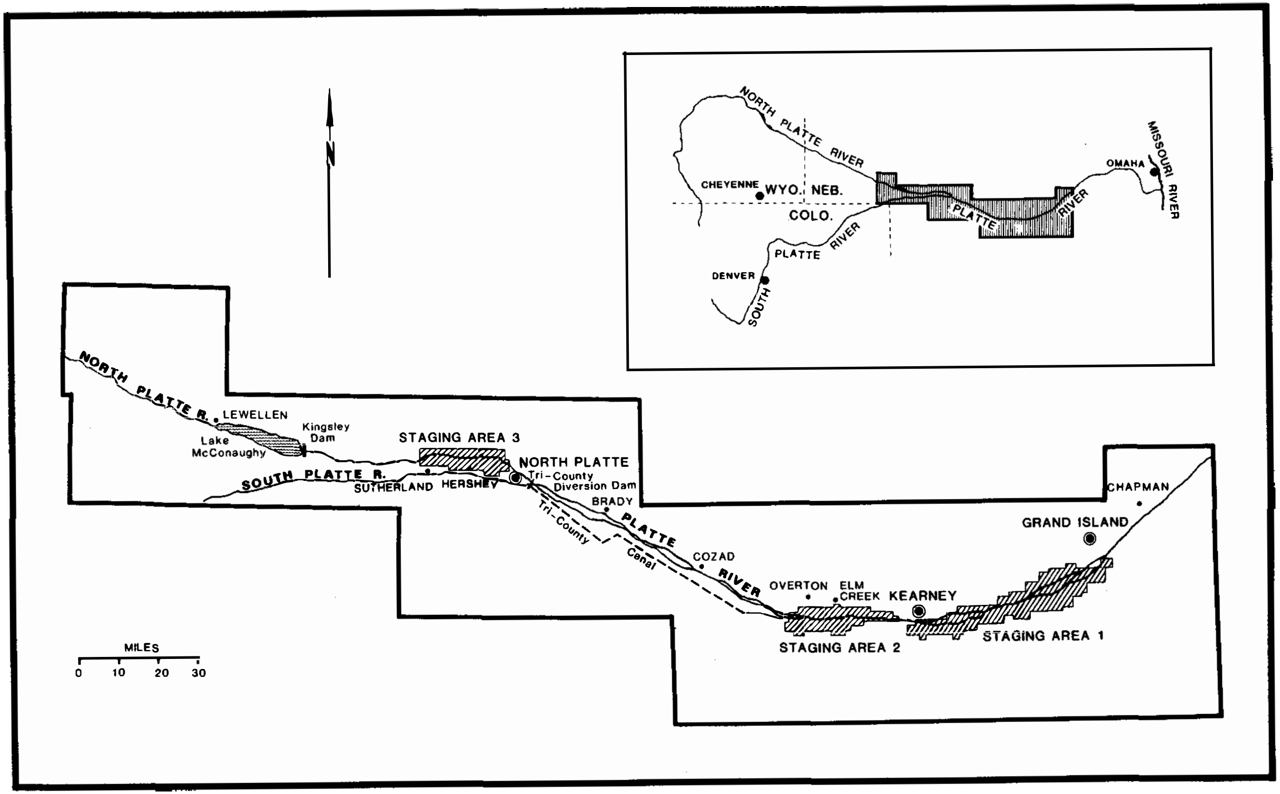


Figure 1. The Big Bend reach of the Platte River and the lower drainages of the North Platte and South Platte Rivers in Nebraska. Studies were conducted on the 203-mile (327 km) reach of river between Kingsley Dam and Chapman, Nebraska. The inset shows the location of the study area within the Platte River Basin.

twentieth century was about 4.5 million acre-feet (5,500 million m^3) in 1917 (Bentall 1975).

Water use and diversions upstream have reduced the channel of the Platte River to a small fraction of its former width. Recently published hydrologic data have indicated, for example, that channel width of the North Platte River downstream from Kingsley Dam, and the mainstem of the Platte above Overton, declined by 80–90 percent from 1865 to 1969 (Williams 1978). Withdrawal of about 1,064,500 acre-feet (1,300 million m^3) annually at the Tri-County Diversion Dam (Missouri River Basin Commission 1975) has decreased channel width drastically in the 60.5-mile (97.6-km) reach upstream from Overton. An average of only 400,000 acre-feet (493 million m^3) of water per year pass Brady. Some of these flows are diverted for irrigation between Brady and Cozad. Below the main Tri-County Canal discharge site, an average of 533,000 acre-feet (660 million m^3) of returning power generation water increase annual flows in the reach between Overton and Grand Island to about 800,000 acre-feet (990 million m^3) (Missouri River Basin Commission 1975).

Explorers that traveled along the Platte during the early to mid nineteenth century noted the presence of trees on islands and in some areas along the banks (Eschner et al. 1981). However, the area encompassed by woody vegetation has expanded many fold in modern times. Most of the former Platte River channel that has been exposed by flow depletion is now covered by stands of woody growth of varying age and height. Cottonwood (*Populus deltoides*) and willow (*Salix* spp.) initially invade exposed channel sites and are followed by numerous other species. Riparian woodlands border almost the entire reach from Kingsley Dam downstream to Grand Island. Channel shrinkage caused by reduced flows is most advanced in the reach between the Tri-County Diversion Dam (near North Platte) and the canal discharge site near Overton. Between these points, the River consists of several narrow braided channels flowing through maturing stands of woodland; our studies indicated unobstructed channel width in 1979 averaged only about 55 yards (50 m) between the Tri-County Dam and discharge site and 155 yards (142 m) downstream from the discharge site to Kearney. The magnitude of channel shrinkage in this century is evident when the above listed measurements of channel width are compared to measurements for this reach of river taken just after the Civil War. A Union Pacific Railroad survey in 1866 reported that the Platte channel from Kearney to North Platte was about 1,310 to 2,190 yards (1,200 to 2,000 m) wide (Williams 1978).

Woody vegetation now maturing in the Big Bend reach became established primarily following construction of a series of dams and reservoirs from 1927 to 1941. Closure of the gates of Kingsley Dam and the Tri-County Diversion Dam in 1941 probably were the most significant factors contributing to the development of woody species on the floodplain, especially between Elm Creek and Chapman (Currier 1981). Encroachment by woody vegetation is continuing in the Overton to Grand Island reach. It is probable that during earlier periods before the higher flows were lost to upstream diversions, these flows scoured away any seedlings that had become established in the channel. The number of seeds dispersing into the channel during summer has grown immensely during modern times as stands of trees became established throughout the reach. Increased seed dispersal in combination with variable flow patterns existing during the growing season have often produced conditions conducive to gennination and seedling growth. Extended perids of low or no flow occurred during 12 years between 1950 and 1975 in the reach from Overton to Grand Island (Bentall 1975).

Changes in the hydrology of the River have also impacted the native meadows bordering the channel because these lands are underlain by extensive sand and gravel deposits containing waters that are linked hydrologically to the river system (Hurr 1981). Heavy flows in the Platte during spring in the past maintained a high water table and extensive wet meadows on the floodplain. The marked reduction in flows because of upstream diversions has lowered the water table in the valley and thereby contributed to the loss of a major part of the meadow habitat. Before 1942, when flows were substantially reduced in the Platte following completion of the Kingsley and the Tri-County Diversion Dams, the meadows were managed primarily as pasture or hayland because water saturated surface soils during most of the growing season and prevented annual tillage. In recent years, however, the combination of agricultural drainage, depleted flows in the River, and extensive pumping of groundwater for irrigation have lowered the water table substantially during the summer months. This set of conditions has made it economically feasible to grow cash crops on most lands in the Valley. A survey undertaken as part of our studies in 1979 indicated about three-fourths of the native meadows had been converted to other uses between Overton and Grand Island. This estimate of meadow losses is conservative as numerous sites have been lost since the inventory.

The Current Distribution of Sandhill Cranes

During the spring stopover period, the sandhill crane population occupies about 400 square miles (1,036 km^2) in the Platte and North Platte River Valleys. Except for about 3,000 cranes that occupy a 7-square-mile (18-km^2) site near Lewellen, virtually all of the birds use staging areas 1-3 (Figure 1). About 69 miles (111 km) of channel are utilized as roosting habitat (Frith and Faanes 1981). Approximately three-quarters of the crane population stages along segments of the 71-mile (115-km) reach between Overton and Grand Island; the remainder occur west of North Platte (Figure 2).

The span of channel that sandhill cranes now occupy is markedly reduced from former periods. The cranes have abandoned the 60.5-mile (97.6-km) reach between the Tri-County Canal intake and its discharge site near Overton. Much of this reach was probably lost in the decade immediately following dewatering of much of the channel in 1941. However, several thousand cranes did remain as far west as Cozad in 1954 (Walkinshaw 1956). By 1979, the 23 miles (37 km) of channel between Cozad and the canal discharge site near Overton had also been lost. Between the Tri-County Canal discharge site and Kearney, a distance of 32 miles (52 km), an estimated 35,000 cranes still use the River. However, the advanced development of woody vegetation at many sites along this reach has resulted in a disjunct crane distribution (Figure 2). Eastward from Kearney, the channel remains relatively wide, averaging 200 yards (183 m) and cranes roost throughout most of the reach to Grand Island (Figure 2). Recent surveys using aerial photographic

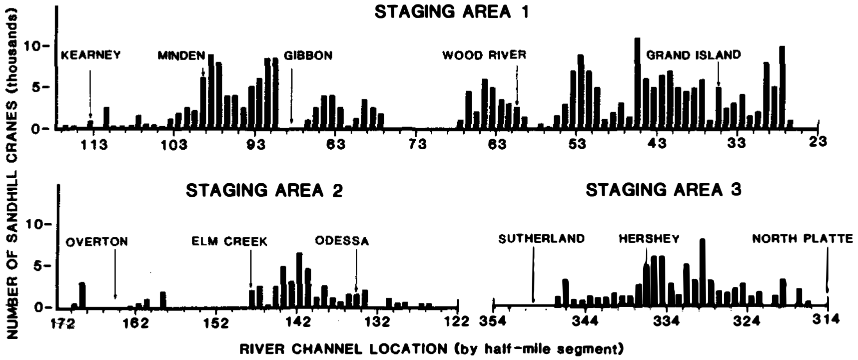


Figure 2. Distribution and estimated number of roosting sandhill cranes by half-mile segment of channel along the North Platte and Platte Rivers. The channel was surveyed for cranes during March 1979 from Kingsley Dam to Chapman, Nebraska.

techniques indicate that about 300,000 cranes use this area (U.S. Fish and Wildlife Service 1981).

Factors Affecting Distribution of Sandhill Cranes

Existing habitat conditions along various reaches of the Platte and North Platte Rivers appear primarily responsible for the current distribution of sandhill cranes. Unobstructed channel width is a particularly important criterion determining reaches of channel occupied. More than 99 percent of all channel occupancy by cranes in 1979 occurred in reaches where unobstructed channel widths exceeded 55 yards (50 m), and almost 80 percent occurred in segments over 164 yards (150 m) wide despite limited access to such habitat (U.S. Fish and Wildlife Service 1981).

The food base supporting the crane population is located on cropland, native grassland, and alfalfa fields. Nearly half of the day is spent in cornfields, a third in native grasslands, and most of the remainder in alfalfa or seeded hayfields (Fritzell et al. 1979). In cornfields, the cranes feed almost exclusively on waste corn, whereas cranes foraging in native meadows search for invertebrates, particularly earthworms, insects, and snails (Reinecke and Krapu 1979). Both alfalfa shoots and invertebrates occur in the diet of cranes feeding in alfalfa fields. Corn supplies most of the energy requirements of the cranes during the staging period. Invertebrates supply essential nutrients that are deficient in corn.

The abundance of waste corn in fields near the Platte has contributed to the build up of large concentrations of cranes on a restricted land base. Our studies indicate that mechanical harvesters leave about 6–7 percent of the corn in the fields; approximately 7,150–9,240 tons (6,500–8,400 metric tons) of corn remain on staging areas when cranes arrive in spring (U.S. Fish and Wildlife Serv. 1981). Sampling during 1979 indicated that the cranes currently utilize only 10–20 percent of the corn available to them.

Current Status of Water Development

During the last 30 years, expansion of irrigation development within the Platte Valley has been from high-yielding groundwater resources through gravity and center pivot irrigation systems. The growth of irrigation from groundwater resources in the counties used by staging cranes has been phenomenal. In Buffalo and Hall counties, for example, which include major parts of staging areas 1 and 2, the number of registered wells rose from 54 in 1919 (Bentall 1975 to 6,162 in 1980 (Johnson and Pederson 1981). An additional 400,000 + acre-feet (490 + million m^3) of Platte flows are expected to be consumed annually by groundwater pumping before the year 2020 (Missouri River Basin Commission 1975).

Although most recent water developments in the Platte River Basin have tapped underground aquifers, several projects are under consideration that would rely on existing surface flows. Among the water projects proposed is Narrows Dam along the South Platte River in Colorado. This project would withdraw approximately 100,000 acre-feet (123 million m^3) annually for irrigation and other uses, but has been stalled in recent years because of environmental and economic concerns. If this authorized project were built, it would remove about 12.5 percent of the remaining 800,000 acre-feet (984 million m^3) of flows destined for the Platte River at Overton.

A proposed plan to transfer waters from the Platte River Basin to the Little Blue Basin in south central Nebraska, if implemented, would divert about 125,000 acre-feet (154 million m^3) or 23 percent of the return flows entering the River at the Tri-County Canal discharge site near Overton. A major obstacle to this project was removed in December 1980 when the Nebraska Supreme Court ruled in favor of allowing inter-basin transfer of waters within the State when deemed in the public interest. The project is under litigation, however, from downstream interests.

Although the Mid-State Project planned for the Big Bend area of south central Nebraska in the early 1970s was tabled following its defeat in a local referendum in 1973, a project named Prairie Bend is now under consideration, which, if authorized and built, would remove up to 210,000 acre-feet (258 million m^3) of flows annually in the upper Big Bend reach.

Existing flows in the Platte are inadequate to meet proposed needs even with total utilization of the remaining surface flows in the River. The cumulative impact of the aforementioned water projects, if built, plus other uses of the remaining flows of the Platte are shown in Figure 3. If the three projects were built, the annual water budget of the Platte would be reduced to about 449,000 acre-feet (552 million m^3). This is about 16 percent of the amount of water the River carried in 1850. Further proposed developments including projected groundwater development theoretically would produce a negative annual water budget.

In addition to the above-mentioned projects that have been under consideration for some time, a project has been proposed in recent months that would store 315,000 acre-feet (388 million m^3) of water in a reservoir to be built on Plum Creek near Lexington. The water stored in this reservoir would come from the Tri-County Canal system and be released back into the Platte to maintain current flows in the Big Bend reach. These flows would be diverted from the River near Chapman just below staging area 1 for use in groundwater recharge and direct irrigation in the Upper Big Blue Natural Resources District. This project is jointly sponsored

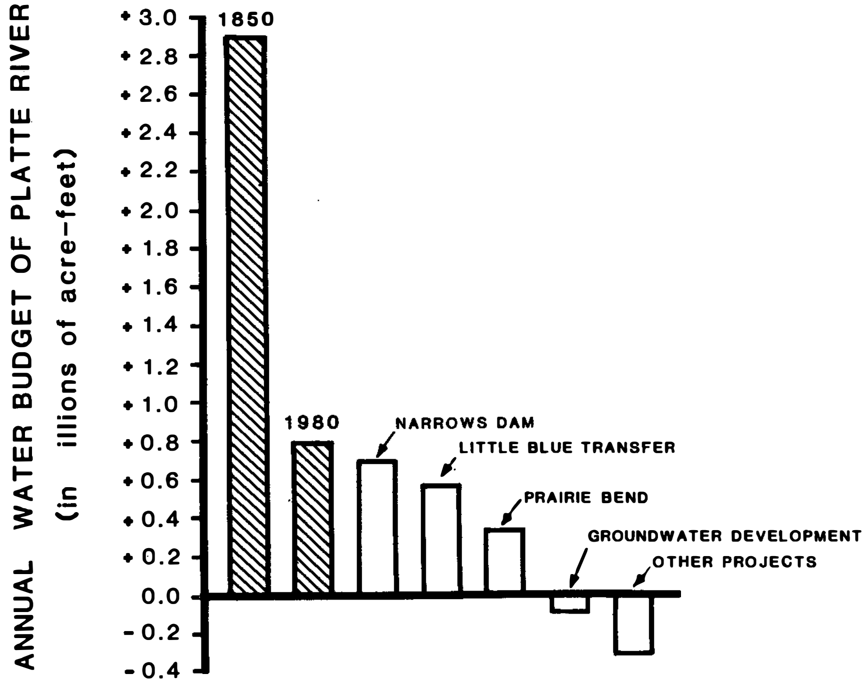


Figure 3. Estimated annual water budget of the Platte River at Overton, Nebraska, in 1850 and at present (cross-hatched bars), and, with the completion of certain proposed projects, projected groundwater development, and other uses (clear bars). Effects of potential future development on the annual water budget are presented in a cumulative setting.

by the Platte River Whooping Crane Trust and local irrigators and reflects an attempt to satisfy both the needs of cranes and agriculture.

Potential Risks to Crane Population From Habitat Deterioration

As with any species whose numbers are concentrated by habitat loss into an area of diminishing size, the midcontinent population of sandhill cranes while at the Platte will become increasingly vulnerable should the present trend of habitat loss continue. Severe local storms, for example, can cause heavy mortality on restricted areas. The susceptibility of cranes when caught in hail storms is documented in the literature (Merrill 1961, Higgins and Johnson 1978, Heflebower and Klett 1980). Although hail storms are infrequent during the spring staging period, several have been recorded in Nebraska during March and April of the past 22 years (U.S. Environmental Data Service 1959–1980). Similarly, oil spills, pesticide contamination, or other forms of accidental pollution grow in importance as the concentration of cranes builds. Powerlines, housing developments, roads, and other changes in the landscape on staging areas also take on added significance when viewed in this context. Previous studies have shown significant crane mortality resulting from collisions with powerlines situated between roosting sites and feeding grounds (Tacha et al. 1979).

Crowding also increases the risk of disease problems. Although sandhill cranes have not suffered known major disease outbreaks along the Platte to date, this situation could change in the future. Avian cholera outbreaks in the Rainwater Basin area, a few miles to the south of crane staging areas 1 and 2, have caused substantial losses of migrant waterfowl. In the spring of 1980, for example, about 31,000 dead ducks and geese were recovered during an outbreak (Friend 1981) that is estimated to have killed 80,000 birds. Prospects of sandhill cranes moving into disease-infected areas of the Rainwater Basin area in significant numbers increase as habitat deteriorates along the Platte. Patterns of whooping crane (*Grus americana*) use of the Platte River lend support to this concern. Until recent decades, whooping cranes were observed more frequently near the Platte River than at any other site along their migration route on the Great Plains (Johnson 1981). Yet in a recent 30-year period (1951–1980), there have been only five confirmed sightings of whooping cranes on or near the Platte River. During the same period, use of the Rainwater Basin area by whooping cranes increased steadily.

Although waste corn is now plentiful in fields along the Platte, reliance on this food source by the cranes increases their vulnerability to abrupt changes in land use. Most of the cropland on crane staging areas is in private ownership and potentially subject to alternate uses should economic or other factors warrant the change. Loss or diminished abundance of corn in the future could create food shortages in light of the high densities of cranes present as a result of the limited suitable roosting habitat now available.

Any circumstances that may reduce recruitment or increase mortality are of particular concern because of the low reproductive rate of sandhill cranes. These birds do not breed until at least their third year (Boise 1979) and usually raise one offspring each summer (Buller 1979), resulting in an annual recruitment rate of only 10 to 12 percent (Johnson 1979).

Conclusions

The midcontinent population of sandhill cranes during their annual stopover period in the Platte River Valley rely principally on three habitat types, i.e. a relatively broad channel for roosting, and cropland and meadows for feeding. The rapid rate of loss of riparian habitats used by cranes has promoted the need for development and implementation of a habitat preservation and management plan to stablize conditions and thereby lessen the risks to the population from increased crowding.

The most critical need of cranes is continued access to suitable roosting habitat in the reach between Overton and Grand Island and upstream from North Platte. Channel roosting habitat can be maintained most effectively through a combination of water management and other cost-effective methods of woody vegetation control.

Meadows supply invertebrates, important to meeting certain nutritional requirements of cranes, and serve as rest sites during the daytime. Past conversion of much of the meadow acreage to other uses and its continuing rapid rate of loss suggests that prompt measures be taken to protect part of the remaining meadows along the River. Protection of meadows can be accomplished through either purchase in fee title or by conservation easement. A plan that involves purchase of certain strategically located tracts to permit application of intensive management practices to increase food supply and protects other important meadows through conservation easements appears well suited for meeting current and future needs of the crane population. Conservation easements would allow current land uses to continue when compatible with the maintenance of crane habitat, but would prevent future development.

The dependence of the crane population on corn for its energy requirements during the annual stopover underscores the need for maintaining an abundance of high energy foods in close proximity to meadows and roosting habitat. Some cropland should be protected against future changes in agricultural land use that could eliminate most of the waste corn presently available in spring. The large numbers of waterfowl that gather along the Platte River during late winter and early spring would also benefit from steps taken to maintain an ample supply of corn.

Acknowledgements

We thank Paul J. Currier, Charles W. Dane, Douglas H. Johnson, James C. Lewis, and Garnett P. Williams for their critical review of this manuscript and Reid Goforth, David Trauger, and Rey Stendell, administrators at the Northern Prairie Wildlife Research Center during the course of these investigations, for their continuing support and encouragement. We are indebted to FWS personnel at the Ecological Services Office at Grand Island, Nebraska, for their major assistance to the project, and in particular, Gene Miller for numerous helpful suggestions throughout the study and Kent Kroonemeyer, former Supervisor of the Grand Island Office, for his support of our efforts. We are grateful to Darold Walls and Al Trout, Managers of the Rainwater Basin Wetland Management District, for their active support of our studies. We also appreciate the assistance provided by personnel in the U.S. Geological Survey, U.S. Bureau of Reclamation, and Nebraska Game and Parks Commission during the course of these studies. Douglas Facey, Mia Hay, and Brooks Gehring are thanked for their assistance in data analysis, Charles Shaiffer and Mavis Meyer for preparing the figures, and Debra Reimers and Tammy Fercho for typing several drafts of the manuscript.

Literature Cited

Anonymous. 1979. Irrigated acreage survey—1979. Irrig. J. 29:58A–58H.

Bentall, R. 1975. Hydrology: Nebraska Mid-State Division and associated areas. Univ. of Nebraska, Institute of Agriculture and Natural Resources, Lincoln. 256 pp.

Boise, C. M. 1979. Lesser sandhill crane banding program on the Yukon-Kuskokwim Delta, Alaska. Pages 229–236 *in* Proc. 1978 Crane Workshop. Colorado State Univ., Fort Collins.

Buller, R. J. 1979. Lesser and Canadian sandhill crane populations, age structure, and harvest. Spec. Sci. Rep. Wildl. 221. U.S. Fish and Wildl. Service., Washington, D.C. 10 pp.

Currier, P. J. 1981. The floodplain vegetation of the Platte River: phytosociology, forest development, and seedling establishment. Ph.D. Thesis. Iowa State Univ., Ames. 332 pp.

Eschner, T. R., R. F. Hadley, and K. D. Crowley. 1981. Hydrologic and morphologic changes in channels of the Platte River Basin: a historical perspective. U.S. Geological Survey Open-File Report 81-1125. 57 pp.

Friend, M. 1981. Waterfowl diseases—changing perspectives for the future. Int. Waterfowl Symp. 4:189–196.

Frith, C. R. 1974. The ecology of the Platte River as related to sandhill cranes and other

waterfowl in south central Nebraska. M.S. Thesis. Kearney State College, Kearney, Neb. 115 pp.
——, and C. A. Faanes. 1981. Inventory of sandhill crane roosting habitat on the Platte and North Platte Rivers, Nebraska. Pages 13–16 *in* Proc. 1981 Crane Workshop. National Audubon Society, Washington, D.C.
Fritzell, E. K., G. L. Krapu, and D. G. Jorde. 1979. Habitat-use patterns of sandhill cranes in the Platte River Valley—a preliminary report. Pages 7–11 *in* Proc. 1978 Crane Workshop. Colorado State Univ., Fort Collins.
Heflebower, C. C., and E. V. Klett. 1980. A killer hailstorm at the Washita Refuge. Bull. Okla. Ornithol. Soc. 13:26–28.
Higgins, K. F., and M. A. Johnson. 1978. Avian mortality caused by a September wind and hail storm. Prairie Natur. 10:43–48.
Hurr, R. T. 1981. Ground-water hydrology of the Mormon Island Crane Meadows Wildlife Area, near Grand Island, Hall County, Nebraska. U.S. Geological Survey Open-File Report 81-1109. 16 pp.
Johnson, D. H. 1979. Modeling sandhill crane population dynamics. Spec. Sci. Rep. Wildl. 222. U.S. Fish and Wildl. Serv., Washington, D.C. 10 pp.
Johnson, K. 1981. Whooping crane use of the Platte River, Nebraska—History, status, and management recommendations. Pages 33–43 *in* Proc. 1981 Crane Workshop. National Audubon Society, Washington, D.C.
Johnson, M. S., and D. T. Pederson. 1981. Groundwater levels in Nebraska, 1980. Nebr. Conserv. and Surv. Div. Water Surv. Pap. 51. 65 pp.
Johnson, R. R. 1978. The Lower Colorado River: a western system. Pages 41–55 *in* Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Gen. Tech. Rep. WO-12.U.S. For. Serv., Washington D.C.
Krapu, G. L. 1979. Sandhill crane use of staging areas in Nebraska. Pages 1–5 *in* Proc. 1978 Crane Workshop. Colorado State Univ., Fort Collins.
Kroonemeyer, K. E. 1979. The United States Fish and Wildlife Service's Platte River National Wildlife Study. Pages 29–32 *in* Proc. 1978 Crane Workshop. Colorado State Univ., Fort Collins.
Lewis, J. C., Chairman. 1977. Sandhill crane (*Grus canadensis*). Pages 5–43 *in* G. C. Sanderson, ed. Management of migratory shore and upland game birds in North America. Intl. Assoc. Fish Wildl. Agencies, Washington, D.C. 358 pp.
McKinley, J. L. 1935. The influence of the Platte River upon the history of the Valley. Ph.D. Thesis. Univ. of Nebraska, Lincoln. 316 pp.
Merrill, G. W. 1961. Loss of 1,000 lesser sandhill cranes. Auk 78:641–642.
Missouri River Basin Commission. 1975. Platte River Basin, Nebraska—Level B Study: Hydrology and hydraulics. 167 pp.
Ohmart, R. D., W. O. Deason, and C. Burke. 1977. A riparian case history: the Colorado River. Pages 35–47 *in* Importance, preservation and management of riparian habitat: a symposium. Gen. Tech. Rep. RM-43. U.S. For. Serv., Fort Collins, Colo.
Reinecke, K. J., and G. L. Krapu. 1979. Spring food habits of sandhill cranes in Nebraska. Pages 13–19 *in* Proc. 1978 Crane Workshop. Colorado State Univ., Fort Collins.
Tacha, T. C., D. C. Martin, and C. G. Endicott. 1979. Mortality of sandhill cranes associated with utility highlines in Texas. Pages 175–176 *in* Proc. 1978 Crane Workshop. Colorado State Univ., Fort Collins.
U.S. Environmental Data Service. 1959–1980. Storm data. Vol. 1–22.
U.S. Fish and Wildlife Service. 1981. The Platte River Ecology Study. Spec. Res. Rep. U.S. Fish and Wildl. Serv. Jamestown, N.D. 187 pp.
Walkinshaw, L. H. 1956. Two visits to the Platte Rivers and their sandhill crane migration. Nebr. Bird Rev. 24:18–21.
Wallenstrom, R. L. 1976. The Platte River National Wildlife Refuge. Pages 141–143 *in* Proc. Int. Crane Workshop. Oklahoma State Univ., Stillwater.
Williams, G. P. 1978. The case of the shrinking channels—the North Platte and Platte Rivers in Nebraska. Circ. 781. U.S. Geol. Surv., Reston, Va. 48 pp.

Wildlife Values Versus Human Recreation: Ruby Lake National Wildlife Refuge

Stephen H. Bouffard
U.S. Fish and Wildlife Service,
Ruby Lake National Wildlife Refuge,
Ruby Valley, Nevada

Expanding human populations are making increased recreational demands on National Wildlife Refuges (NWR). The U.S Fish and Wildlife Service (FWS) is trying to accommodate these demands whenever possible. An important, but not primary objective of NWRs is to provide for various public uses, including recreation (U.S. Fish and Wildlife Service 1976a). The Refuge Recreation Act of 1962 (16 U.S.C. 460K-460K-4) authorizes the FWS to allow recreational uses on NWRs, National Fish Hatcheries and similar lands. This act specifies that all recreational uses must be secondary to the primary purpose of the refuge. While most refuge recreation programs do not conflict with the primary refuge purpose, some conflicts have occurred. Some recreation programs were started before conflicts with wildlife became apparent. Others were not in conflict with wildlife while public visits were low, but later came into conflict after public use increased. Conflicts of this type become very difficult to change because the public has come to expect and demand these recreation opportunities. This paper will discuss FWS attempts to manage such a recreational program at Ruby Lake NWR where recreational boating had grown from low use and little wildlife conflicts to heavy use and substantial conflicts with nesting waterfowl.

Ruby Lake NWR was established in 1938 by Presidential Order No. 7923 as a migratory bird breeding area. The 37,630 acre (15,236 ha) refuge lies in a high (6,000 feet, 1,829 m) closed basin in northeastern Nevada. The South Sump is the largest marsh unit on the refuge and contains 7,000 (2,835 ha) of the 12,000 acres (4,680 ha) of wetlands on the refuge. This unit has interspersed open water, uplands and emergent vegetation, a habitat mixture that attracts large numbers of nesting waterfowl, particularly diving ducks. About 85 percent of the canvasbacks *(Aythya valisineria)* and redheads *(A. americana)* on the Refuge nest in this unit. Various other waterfowl and wading birds nest on the Refuge including trumpeter swans *(Olor buccinator)* and sandhill cranes *(Grus canadensis)*. Nearly eighty percent of the fishing and all of the recreational boating on the Refuge occur on the South Sump (Green 1981).

Ruby Lake NWR is the major canvasback breeding area in the western United States. No other single refuge in the lower 48 states regularly produces as many canvasbacks (1,200–3,500 ducklings fledged each year). About 400 pairs of canvasbacks and 430 pairs of redheads nest on the refuge annually. Averaged over the entire refuge, two-thirds of which is dry uplands, this represents a breeding population of 13.6 canvasbacks per square mile (5.2/km^2) as compared to 10 or more per square mile (>3.8/km^2) in the best prairie pothole area near Minnedosa, Manitoba (Bellrose 1980:303).

Ruby Lake NWR is one of the few remaining major wetlands of Nevada. Surprisingly, Nevada once had large areas of wetlands, but because of water demands many areas have been lost. In western Nevada nearly 30,000 acres (12,000 ha) of wetlands remain in wet years where there were once over 123,000 acres (50,000 ha) (Nevada Chapter, The Wildlife Society 1980). The scarcity of wetlands in Nevada makes each remaining area more valuable to wildlife. It also tends to concentrate water based recreation on these same areas, leading to conflicts with wildlife.

The boating-wildlife conflict had its origin before the Refuge was established. In the early 1930s, largemouth bass *(Micropterus salmoides)* were stocked in the marsh. They were not seen again until 1941; fishing began in 1942 (Trelease 1948). Because the first fishermen were relatively few in number and fished mostly from shore (Green 1980), they caused little disturbance. The number of public visits (Table 1), the number of boats, and motor size increased over the years. Currently about 90 percent of the visits involve fishing and 65 percent of the visits involve fishing from boats (U.S. Fish and Wildlife Service 1981). Public visits were not evenly distributed throughout the year, but were concentrated from May through early September. Heaviest public use coincided with the waterfowl breeding season. In 1976 a survey of over 100 boats owned locally and used primarily on the Refuge indicated that the average motor size on these boats was over 90 horsepower (hp); several motors exceeded 250 hp (U.S. Fish and Wildlife Service 1976b). Sometime during the 1950s waterskiing began on one pond about 30 acres (12 ha) in size.

Boating and waterskiing were, for the most part, uncontrolled and were allowed in the prime diving duck nesting habitat during the nesting season. This uncontrolled use of boats created several conflicts with waterfowl production. Disturbance to breeding diving ducks was considerable. Courting canvasback and redhead pairs flushed an average of nearly 300 yards (271 m) from any boat regardless of motor size (Howard 1978). Noise from outboard motors flushed canvasbacks and redheads off their nests at an average of about 38 yards (35 m), and some flushed over 110 yards (100 m) away (Bouffard 1980). Few females covered their nest when flushed, exposing the eggs to chilling, overheating, or predation by ravens *(Corvus corax),* the major egg predator on the Refuge (Bouffard 1980). Repeated flushing of birds and anchoring of boats near nests led to nest desertion. Boats dispersed broods and forced them into less desirable habitat.

In addition to disrupting breeding waterfowl, boats also caused habitat damage.

Table 1. Public visits for selected years at Ruby Lake National Wildlife Refuge. Data was taken from Refuge files and Public Use Reports.

Calendar Year	Boating and Waterskiing[a]	Fishing	Total Refuge Visits
1955		700	1,500
1960		8,000	18,249
1965	4,030	15,000	20,100
1970	1,700	31,450	34,205
1975	2,945	41,575	45,680
1980		57,698	65,568

[a]Records of visits for boating and waterskiing were not maintained separately until 1963. Boating refers to recreation boating only. Boating associated with fishing is recorded under fishing, the primary activity.

The cutting action of the propellers totally removed the aquatic vegetation in some channels and changed the species composition of the vegetation in other areas. Areas with heaviest boat use had less submergent vegetation (10.7 tons/acre) than non-use areas (45.9 tons/acre) (U.S. Fish and Wildlife Service 1976c.). Loss of vegetation followed by wakes from larger boats caused bank erosion and siltation in some areas. This erosion was most common in the pond where waterskiing was practiced.

By the late 1960s, public use had increased to the point where conflicts with wildlife became apparent. The FWS began a study in 1969 to document the effects of recreational boating on waterfowl production. The boating regulations and study areas changed each year, so the study ended in 1971 with no conclusive results. Only in 1971 was there a difference in redhead nest success between the public use area (61.1 percent) and the control area (93.6 percent) (Napier 1972). Because of pressure from the boating public and the lack of conclusive information from Napier's research, boating regulations were relaxed further in 1972, allowing motorboating throughout the South Sump after 1 July (Appendix 1).

A renewed effort to control boating began in 1974 with a literature review and compilation of data leading to the completion of an environmental impact assessment (EIA) published in 1976. The EIA reviewed the literature on disturbance to breeding waterfowl from recreational boating and documented some effects of boating on waterfowl production at Ruby Lake NWR (U.S. Fish and Wildlife Service 1976c.). Four public hearings were held throughout Nevada; reaction to the conclusions of the EIA was very negative. After considering several alternatives, the FWS proposed regulations to begin in 1978 allowing motorless boats or boats with electric motors year round in designated areas. Outboard motors (10 hp or less) would be allowed in the South Sump after 31 July; waterskiing would be prohibited. Public reaction to this proposal was also very negative and prompted the Assistant Secretary of the Interior to tour the Refuge in June 1977. In April 1978, the following regulations were issued: Motor size restrictions were dropped in favor of speed limits, and the South Sump was divided into four zones: One was open year round for motorless boats only and the other three opened to motorboats on 1 July, 15 July and 1 August. (See Appendix 1 for review of boating regulations). FWS felt that these regulations would adequately reduce conflicts between recreation and wildlife and be more agreeable to the boaters.

Local boaters were not the only group interested in the Refuge. The Defenders of Wildlife (DOW) contended that the altered regulations violated the Refuge Recreation Act and threatened to sue to stop the use of large boats. On 29 June 1978, two days before outboard motors could be used, the DOW obtained a temporary restraining order against the FWS, prohibiting the use of outboard motors on Ruby Lake NWR pending the outcome of their lawsuit. Public reaction to the order was negative and the opponents of the order organized a civil disobedience in response to the ruling. There were threats and heated words, but no injuries, arrests or property damage. The DOW won the court case. On 11 July, the judge declared the regulations unlawful and ordered the FWS to issue new regulations. On 25 July, the FWS issued regulations that allowed outboard motors with a 10 hp restriction through 31 July and allowed waterskiing and motorboating with no motor size restrictions after 31 July. The DOW did not concur with these revised regulations and obtained another temporary restraining order prohibiting outboard motors larger than 10 hp and won the second suit. The court again directed the FWS to issue new regulations. The new regulations were issued 7 September, allowing outboard motors 10 hp or less until 31 December. Waterskiing was prohibited. On 23 April 1979 the following regulations were published: Motorless boats and boats with electric motors were allowed on the South Sump from 15 June through 31 December, boats with outboard motors no larger than 10 hp were allowed 1 August through 31 December. Wildlife disturbance under these regulations has been greatly reduced. These regulations, with minor changes are still in effect today.

The Refuge Recreation Act was the basis of the lawsuits by the DOW against the FWS. The following were the major points made in the court's decision of 14 July. The Secretary of the Interior must determine "that such use is incidental to, compatible with and does not interfere with the primary purpose of the refuge" (U.S. District Court, District of Columbia 1978:9). Allowing a recreational use and afterward determining whether that use is harmful to wildlife cannot be allowed. The determination must be made first. Secondly, "the Refuge Recreation Act does not permit the Secretary to weigh or balance economic, political, or recreational interests against the primary purpose of the refuge" (U.S. District Court, District of Columbia. 1978:9) Finally, past use has no bearing on current decisions for recreational use.

> Neither poor administration of the refuge in the past, nor prior interferences with its primary purposes, nor past recreational uses, nor deterioration of its wildlife resource since its establishment, nor administrative custom nor tradition alters the statutory standard. The Refuge Recreation Act permits recreational use only when it will not interfere with the primary purpose for which the refuge 'was established.' The prior operation of the refuge in a manner inconsistent with that purpose does not change the base point for applying the statute's standard. Past recreation use is irrelevant to the statutory standard except insofar as deterioration of the wildlife resource from prior recreational uses serves to increase the need to protect, enhance and preserve the resource (U.S. District Court, District of Columbia. 1978:10).

The first test of the Refuge Recreation Act set some important precedents for lands managed by the FWS for wildlife. The Act and court decision provided some very strong protection for wildlife from incompatible recreational pressures on NWRs.

The FWS will continue to accommodate recreational use on NWRs when compatible with wildlife objectives. As at Ruby Lake NWR, the Refuge Recreation Act will continue to be used to protect wildlife objectives should recreational programs conflict with these objectives.

References Cited

Bellrose, F. C. 1980. Ducks, geese and swans of North America, 3rd ed. Stackpole Books, Harrisburg, Pa. 540 pp.

Bouffard, S. H. 1980. Breeding biology and productivity of canvasbacks and redheads at Ruby Lake National Wildlife Refuge. U.S. Fish and Wildlife Service, Ruby Valley, Nev. 35 pp.

Green, M. 1980. Preliminary Ruby Marsh fisheries management plan. Nevada Dep. Wildlife, Reno. 62 pp.

———. 1981. Job progress report. P-R project F-20-16, Job 201. Nevada Dep. Wildlife, Reno. 30 pp.
Howard, R. L. 1978. Effects of revised boating regulations on waterfowl production on the Ruby Lake National Wildlife Refuge—1977 progress report. U.S. Fish and Wildlife Service, Ruby Valley, Nev. 27 pp.
Napier, L. L. 1972. Effects of public use on waterfowl nesting success on Ruby Lake National Wildlife Refuge. U.S. Fish and Wildlife Service, Ruby Valley, Nev. 39 pp.
Nevada Chapter, The Wildlife Society. 1980. Position statement: The maintenance and management of wetlands on public lands for public benefit in Lahontan Valley, Nevada. Nevada Chapter, The Wildlife Society. 12 pp.
Trelease, T. J. 1948. Report of field survey and investigation of the fisheries resources of Ruby Lakes, Nevada. Nevada Fish and Game Comm., Reno. 13 pp.
U.S. District Court, District of Columbia. 1978. Defenders of Wildlife et al. v. Cecil Andrus et al. Findings of fact and conclusions of law. Civil Action 78-1210. U.S. District Court, District of Columbia. 13 pp.
U.S. Fish and Wildlife Service. 1976a. Final Environmental Statement: Operation of the National Wildlife Refuge System. U.S. Fish and Wildlife Service, Washington, D.C.
———. 1976b. Addendum to Environmental Impact Assessment: Effect of boating on management of Ruby Lake National Wildlife Refuge. U.S. Fish and Wildlife Service, Portland, Ore.
———. 1976c. Environmental Impact Assessment: Effect of boating on management of Ruby Lake National Wildlife Refuge. U.S. Fish and Wildlife Service, Portland, Ore.
———. 1981. Ruby Lake NWR: public use reports. On file at Ruby Lake NWR, Ruby Valley, Nev.

Appendix I—Summary of Boating Regulations at Ruby Lake NWR

1981 to 1979 Motorless boats and boats with electric motors were permitted from 15 June through 31 December on the entire South Sump. Boats propelled by 10 horsepower motors or less were allowed on the marsh from 1 August through 31 December. Internal combustion generators prohibited in 1981.

1978
I. Original Regulations
- A. Zone 1—Open year round to boats without motors.
- B. Zone 2—Open to powerboats with no horsepower restrictions from 1 July to 31 December on the east side, 15 July to 31 December on the west side.
- C. Zone 3—Open to powerboats with no horsepower restrictions 1 August to 31 December.

II. Second Set of Regulations

On 29 June the Service was served an order prohibiting the use of motors larger than 10 horsepower. The judge ruled in favor of the plaintiffs and the Service issued regulations. There were no changes in the zoning and motorboats with no horsepower restrictions could be used beginning 1 August. Prior to 1 August motors were restricted to 10 horsepower. These regulations went into effect on 25 July.

III. Third Set of Regulations

On 21 July the Service received another order prohibiting the use of motors larger than 10 horsepower. Again the judge found in favor of the plaintiffs and the Service issued new regulations on 7 September. The zoning was abolished and the whole South Sump was opened to powerboats with motors no larger than 10 horsepower.

1977 to 1972 Boats without motors were allowed throughout the South Sump year round. Power boating with no horsepower restrictions was allowed year round in designated areas. Power boating with no horsepower restrictions was allowed through the remainder of the South Sump 1 July through 31 December.

1971 Boats without motors were allowed throughout the South Sump year round. Power boating with no horsepower restrictions was allowed year round in designated areas. Power boating with no horsepower restrictions was allowed through the remainder of the South Sump 24 July through 31 December.

1970 Boats without motors permitted year round on the entire South Sump. Powerboats with no horsepower restrictions were allowed on the entire South Sump 13 June through 31 December.

1969 Boats without motors permitted year round on the entire South Sump. Power boats with no horsepower restrictions were allowed on the entire South Sump 14 June through 31 December.

1968 Boats without motors were allowed year round in the South Sump. Power boats with no horsepower restrictions were permitted in the South Sump 15 June through 31 December. Boats without motors were allowed in the dike units 15 June through 31 October.

1967 I was unable to locate any records of boating regulations prior to 1968. Some of the earlier regulations may have been tied to fishing seasons.

Waterfowl Production at Malheur National Wildlife Refuge, 1942–1980.

John E. Cornely
U.S. Fish and Wildlife Service,[1]
Malheur National Wildlife Refuge,
Burns, Oregon

Introduction

Malheur National Wildlife Refuge (NWR), Harney County, Oregon, is an important breeding area for Pacific Flyway Waterfowl. Trumpeter swans *(Olor buccinator),* Canada geese *(Branta canadensis),* and 14 species of ducks nest at Malheur NWR. The refuge is one of the most important redhead *(Aythya americana)* nesting areas in the western United States. Malheur NWR was established by President Theodore Roosevelt in 1908, primarily as a nesting area for migratory birds. The refuge also serves as an important migration stop for thousands of waterfowl and other migratory birds. Originally the refuge was called Malheur Lake Reservation and included only Malheur, Mud, and Harney Lakes. The 60,000 acre (24,280 ha) Blitzen River Valley was added in 1935, primarily to help protect the water supply for Malheur Lake. The 22,000 acre (8,900 ha) Double-O Ranch was acquired in 1941 and smaller parcels have been added more recently. Relatively complete records have been kept of annual waterfowl production estimates at the refuge since 1942. The objectives of this paper are to summarize those historical records, describe apparent trends, and discuss some of the factors that may influence waterfowl production at Malheur NWR.

Description of Malheur NWR

Malheur NWR is comprised of approximately 183,000 acres (74,100 ha) of shallow marshes, irrigated meadows, brush-grass uplands, alkali flats, and brushy alkali uplands. The refuge is 27 miles (43 km) wide and 41 miles (66 km) long. The elevation averages 4,100 feet (1,250 m). The climate is characterized by warm, dry summers and cold winters. Maximum temperatures seldom exceed 90°F (32°C) in the summer and subzero temperatures are recorded in most winters. The surfaces of most lakes and ponds are usually frozen from December through mid-February, but snow depths rarely exceed 6 inches (15 cm). Average annual precipitation is 9 inches (23 cm), occurring mainly from November through January with a smaller peak in May and June.

The principal sources of water are the Silvies and Blitzen rivers and Silver Creek (see Figure 1). The Silvies River originates in the Blue Mountains and empties into the north side of Malheur Lake. Silver Creek also originates in the Blue Mountains, but flows through the Double-O Ranch into the west side of Harney Lake. The Blitzen River arises on Steens Mountain, southeast of the refuge. It provides water for the Blitzen Valley before entering Malheur Lake. The Blitzen River is the

[1]Present address: Willamette Valley and Oregon Coastal National Wildlife Refuge Complex, Route 2, Box 208, Corvallis, Oregon 97333

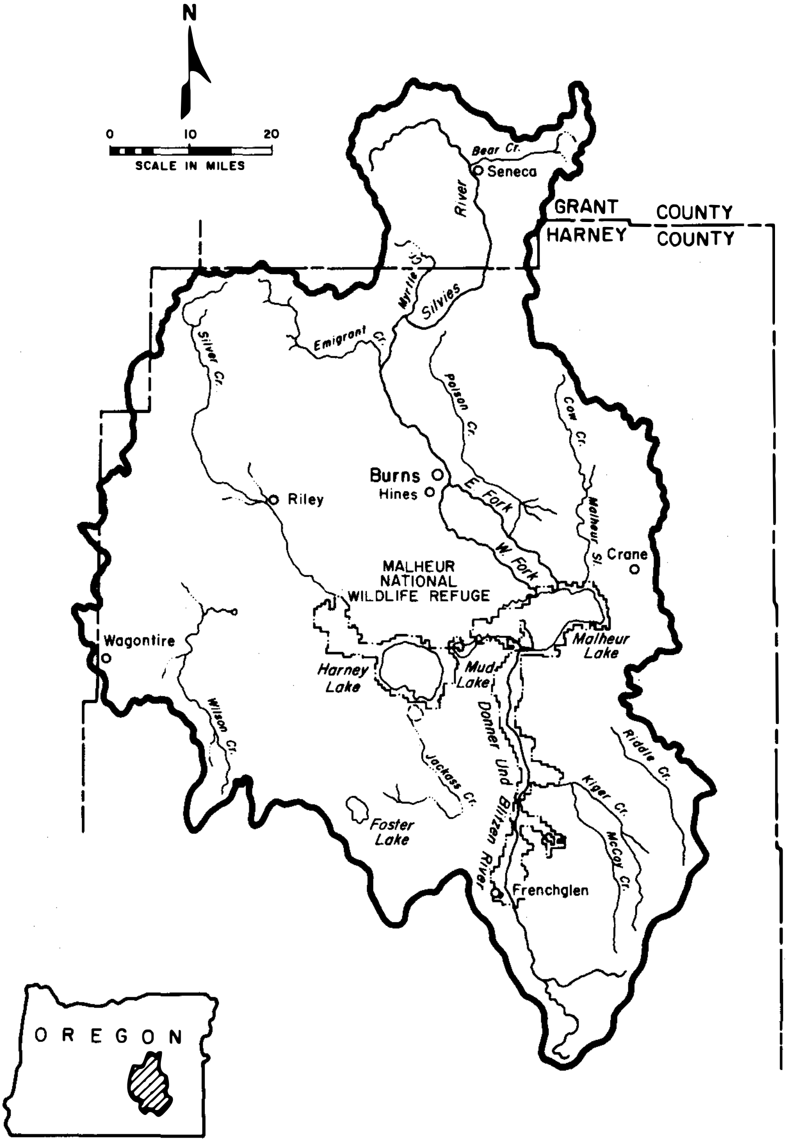


Figure 1. Map of the Harney Basin, Oregon, including Malheur National Wildlife Refuge.

largest source of inflow to Malheur Lake. From October 1971 through September 1973 the Blitzen River provided 57 percent of the inflow, the Silvies River provided 20 percent, 17 percent came from direct precipitation, and 6 percent came from Sodhouse Spring (Hubbard 1975).

Malheur Lake is one of the largest freshwater marshes in the western United

States. It ranges from less than 10,000 surface acres (4,000 surface ha) of water in dry years to over 60,000 surface acres (24,300 surface ha) in years with high runoff. Water depths range from 1 to 6 feet (0.3 to 2 m) with an average of 3 feet (1 m). Hardstem bulrush *(Scirpus acutus)* is the dominant emergent plant and sago pondweed *(Potamogeton pectinatus)* is the most important submergent plant. The western section of Malheur Lake is a series of natural ponds separated by a network of low islands and peninsulas. The center section, the deepest area of the lake, is predominantly hardstem bulrush interspersed with open water. The eastern section is the most alkaline and has the best stands of sago pondweed in most years. For more details on the hydrology of Malheur Lake see Hubbard (1975). Duebbert (1969b) reviewed the ecology of Malheur Lake.

At one time Mud Lake was a shallow marsh between Malheur and Harney Lakes. A channel and dike were constructed through the marsh. Although a couple of small marshes remain, most of Mud Lake is wet meadow or agricultural fields.

Harney Lake is the sump of the closed Harney Basin. Water often enters Harney Lake through Silver Creek, but a majority of the inflow enters from Malheur Lake through Mud Lake. Harney Lake ranges from zero to 30,000 surface acres (0 to 12,100 surface ha).

The Blitzen River Valley is flat, long and narrow. Small ponds and sloughs are interspersed among irrigated meadows and drier uplands. Most of the water in the valley wetlands originates from snow melting on Steens Mountain. When runoff is sufficient, ponds and sloughs are filled in the spring from runoff water diverted from the river through a complex system of canals, dams and dikes.

The Double-O Ranch is the westernmost section of Malheur NWR. This area receives inflow from Silver Creek and much of the area is watered by springs.

In addition to hardstem bulrush, common emergents at Malheur NWR are broad-fruited burreed *(Sparganium eurycarpum)*, broad-leafed cattail *(Tyhpa latifolia)*, Baltic rush *(Juncus balticus)* and alkali bulrush *(Scirpus maritimus)*. Submergents are dominated by pondweeds *(Potamogeton spp.)*, coontail *(Ceratophyllum demersum)*, water milfoil *(Myriophyllum exalbescens)* and bladderwort *(Utricularia vulgaris)*. Uplands are covered with big sagebrush *(Artemesia tridentata)*, rabbitbrush *(Chrysothamnus spp.)* and black greasewood *(Sarcobatus vermiculatus)*. These shrubs are interspersed with Great Basin wild rye *(Elymus cinereus)*, alkali wild rye *(E. triticoides)* and salt grass *(Distichlis stricta)*.

Methods

Annual waterfowl production estimates were reported in refuge quarterly or annual narrative reports, or annual production summaries. These reports are on file at the headquarters, Malheur NWR. Methods of estimating duck and goose production have varied through the years. From 1942 through 1945 estimates were based on general field observations; no standardized sampling procedures were used. From 1946 through 1952, production estimates were based on nest success from nesting studies. No standardized routes were used for breeding pair or brood counts. There was a dearth of information from 1953 through 1955. Production was based on general observations during routine field activities. From 1956 through 1960 production estimates were based on pair, nest, and brood observations from sample plots checked twice a month during the breeding and brooding season.

Those results were supplemented with general observations during aerial, boat, and ground surveys. From 1961 through 1967 estimates were based on random ground and aerial surveys of breeding pairs and random brood counts on the principal brooding areas.

Beginning in 1968, breeding pairs and broods were censused along standard aerial, boat, and ground routes and nesting success was determined from sample plots. Production estimates from 1968 through 1971 were based on extensive brood counts. From 1972 through 1980 production estimates for ducks and geese were calculated by multiplying the breeding pair estimate × nest success × mean brood size just prior to fledging.

Trumpeter swan production was determined by an actual count of cygnets just prior to fledging. Currently, a combination of aerial and ground surveys is used to determine the number of swan pairs, nests, broods, and cygnets.

Malheur Lake acreages were derived from staff gauge readings at the mouth of the Blitzen River (Refuge files). Readings recorded prior to April 1972 were converted to surface acreage using the table in Piper et al. (1939). Subsequent readings were converted using a table developed as a result of a U.S. Geological Survey hydrology study (Hubbard 1975). Sago pondweed beds were mapped from the air or by boat. Acreages were determined by using a polar planimeter or a "dot" method.

Grazing was reported in animal unit months (AUMs). One animal unit month is the amount of forage consumed by an adult cow in 30 days.

Data Limitations

Because of the changes in methodology through the years, waterfowl production estimates at Malheur NWR are difficult to interpret. Those changes sometimes coincided with changes in biologists and reflected a continuing effort to refine sampling techniques. The estimates were never intended to be interpreted as precise measurements of annual waterfowl production. They were calculated to provide general trend information. Production estimates at Malheur NWR are made difficult by the expanse of the area, limited access, and large fluctuations in water availability. These limitations prevent analyses of the data in any depth. I have assumed that the trends exhibited by these estimates reflect the actual historical trends in waterfowl production at Malheur NWR.

Results

Annual waterfowl production estimates from 1942 to 1980 averaged over 51,000 birds. Production was the highest in the 1940s averaging over 100,000 birds per year (Table 1). Between 1948 and 1954, production declined precipitously (Figure 2). Annual production averaged less than 44,000 birds in the 1950s and was even lower in the 1960s when less than 25,000 birds were fledged annually. A moderate upward trend followed during the 1970s when annual production increased to almost 33,000 birds. The highest annual estimate, recorded in 1948, was 150,950 waterfowl and the lowest was 6,900 reported in 1959.

Duck Production

Ducks comprised over 95 percent of the waterfowl produced annually at Malheur NWR. An average of over 48,000 ducks was produced annually, with a high of

Table 1. Average annual waterfowl production during four periods from 1942 to 1980 at Malheur National Wildlife Refuge.

Species	1942–1950	1951–1960	1961–1970	1971–1980
Gadwall	37,556	19,431	6,682	5,840
Mallard	32,556	5,518	3,457	4,592
Redhead	9,256	8,149	3,870	7,552
Cinnamon/blue-winged-teal	9,588	4,412	4,800	6,953
Pintail	7,278	587	926	1,139
Ruddy duck	5,044	969	866	2,823
Northern shoveler	3,478	1,093	627	1,187
American wigeon	455	146	685	706
Green-winged teal	867	237	238	486
Canvasback	266	241	350	420
Lesser scaup	589	298	227	156
Common merganser	152	103	90	53
Canada goose	4,267	2,480	1,381	1,237
Trumpeter swan	—	2.7	9.8	12.5
Total waterfowl	111,352	43,667	24,209	33,157

146,950 in 1948 and a low of 5,610 in 1959. Of the ducks produced from 1942 to 1980, 79 percent were dabblers and 21 percent were divers, but these proportions were quite variable (Figure 3). For example, in 1959 about 2 percent of the ducks produced were divers, but in 1979 almost 46 percent were divers. More gadwall *(Anas strepera)* were produced than any other species from 1942 to 1980 (Table 2). The next five most productive ducks were mallard *(Anas platyrhynchos)*, redhead, cinnamon/blue-winged teal *(Anas cyanoptera/Anas discors)*, pintail *(Anas acuta)*, and Ruddy duck *(Oxyura jamaicensis)*. Cinnamon and blue-winged teal are lumped because of the difficulty in distinguishing between females of the two species during field censuses. Ratios of male teal suggest that 90 percent or more are cinnamon teal. Other ducks that nested included northern shoveler *(Anas clypeata)*, American wigeon *(Anas americana)*, green-winged teal *(Anas carolinensis)*, canvasback *(Aythya valisineria)*, lesser scaup *(Aythya affinis)*, common merganser *(Mergus merganser)*, and ring-necked duck *(Aythya collaris)*. Broods of ring-necked ducks were observed in 1964, 1971, and 1980 (Marshall and Duebbert 1965, Cornely et al. 1981). They apparently do not nest every year and are not common when they do nest.

In the 1970s the ranking of ducks in order of mean annual production was different than the long term ranking above. For the period 1971 to 1980, ranking was as follows: (1) redhead, (2) cinnamon/blue-winged teal, (3) gadwall, (4) mallard, (5) ruddy duck. During that period the production of redhead, cinnamon/blue-winged teal, American wigeon, and green-winged teal was above the long term average.

Since 1942, production trends have been similar for most duck species (see Table 1). Except for American wigeon and canvasback, the highest production reported

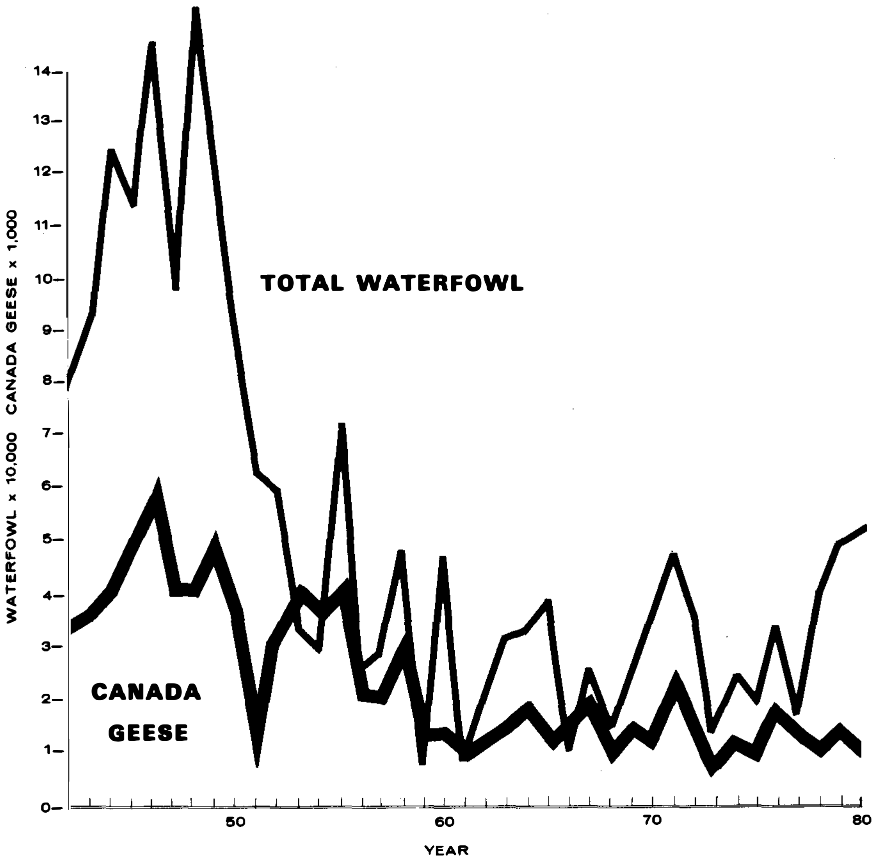


Figure 2. Total waterfowl production and Canada goose production at Malheur National Wildlife Refuge, 1942–1980.

for each species was in the 1940s. The first record of canvasback nesting in the Harney Basin was not until the late 1930s. Every species declined in production during the 1950s. Mean production declined again in the 1960s as production of nine species declined, one was unchanged, and four increased. Production of American wigeon and canvasback reached new highs in the 1960s. In the 1970s the average production of most duck species was higher than in the 1960s. Production of American wigeon and canvasback was the highest ever, but that of gadwall, lesser scaup and common mergansers was the lowest on record. The species that suffered the greatest decline in production between the 1940s and the 1970s were mallard, gadwall and pintail.

Canada Goose Production

Production of Canada geese at Malheur NWR was highest in the 1940s and declined through the 1950s and 1960s (Figure 2, Table 1). Unlike production of

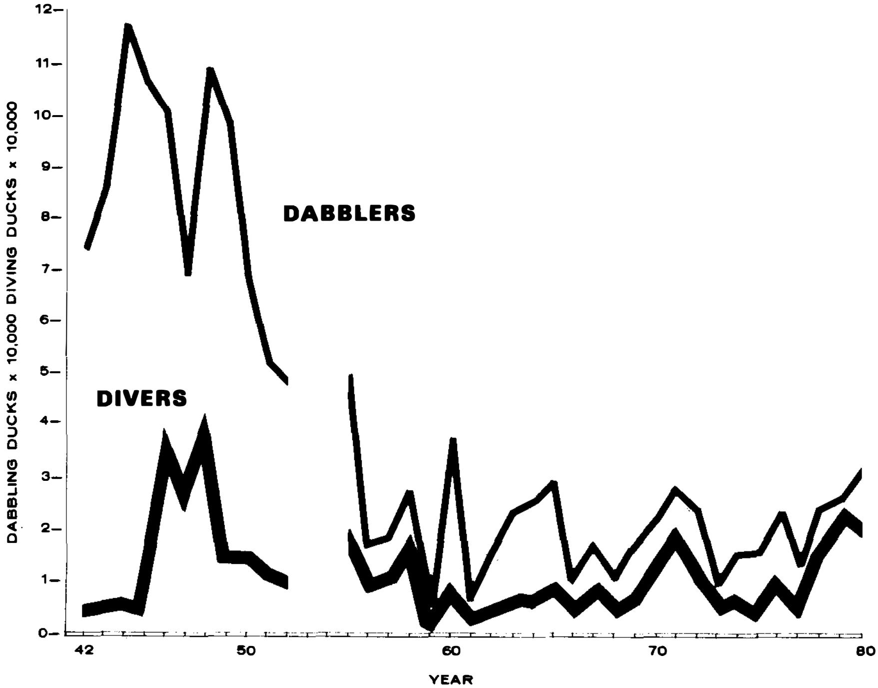


Figure 3. Dabbling duck and diving duck production at Malheur National Wildlife Refuge, 1942–1980.

most waterfowl species on the refuge, production of Canada geese continued to decline in the 1970s, although at a much slower rate.

Trumpeter Swan Production

There are no historical records of nesting trumpeter swans at Malheur NWR. Transplants from Red Rock Lakes NWR, Montana were initiated in 1939 and continued until the first brood was observed at Malheur NWR in 1958. From 1958 through 1980, 239 cygnets were fledged at Malheur NWR. Mean brood size was 2.9 and the mean number of successful broods was 3.6 annually. Mean annual trumpeter swan production gradually increased through the 1960s and 1970s (Tables 1 and 2).

Discussion

Because waterfowl are migratory, conditions and events many miles away as well as locally may influence production at Malheur NWR. Because numerous factors may be invloved and many of them may be interrelated, direct cause and effect relationships are difficult to identify and analyze. Conditions and events that occur outside Malheur NWR and some local factors are beyond the control of the

Table 2. Range and average annual production of 14 waterfowl species during 1942–1980 at Malheur National Wildlife Refuge.

Species	High production	Year	Low production	Year	Mean
Trumpeter swan	33	1979	0	1959, 1961 1977	10
Canada goose	6,000	1946	680	1973	2,548
Gadwall	45,000	1948, 1949	2,000	1959	16,648
Cinnamon/blue-winged teal	17,120	1949	1,100	1957	6,463
Mallard	50,000	1944	600	1959	11,287
Pintail	20,000	1944, 1945	0	1959	2,507
Northern shoveler	8,000	1948, 1949	0	1959	1,528
American wigeon	2,051	1980	50	1950, 1959	508
Green-winged teal	2,000	1948	30	1955, 1962	458
Redhead	30,000	1946	100	1959	7,100
Ruddy duck	15,000	1948	10	1959	2,434
Canvasback	1,400	1980	0	1959, 1961	332
Lesser scaup	2,000	1948	0	Several	310
Common merganser	1,000	1944	0	Several	98

refuge staff. Other factors may be modified to some degree by refuge management activities.

Off-refuge Factors

The quality and quantity of wintering habitat, food availability at migration stops, and hunting, disease, and other mortality at wintering areas or during migration may influence the numbers and condition of waterfowl that nest at Malheur NWR. Although some locally produced birds are harvested in the Harney Basin, most of the hunting mortality of mallards and Canada geese appears to occur after they have left the area (Jarvis and Furniss 1978, Furniss et al. 1979). The highest hunting pressure was in the Central Valley of California. In addition, significant numbers of Canada geese produced at Malheur NWR were harvested in southern Alberta, Canada. The geese were probably harvested in Canada during molt migration (Krohn and Bizeau 1979).

Conditions in other nesting areas may influence the number of breeding pairs at Malheur NWR. In 1980 and 1981, when some of the Canadian prairie breeding areas experienced drought conditions, increased numbers of blue-winged teal were noted at Malheur NWR. A similar occurence was noted at Tule Lake NWR (Jim Hainline, pers. comm.). It is possible that some of these teal returned southward after finding conditions at their traditional nesting areas unfavorable.

Uncontrolled Local Factors

Local weather influences waterfowl production at Malheur NWR. A prerequisite for successful nesting and brooding is an adequate water supply. In the semi-arid climate of southeastern Oregon, water availability depends, to a large degree, on runoff from the surrounding mountains. Mountain snow pack varies considerably from year to year causing marked fluctuations in water availability. The amount of runoff influences the amount of suitable nesting habitat.

For the period 1955 to 1980, there is a significant correlation between diving duck production and the size of Malheur Lake (Figure 4). The highest correlation is with minimum annual lake acreage ($r=0.6134$, $P<0.01$), followed by mean annual lake acreage ($r=0.6069$, $P<0.01$), and maximum annual lake acreage ($r=0.4937$, $P<0.05$). There is not a significant correlation between lake acreage and dabbling duck or goose production. A low, but significant, correlation is evident between trumpeter swan production and minimum lake acreage ($r=0.4530$, $P<0.05$) and mean lake acreage ($r=0.4382$, $P<0.05$), but not maximum lake acreage ($P>0.05$).

Hail, snow, or freezing temperatures can occur during the nesting season and may stress or kill incubating females and young birds. Uncontrolled runoff has destroyed numerous waterfowl nests in recent years by flooding. Hot, dry summer weather may dry up important brooding areas before the young birds fledge.

Local Factors That May Be Controlled

Sago pondweed provides food for breeding waterfowl and their young. The pondweed beds also provide excellent habitat for numerous aquatic invertebrates that provide important food resources. There is a low, but significant correlation

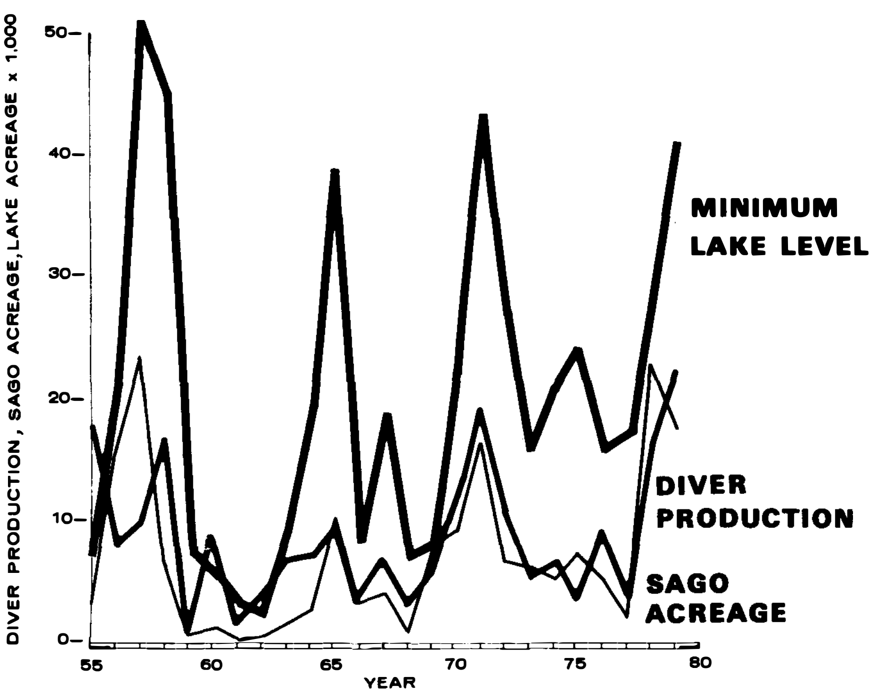


Figure 4. Minimum annual acreage of Malheur Lake (broad line), diving duck production (medium line), and acreage of sago pondweed in Malheur (narrow line), 1955–1980.

between sago pondweed and diving duck production from 1955 to 1980 ($r=0.4020$, $P<0.05$). Sago pondweed production fluctuates greatly, especially in Malheur Lake. There appears to be an inverse relationship between carp *(Cyprinus carpio)* numbers and sago pondweed production. Carp were accidentally introduced in the early 1920s. In the 1950s, greatly reduced submergent vegetation was thought to have been the result of the activities of carp. This led to a major carp control program in 1955 with subsequent efforts in 1960–1961, 1968–1969, and 1977. Following each control program, production of sago pondweed increased dramatically (Figure 4). Because carp control was conducted only during drought years, some of the increased pondweed productivity may have been due to drying out of large areas of the lake bed. The highest redhead production since 1948 occurred in 1979, a year that combined excellent water availability and excellent sago pondweed production.

Numerous authors have suggested that annual grazing and/or mowing reduced waterfowl production (Keith 1961, Gates 1962, Martz 1967, Duebbert 1969a, Krapu et al. 1970, Page and Cassel 1971, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1976, Kirsch et al. 1978). A study conducted at Malheur NWR in 1964 provided indirect evidence that annual mowing and grazing reduced vegetation density and waterfowl production (Jarvis and Harris 1971). More recent studies (Clark 1977, Jarvis 1980) have substantiated this relationship.

Refuge records indicate an increase in grazing from less than 40,000 AUMs in 1942 to over 100,000 in 1951 (Figure 4). Grazing remained high through the 1950s and 1960s. After peaking at about 126,600 AUMs in 1973, grazing has decreased steadily, reaching 42,056 AUMs in 1980. Annual mallard production exhibits a significant negative correlation ($r=0.7507$, $P<0.01$) to AUMs of grazing and haying (Figure 5). Other waterfowl with significant ($P<0.01$) negative correlations between production and AUMs are green-winged teal ($r=-0.5373$), gadwall ($r=-0.4728$), and Canada geese ($r=-0.4255$). Before grazing reductions were initiated, virtually every grazable acre of Malheur NWR was grazed annually. Since the early 1970s nesting cover for upland nesting waterfowl has improved in both quantity and quality.

Numerous nests of waterfowl are destroyed by predators each year. Sooter (1946) reported that common ravens *(Corvus corax)* and coyotes *(Canis latrans)* were major predators of waterfowl nests at Malheur NWR. Jarvis and Harris (1967) reported that 34.6 percent of the 78 Canada goose nests he studied in 1964 were destroyed by predators. Raccoons *(Procyon lotor)*, coyotes, and ravens were the major nest predators. In 1974 and 1975, 72 percent of the duck nests in study plots in the upper Blitzen River Valley were depredated. Avian predators accounted for 57 percent of that total, and mammals caused 36 percent (Clark 1977). Nest predation remained high during a follow-up study from 1976 through 1979 (Jarvis 1980). A nesting study in the Double-O Ranch area disclosed high nest predation rates in 1981. Predators destroyed 88 percent of the waterfowl nests in the study plots.

In addition to destroying nests, predators kill both immature and adult waterfowl. The extent of this predation is difficult to assess and, therefore, it is not known to what degree this affects production.

From the mid-1930s until 1976 some type of predator control was practiced at Malheur NWR. A variety of methods were used, including poisons traps, and

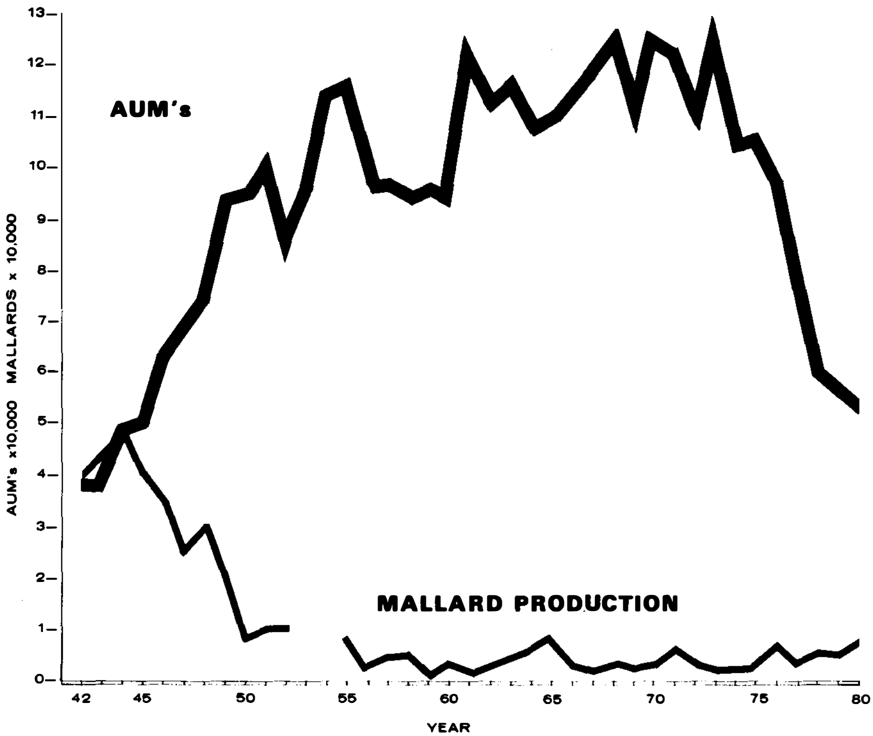


Figure 5. Grazing in animal unit months (AUMs) and mallard production at Malheur National Wildlife Refuge, 1942–1980.

guns. Poisoning was halted during the winter of 1970–1971. A very limited amount of shooting occurred from 1976 to 1980 in peripheral areas of the refuge. Predation of nests appears to have increased following the halting of intensive predator control.

In general, water availability is dictated by snow pack, but some measure of water control is possible with man-made water control structures. If sufficient water is available, the timing and depth of the flooding of meadows and ponds can be regulated. General observations suggest that early spring flooding of meadows attracts more pairs of early nesting species than later flooding. Similar results were reported by Schroeder et al. (1976) in Colorado. Water control can also influence the quantity of nesting habitat and the amount and distribution of brood water. Results from nesting studies at Malheur NWR suggest that water timing, distribution, and depth are important to nesting waterfowl (Clark 1977, Jarvis 1980). These factors need to be examined in more detail so that water management planning can be refined.

Interactions

The factors discussed above interact in complex ways. The number and condition of breeding waterfowl determines the potential for production in a given year. The complex interactions of the breeding birds with each other, with the habitat, with the weather, and with predators determines how much of that potential will be realized. If all of these factors are favorable, a large number of waterfowl can be produced at Malheur NWR. If one or more of the factors are unfavorable, production will be reduced. For example, if adequate water is available, but production of submergent vegetation is poor, diver production may be relatively low. Although cover for upland nesting waterfowl improved after grazing was reduced at Malheur NWR, the increase in waterfowl production was not as pronounced as some observers expected. This may be due, in part, to the simultaneous decrease in predator control.

Two or more unfavorable conditions may combine to compound the problems of breeding waterfowl. Poor cover or poor water conditions may increase the susceptibility of nests and young birds to predation. High water can limit the amount of upland nesting habitat, causing waterfowl to concentrate their nesting in relatively small areas. This may also leave them more vulnerable to predation. These are just a few examples of the almost endless list of interactions that can influence waterfowl production.

Conclusions

The production of waterfowl at Malheur NWR is influenced by a number of interacting factors. Some of these, such as the number of breeding pairs of waterfowl that arrive in the spring, the availability of water, and local weather conditions, are largely uncontrolled. Others, like upland nesting habitat, submergent vegetation, and predation, may be managed to some extent. Increases in grazing between the early 1940s and the early 1970s reduced the quality and quantity of upland nesting cover, but this trend has been reversed. Submergent vegetation production problems in Malheur Lake remain an important influence on diving duck production. The destruction of numerous waterfowl nests by predators continues. Despite these problems, it appears that the long decline in waterfowl production at Malheur NWR has been reversed. With additional research and refined resource management this positive trend should continue. As more waterfowl breeding habitat is lost to urban and agricultural development, production areas, such as Malheur NWR, will be increasingly important.

Acknowledgements

I am grateful to the following people for their critical review of earlier versions of this paper: Dick Bauer, Dan Boone, Larry Ditto, John Doebel, Brad Ehlers, Chuck Henny, Bob Jarvis, C. D. Littlefield, Joe Mazzoni, Dave Paullin, Palmer Sekora, and Steve Thompson. Typing was done by Sheila Settles.

Literature Cited

Clark, J. P. 1977. Effects of experimental management schemes on production and nesting ecology of ducks at Malheur National Wildlife Refuge. M.S. Thesis. Oregon State University, Corvallis. 66 pp.

Cornely, J. E., C. L. Foster, M. A. Stern, and R. S. Johnston. 1981. Additional record of ring-necked duck nesting at Malheur National Wildlife Refuge, Oregon. Murrelet 62:55–56.

Duebbert, H. F. 1969a. High nest density and hatching success of ducks on South Dakota CAP lands. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 34:218–228.

———. 1969b. The ecology of Malheur Lake and management implications. Refuge Leafl. 412. U.S. Fish and Wildlife Service, Washington, D.C. 24 pp.

———, and H. A. Kantrud. 1974. Upland duck nesting related to land use and predator reduction. J. Wildl. Manage. 38:257–265.

Duebbert, H. F., and J. T. Lokemoen. 1976. Duck nesting in fields of undisturbed grass-legume cover. J. Wildl. Manage. 40:39–49.

Furniss, S. B., E. J. O'Neill, and E. McLaury. 1979. Recovery patterns of northeastern California and southeastern Oregon breeding Canada geese populations. Pages 213–222 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Bookstores, Inc., Corvallis. 346 pp.

Gates, J. M. 1962. Breeding biology of the gadwall in northern Utah. Wilson Bull. 74:43–67.

Hubbard, L. L. 1975. Hydrology of Malheur Lake, Harney County, southeastern Oregon. Water Resour. Invest. 21-75. U.S. Geol. Survey, Reston, Va. 40 pp.

Jarvis, R. L. 1980. Nesting ecology of ducks at Malheur National Wildlife Refuge. Final report, contract No. 14-16-0001-77003. 30 pp.

———, and S. B. Furniss. 1978. Distribution and survival of mallards banded at Malheur National Wildlife Refuge. Northwest Sci. 52:292–302.

Jarvis, R. L., and S. W. Harris. 1967. Canada goose nest success and habitat use at Malheur Refuge. Murrelet 48:46–51.

Jarvis, R. L., and S. W. Harris. 1971. Land-use and duck production at Malheur National Wildlife Refuge. J. Wildl. Manage. 35:767–773.

Keith, L. B. 1961. A study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Monogr. 6:1–88.

Kirsch, L. M., H. F. Duebbert, and A. D. Kruse. 1978. Grazing and haying effects on habitats of upland nesting birds. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 43:486–497.

Krohn, W. B., and E. G. Bizeau. 1979. Molt migration of the Rocky Mountain population of the western Canada goose. Pages 130–140 *in* R. L. Jarvis and J. C. Bartonek, eds. Management and biology of Pacific Flyway geese. Oregon State Univ. Bookstores, Inc., Corvallis. 346 pp.

Krapu, G. L., D. R. Parsons, and M. W. Weller. 1970. Waterfowl in relation to land-use and water levels on the Spring Run Area. Iowa St. J. Sci. 44:437–452.

Marshall, D. B., and H. F. Duebbert. 1965. Nesting of the ring-necked duck in Oregon in 1963 and 1964. Murrelet 46:43.

Martz, G. R. 1967. Effects of nesting cover removal on breeding puddle ducks. J. Wildl. Manage. 31:236–247.

Page, R. D., and J. F. Cassel. 1971. Waterfowl nesting on a railroad right-of-way in North Dakota. J. Wildlife. Manage. 35:544–549.

Piper, A. M., T. W. Robinson, and C. F. Park, Jr. 1939. Geology and groundwater resources of Harney Valley, Oregon. Water-Supply Pap. 841L1-189. U.S. Geol. Survey, Reston, Va.

Schroeder, L. D., D. R. Anderson, R. S. Pospahala, G. W. Robinson, and F. A. Glover. 1976. Effects of early water application on waterfowl production. J. Wildl. Manage. 40:227–232.

Sooter, C. A. 1946. Habits of coyotes in destroying nests and eggs of waterfowl. J. Wildl. Manage. 10:33–38.

Alaska: Resource Management Progress and Challenges

Chairman:
RONALD O. SKOOG
Commissioner
Alaska Department of Fish and Game
Juneau
Cochairmen:
E. RICHARD LOGAN
Director, Division of Habitat Protection
Alaska Department of Fish and Game
Juneau
DONALD E. McKNIGHT
Supervisor of Game, Southeast Region
Alaska Department of Fish and Game
Juneau

Renewable Resource Commitments and Conflicts in Southeast Alaska

John W. Matthews and Donald E. McKnight
Alaska Department of Fish and Game, Juneau

Introduction

Historically, wildlife managers have embraced timber harvesting as a panacea for increasing numbers of deer *(Odocoileus sp.)*, ruffed grouse *(Bonasa umbellus)* and other forest dwelling species. Numerous studies had demonstrated a positive response by these species to plant succession induced by logging. As pointed out by Schoen et al. (1981), however, many of these studies were conducted in second-growth forests, which now have been found to be of very low value to many species of wildlife.

As awareness of wildlife has intensified, biologists have studied a broader spectrum of species than just those managed for sport or subsistence hunting. Recently it has become apparent that some species, in some situations, are dependent upon old-growth forest habitats. Forsman et al. (1977) clearly demonstrated the dependence of the northern spotted owl *(Strix occidentalis caurina)* on old-growth forest, and studies by Meslow and Wight (1975) in western Oregon demonstrated the same dependence by a number of passerine species. Luman and Neitro (1980) and Meslow et al. (1981), citing these studies and a number of others, argued that retention of large areas of old-growth timber may be necessary to preserve present populations of these species and others in the Pacific Northwest.

Recent studies of big game in areas still possessing old-growth timber have demonstrated dependence of certain species on old-growth forests—particularly where winter weather favors heavy snow accumulations. Mundinger (1980) reported that white-tailed deer *(Odocoileus virginianus ochrourus)* on at least some high elevation ranges in Montana required old-growth stands for winter habitat. In southeastern Alaska, Wallmo and Schoen (1980) concluded that removal of old-growth forest can be expected to decrease base carrying capacity for Sitka black-tailed deer *(Odocoileus hemionus sitkensis)*. Similar studies of Columbian black-tailed deer *(O. h. columbianus)* on Vancouver Island, British Columbia (Jones 1975, Harestad 1979) showed the importance of old-growth forests as winter deer habitat, even in more southerly maritime situations.

This new evidence necessitates a reappraisal of timber/wildlife relationships as they relate to management of remaining old-growth forests in southeastern Alaska. Schoen et al. (1981) concluded the importance of old growth to many species of wildlife remains largely unstudied and poorly understood. Nevertheless, we presently know that widespread clearcut logging of these old-growth forests can result in reduced deer populations. This knowledge and the recognition that other species as well may be harmed by present timber management practices must weigh heavily on decisions regarding the future management of publicly-owned forest lands.

The 16.9-million-acre (6.8-million-ha) Tongass National Forest encompasses essentially all of southeastern Alaska. Its approximately 9.5 million acres (3.8 million ha) of forested lands contain 5.7 million acres (2.3 million ha) classified as commercial forests by the U.S. Forest Service (R. Philips, U.S. Forest Service, pers. comm.). Harvesting of these old-growth hemlock-spruce stands began in earnest only about two decades ago, before the effects of logging on deer were understood. Although we now recognize conflicts between logging and deer (Wallmo and Schoen 1980), and also mountain goats *(Oreamnos americanus)* (Schoen 1982) and the Vancouver Canada goose *(Branta canadensis fulva)* (Lebeda 1980), much of this timber remains scheduled for harvesting.

In this paper we shall summarize the existing biological knowledge of the relationships between wildlife and old-growth habitats, chart those events leading to existing commitments of and conflicts between renewable resources in southeastern Alaska, and suggest means through which these conflicts may be resolved.

The Ecological Conflict

Like Schoen et al. (1981), we will equate the term "old growth" to the "Shifting-Mosaic Steady State" definition of Bormann and Likens (1979). This definition refers to forest stands that contain trees of all ages representing most species, including early successional species, on a recurring basis. In southeastern Alaska most of the uncut stands are old growth, in which individual trees range in age from 1 to 1,000 years. Death of old trees and replacement by new trees is a continuing process that provides great variability in tree ages, diameters, heights, canopy layers and understory conditions. Stands of this nature are optimal winter habitat for Sitka black-tailed deer (Wallmo and Schoen 1980), and may provide unique habitat for other wildlife species. The multi-layered canopy intercepts large amounts of snow, allowing deer freedom of movement and enhancing food availability. Variable tree spacing and crown structure permit sufficient light penetration to allow an abundant forb/shrub community to develop. This vegetation provides forage necessary for over-winter survival by deer (Wallmo and Schoen 1980).

Prolonged snow accumulations, and the consequent decreased availability of food, are the most important limiting factors for deer throughout most of southeastern Alaska (Wallmo and Schoen 1980). The higher volume, old-growth stands occurring from sea level up to 1,000 feet (0.31 km) elevation, and from the beach inland one-half mile (0.81 km) or more, are key deer wintering areas. These stands often contain wood volumes upwards of 30,000 board feet/acre, and receive the most deer use during periods of snow accumulation (Schoen et al. 1981).

Even-aged silviculture (clearcutting) on a 90 to 125 year rotation is the timber management system presently used on the Tongass Forest (Harris and Farr 1974). Clearcutting leaves a site in a disturbed condition with varying amounts of residue or slash. After about one or two years there is much new plant growth including forbs, ferns, shrubs and conifer seedlings. Conifers usually begin to dominate the site about 10 to 15 years following cutting, and after about 25–30 years most understory shrubs and forbs disappear, reducing species richness and biomass of deer forage (Alaback 1981). In contrast to old-growth forests, even-aged, second-growth forests are comprised of trees of relatively uniform diameter, height, spacing, and canopy coverage. This dense, uniform canopy will intercept snow to some extent, but these areas provide little forage for deer (Alaback 1981).

The exact time required for a stand, once cut, to develop again into a true "old growth" condition is unknown, although some ecologists believe it may take 200 to 300 years (Alaback 1981, Harris and Farr 1974). Regardless, once a stand is placed under standard silvicultural rotation (90 to 125 years) it can never again become old-growth forest. The result of this forest management practice is a permanent conversion of critical deer habitat to a successional stage of inferior value to deer and perhaps other wildlife species. Clearly, under present forest management practices on the Tongass National Forest, critical wintering habitat for Sitka black-tailed deer will decline. That those timber stands which are critical deer winter habitat (low elevation, high volume stands) are also those most attractive for timber production constitutes a major resource use conflict.

If we assume the fate of other wildlife species will be similar to that of Sitka black-tailed deer, this conflict becomes even more significant. Fisheries scientists have already documented adverse impacts of logging on salmonid resources (Gibbons and Salo 1973); these valuable resources as well must be considered in the overall ecological costs of widespread clearcut logging.

The Management Conflict

Small scale logging occurred in Southeast Alaska as early as 1900 and continued up to World War II. During this time individuals or small companies worked the coastline for individual big trees within reach of saltwater. The resulting impact, though selective, was not intensive. During and after World War II, logging began to intensify in response to demands for high quality spruce lumber for aircraft and attempts to stabilize the region's economy (Harris et al. 1974). It was not until the 1950s, however, that logging began as an intensive commercial endeavor on the Tongass National Forest. The U.S. Forest Service, in a further attempt to diversify and stabilize the area's economy, negotiated three 50-year contracts, the first in 1951, guaranteeing timber companies a supply of timber and a profit margin (Harris et al. 1974). It was perhaps fortuitous that this increased interest in the timber resources of southeastern Alaska occurred concurrent with an awakened public awareness of and concern for the environment. During the 1960s and on into the 1970s Congress passed a number of laws designed to protect amenities and commodities other than timber on Federal lands (Hoopes 1982).

The *Southeast Alaska Area Guide* (U.S. Forest Service 1977) was an effort of the U.S. Forest Service to incorporate these and other concerns and mandates into a set of specific guidelines that would be adhered to by all management agencies. The *Guide* states "This Guide carries more than just words; it also carries a commitment to a quality job of resource management. This commitment means that if funding is not adequate to ensure quality control for a targeted output, whether it be timber volume or acres of habitat enchancement, then the output will be reduced rather than risk sacrificing a quality job." It further states "The Forest Service recognizes wildlife resources as a major component of the Tongass National Forest and the source of numerous important products, benefits and services. Wildlife resources are to be considered no more or no less important than the other renewable resources of the National Forest."

The next step in the planning process mandated by Federal Law (Hoopes 1982) was development of the Tongass Land Management Plan (TLMP) in 1979. This Plan allocated Tongass Forest lands to specified levels and types of use. Land Use Designations (LUDs) were used to identify four basic classes of areas with LUD I and LUD II designations used to identify areas for permanent protection from timber harvesting. Within those areas allocated for timber harvest (LUDs III and IV) a percentage of the commercially operable old-growth forest was to be permanently retained for values other than timber (i.e., wildlife habitat, scenery, or recreation). The compromise recommendation by an interdisciplinary team called for 40 percent timber retention on lands designated as having high amenity values as well as high commodity values (LUD III), and 18 percent retention on lands having primarily high commodity values (LUD IV). These retention values were later reduced to 30 and 13 percent, respectively, on LUD III and LUD IV areas.

National Forest Management Act Regulations of 1979 (*Fed. Register,* Vol. 44, No. 181, 17 Sept. 1979) further complicated this matter. Several key points from these regulations (Forest Planning Actions, 36CFR 219.12) reinforce the provisions of the *Southeast Alaska Area Guide* but, because of the basic incompatibility between logging and maintenance of deer habitat, conflict with provisions of the TLMP. For example, the regulations state:

> (g) fish and wildlife habitats will be managed to maintain viable populations of all existing native vertebrate species in the planning area and to maintain and improve habitat of management indicator species. To meet this goal, management planning for fish and wildlife resources will meet the requirements set forth in paragraphs (1) through (7) of this paragraph and be guided by Chapter 2620, Forest Service Manual.

Management indicator species are defined in paragraphs (1) through (7) as:

> Endangered and threatened plant and animal species. . . species with special habitat needs that may be influenced by planned management programs. . . . Population trends of the management indicator species will be monitored and relationships to habitat changes determined.

These statements make it appear that Congress and the Forest Service have, through legislation and policy guidelines, provided for the welfare of wildlife on the Tongass National Forest.

Because of existing conflicts between logging and wildlife, and the heavy commitment of timber in TLMP, the welfare of wildlife is anything but secure. Passage of the Alaska National Interest Lands Conservation Act (ANILCA) in 1980 brought with it a mandated timber harvest of 4.5 billion board feet per decade and the conveyance of land to the State of Alaska and Native corporations, which further reduces the land base for timber production. Additionally, timber harvest from State and Native lands is expected to exceed 250 million board feet annually. This translates to approximately 700 million board feet cut annually from the commercial forest lands of southeast Alaska. The Alaska Department of Fish and Game views this as a major impediment to meeting its mandated responsibilities to manage, protect, maintain, improve, and extend the fish, game and aquatic plant resources of the State in the interest of the economy and general well-being of the State.

At first glance it appears that with over 16 million acres (6.5 million ha) of land there are adequate resources to meet all concerns. However, a closer look at these lands and their values to fish, wildlife, and timber immediately points out why conflicts exist. The TLMP classified 8.1 million acres (3.3 million ha) as LUDs I and II, of which only 22 percent was considered suitable intermediate and critical deer habitat. Approximately 7 million acres (2.8 million ha) were classified as LUDs III and IV, of which 86 percent was classified as important to deer. The ANILCA of 1980 will change this allocation to some extent, shifting those LUD I's that were not established as wilderness areas into LUDs III or IV where logging will occur. State and Native selections will also come out of this base, and much of that will be valuable commercial forest land that is also important wildlife habitat.

The Forest Service has scheduled timber harvest to occur in three entries over the rotation. The first entry typically takes a greater proportion of the best timber in an attempt to offset roading cost. Available harvest records indicate that, until 1980, timber harvest averaged over 50,000 board feet per acre. However, because less than 2 percent of the commercial forest land is classified in this volume class, it is apparent that the Forest already has been highgraded. Congress, through ANILCA 1980, recognized the need to make lower volume timber stands attractive for harvest and thus provided $40 million annually or as much as needed to ensure that the mandated harvest level was attained. Realistically, under the three entry concept, given the required harvest volume, virtually every drainage not classified as wilderness will have to be entered. Biologists are then faced with identifying retention areas that may or may not be permanently retained. Additionally, application of retention values for wildlife and other amenities varies between Ranger Districts, further complicating our efforts to adequately plan for wildlife needs.

Alaska's Governor Hammond recognized this problem and, through a decision memorandum on 16 June 1981, directed the Department of Fish and Game to "Seek agency cooperation and industry support for preserving adequate stands of high-volume, old-growth timber to provide healthy, viable fish and wildlife populations to meet recreational and subsistence use requirements in areas selected for cutting." In a joint meeting, the Alaska Board of Fisheries and the Board of Game passed a series of resolutions (80-80-JB) supporting the Department's contention that old-growth forest habitat must be permanently retained if fish and wildlife populations dependent on old growth are to flourish. The Alaska Chapter of The

Wildlife Society (1980) recognized this issue developing and in 1979 put forth a position paper supporting the concept of old-growth forest as the best habitat for some wildlife. In 1980 The Chapter filed a notice of appeal of the record of decision for the Final Environmental Impact Statement for Alaska Lumber and Pulp's 1981–86 timber operating plan in the Chatham area. After months of delay, the appeal was rejected by the Secretary of Agriculture's office.

This is the essence of the present situation in southeastern Alaska—timber resources that are overcommitted for harvest and wildlife resources that, in part at least, are dependent upon old-growth (unlogged) habitats. As mentioned previously, the Alaska Chapter of the Wildlife Society appealed the Forest Service's 1981—1986 timber sale plan in southeastern Alaska, stating that the Forest Service failed to acknowledge "uneven-aged, old-growth forest is non-renewable and lost as an ecosystem once the forest is harvested under a cutting plan with a 100—125 year rotation cycle." The Alaska Board of Game, Alaska's regulatory board for wildlife, supported the Wildlife Society appeal and strongly recommended that:

1. the 1981—1986 AL&P Timber Operating Plan should not be allowed to proceed until the issues raised in the Alaska Chapter of the Wildlife Society's appeal are answered, and
2. an impartial panel of experts should be convened to evaluate the claims made by both the U.S. Forest Service and the Alaska Chapter of the Wildlife Society.

To date neither the Wildlife Society appeal nor the Game Board's concerns have been adequately resolved.

Resolution of these Conflicts

The timber, wildlife and fisheries of the Tongass National Forest are publicly owned and all product allocations should be made with public awareness of, and concurrence with, the trade-offs involved. Perhaps the greatest criticism of Forest Service policies and plans regarding commitment of timber resources stems from the agency's reluctance to advise the public of resource use conflicts and trade-offs. An example of this may be found in the Wildlife Society's appeal of the 1981–1986 AL&P Timber Sale Operating Plan. This stated:

> The proposed sale also violates various mandates and promises contained in the Southeast Alaska Area Guide. By its own language, the Guide is a promise to the public and represents a document on which the public is encouraged to rely when seeking to find out how the government intends to manage forest resources (*Guide,* p. 18). The express purpose of adoption of the Guide by the U.S. Forest Service is to notify the public of planning and management processes, and inform the public of Service intent as to how the resources of the Tongass National Forest will be used (*Guide,* p. 8). The Guide should be treated as both a contractual promise and as a regulation having the force and effect of law to which the agency must adhere. Perhaps the single most important point on which the Timber Operating Plan abandons and contradicts the Area Guide pertains to wildlife. The Guide promises that "Management decisions concerning fish (and wildlife) habitat will be based on sufficient knowledge, information, and data to provide a sound basis for professional judgement." (*Guide,* p. 80). The Guide further states that information on the effect of clearcutting on Sitka black-tailed deer, mountain goats and brown bear must be obtained or "serious deterioration of wildlife habitat may occur in significant areas of the Forest." (*Guide,* p. 86). Finally, the Guide promises

> that "the primary management goal within and adjacent to wildlife habitat will be to protect and enhance wildlife resources and their habitat." (*Guide*, p. 89).

The Wildlife Society appeal went on to state:

> Congress has spoken to the weight to be accorded wildlife considerations whenever clearcutting is to be employed (See NFMA, Sec. 6). The Area Guide has promised even more diligent attention will be given to wildlife than the NFMA promises. The NFMA and the Southeast Alaska Area Guide provide clear direction and mandate with a greater concern for wildlife than previously required under the Multiple Use Sustained Yield Act of 1960. "Some consideration" is no longer sufficient to comply with the law; if clearcutting is to be the harvest technique, sedulous attention to protecting wildlife is required (NFMA, Sec. 6 [f] [v]).

Other examples of such inconsistencies may be found in the form of timber sale Environmental Assessment Reports such as that for Sumez Island. In this case Forest Service biologists predicted significant impacts to deer populations on the Island, yet in the final Environmental Assessment and Finding of No Significant Impact it was stated that wildlife targeted outputs as identified in RPA 1980 would be met under this proposed action.

During 1981 the Alaska Department of Fish and Game committed itself to a major public relations program to inform the public of the loss of fish and wildlife habitat as a result of extensive clearcutting on the Tongass National Forest. The Department also is continuing its studies on black-tailed deer and mountain goats and their habitat requirements, and in 1981 initiated research on brown bear *(Ursus arctos)* and moose *(Alces alces)* habitat requirements. Deer studies, now in their 6th year, and a portion of the goat research are a cooperative effort of the Department and the U.S. Forest Service, Forest and Range Experiment Station. Meanwhile, the Forest Service (Region 10) is funding graduate research on mink *(Mustella vison)* and river otter *(Lutra canadensis)* through the University of Alaska, and research on Canada geese, black bears *(Ursus americanus)* and passerines through other organizations. This research will yield information on the effects of logging on these species.

Recognizing timber cutting at the levels planned by the Forest Service and mandated by ANILCA poses a serious threat to the maintenance of deer and probably other wildlife populations in southeastern Alaska, the Alaska Department of Fish and Game has developed the Forest Habitat Integrity Plan (FHIP). The FHIP, which the Department feels gives adequate recognition to protection of wildlife and fishery habitats (at least temporarily), has been transmitted to the Forest Service as an alternative to TLMP. This Plan meshed new information about wildlife and fishery use with existing habitat inventories from TLMP, to reallocate lands for timber harvesting based upon fish and wildlife values and the recently recognized conflict between logging and these values.

For the FHIP, wildlife values were based upon the following criteria: (1) biological productivity, which was a measure of species abundance and diversity; (2) human use, past, present and future; (3) forest and land type diversity derived from TLMP data; and (4) percentage of area in high volume, old growth stands (30,000mbf or greater per acre), which, in turn, appears directly related to the amount of critical deer habitat (Wallmo and Schoen 1980). Fishery values were based upon species diversity, species abundance, stream system morphology and system components such as lakes and impoundments. Additional fishery value scores were incorporated to note unique watersheds, those with road access or recreational cabin sites, or those with other special status.

Resulting classifications of fishery and wildlife values were combined on a drainage by drainage basis and used to identify those drainages that (1) now may be cut with minimum damage to fish and wildlife, (2) should never be cut, or (3) must be further assessed before being allocated to the cut or no cut group. Through this approach the Department has identified large units that likely provide optimum habitat for most species, receive intensive human use, and should be protected from additional logging. Conversely, the Department also has identified areas containing commercial timber where logging is expected to have less severe impacts upon fish and wildlife and related use. This Plan, in effect, focuses immediate needs for timber into those areas with least potential for irreparable damage from logging. If adopted by the Forest Service it will provide time necessary for the Department and the Forest Service to conduct research necessary for more knowledgeable allocations in the future. In addition, it allows the Department to focus its assessment activities into areas for which there are presently inadequate data upon which to base decisions. Basic to this concept is recognition that the Department currently has too little information to make informed decisions potentially affecting a number of species. It is believed, however, that by protecting entire drainages habitat requirements for all species will be met.

The Department's FHIP Program recognizes that losses to wildlife will occur as a result of logging and is based on negating these losses in areas providing maximum fish and wildlife recreation, subsistence, and commercial human uses. Adoption of this Plan by the Forest Service will help assure permanent retention of acceptable levels of high quality, readily accessible, heavily used wildlife and fisheries habitat in southeastern Alaska.

To compliment the FHIP, the Alaska Department of Fish and Game is presently developing a program through which wildlife habitat values of each drainage may be assessed more critically. As additional information on wildlife habitat needs becomes available through research, intensive, on-the-ground assessments will be used to identify drainages or enclaves of drainages for permanent retention of old growth or for timber production. The staff of the Chatham Area of the Tongass National Forest has developed a similar and apparently complimentary program for on-the-ground assessments to determine wildlife habitat values (A. Collotzi, USFS, pers. comm.). A team consisting of a wildlife biologist, hydrologist, soil scientist, and plant ecologist, working with aerial photographs, develops a land type map of an area's capability to support wildlife in the drainages scheduled for cutting. Site characteristics, including understory, timber volume, soil types and drainage patterns, are determined in the field.

The Forest Service also has adapted the Fish and Wildlife Habitat Relationships Program (WHR program), developed for the Blue Mountains of Oregon (Thomas 1979), for application to the Tongass National Forest. This program is a system for organization of biological data into a framework that can assist in the prediction of consequences of timber management and aids in the development of alternatives. The major limitation to its application in southeastern Alaska is the paucity of biological information pertaining specifically to this region's ecosystems.

Not until information from ongoing research is available can wildlife scientists and managers predict the impacts logging will have on a species through changes in its habitat. Additional studies are needed, and are planned, to determine if alternate silvicultural techniques will ameliorate the adverse impacts of logging on deer or if, through intensive management, regrowth stands can be modified to increase their presently low carrying capacity for deer and other wildlife. Unfortunately, there is no indication intensive habitat management will significantly enchance carrying capacity to cutover lands for wildlife (Kessler 1981).

Management for timber resources and assuring perpetuation of fish and wildlife resources will require much additional research of fish and wildlife and their habitats. Closely coordinated agency cooperation, based on the best scientific knowledge available, and compromises by both timber and wildlife managers are needed. The public must be kept abreast of new information as it becomes available and must become full partners in the allocation of forest lands for timber production or for wildlife habitat. Because of the incompatibility of clearcut logging and deer, both foresters and wildlife managers must recognize a given timber stand will support either deer or timber harvesting, but that the two are mutually exclusive to a great extent. The only reasonable solution lies with a compromise in which timber values and fish and wildlife values are treated equitably.

Acknowledgements

Many people gave freely of their advice during preparation of this paper. We wish to extend special thanks to the following for constructive review and criticism of the manuscript: G. Cook, N. Johnson, J. Schoen, D. Schmiege, J. Thilenius.

Literature Cited

Alaback, P. B. 1981. Dynamics of understory biomass in Sitka spruce-western hemlock forests of southeast Alaska. Manuscript No. 1514, Forest Research Laboratory, Oregon State Univ. Corvallis, 59 pp.

Alaska Chapter, The Wildlife Society. 1980. Statement of Reasons for Appeal of 1981–1986 Alaska Lumber and Pulp timber sale operating plan. 11 pp.

Bormann, F., and G. Likens. 1979. Pattern and process in a forested ecosystem. Springer-Verlag, New York.

Forsman, E., C. Meslow, and M. Straub. 1977. Spotted owl abundance in young versus old-growth forest, Oregon. Wildl. Soc. Bull. 5(2):43–46.

Gibbons, D. R., and E. O. Salo. 1973. An annotated bibliography of the effects of logging on the fish of the Western United States and Canada. Gen. Tech. Rep. PNW-10. USDA For. Service Portland, Ore, 145 pp.

Harestad, A. S. 1979. Influences of forestry practices on dispersal of black-tailed deer. Ph.D. Thesis. Univ. of British Columbia, Vancouver.

Harris, A. S., and W. A. Farr. 1974. The forest ecosystem of southeast Alaska—forest ecology and timber management. USDA, Forest Service Tech. Rep. PNW-25. Pacific N. W. Forest and Range Exp. Sta., Portland, Ore.

Harris, A. S., O. K. Hutchison, W. R. Meehan, D. N. Swanston, A. E. Helmers, J. C. Hendee, and T. M. Collins. 1974. The forest ecosystem of southeast Alaska. Vol. 1. The setting. General Tech. Rep. PNW-12. USDA Forest Serv. Portland, Ore. 40 pp.

Hoopes, D. T. 1982. Old-growth timber management in southeast Alaska: a question of balance. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 47:588–604.

Jones, G. 1975 Aspects of the winter ecology of black-tailed deer *(Odocoileus hemionus columbianus* Richardson) on northern Vancouver Island. M.S. Thesis. Univ. of British Columbia, Vancouver.

Kessler, W. B. 1981. Wildlife and second-growth forests of southeast Alaska: problems and potential for management. USDA Forest Serv., Alaska Reg. Unpub. Rep. 100 pp.
Lebeda, C. 1980. Nesting and brood rearing ecology of the Vancouver Canada goose on Admiralty Island in southeast Alaska. M.S. Thesis. South Dakota State Univ., Brookings.
Luman, I. D., and W. A. Neitro. 1980. Preservation of mature forest seral stages to provide wildlife habitat diversity. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 45:271–277.
Meslow, E. C., and H. Wight. 1975. Avifauna and succession in the Douglas-fir forests of the Pacific Northwest. Pages 266–271 *in* Proc. Symposium on management of forest and range habitats for nongame birds. General Tech. Rep. WO-1. USDA Forest Service, Washington, D.C. 323 pp.
Meslow, E. C., C. Maser, and J. Verner. 1981. Old-growth forests as wildlife habitat. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:329–335.
Mundinger, J. G. 1980. Population ecology and habitat relationships of white-tailed deer in coniferous forest habitat of northwestern Montana. Pages 8–92. *in* Montana deer studies. Progress Rep. for Fed. Aid Project W-120 R-11. Montana Dep. of Fish and Wildlife and Parks, Helena.
Schoen, J. W. 1982. Winter habitat use by mountain goats. Alaska Final Rep. for Federal Aid Project W-17-11. Alaska Dep. of Fish and Game, Juneau.
——, O. C. Wallmo, and M. D. Kirchhoff. 1981. Wildlife forest relationships: is a reevaluation of old growth necessary? Trans. N. Amer. Wildl. and Natur. Resour. Conf. 46:531–544.
Thomas J. W., tech. ed. 1979. Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington. Agricultural Handbook No. 553. USDA Forest Service, Washington, D.C.
U.S. Forest Service. 1977. Southeast Alaska Area Guide. USDA Forest Service, Alaska Region, Juneau, Alaska 280 pp.
——. 1979. Tongass Land Management Plan. USDA Forest Service, Alaska Region, Juneau, Alaska.
——. 1980. Sumez Island Timber Sale, Final Environmental Assessment. USDA Forest Service, Ketchikan Area, Ketchikan, Alaska 36 pp.
Wallmo, O. C., and J. W. Schoen. 1980. Response of deer to secondary forest succession in southeast Alaska. For Sci. 26(3):448–462

Resource Allocation Challenges on the Tongass National Forest in Southeast Alaska

Robert W. Phillips
U.S. Forest Service
U.S. Department of Agriculture
Alaska Region, Juneau

Introduction

The National Forests in Alaska are confined to the coniferous forest biome, stretching from the southern tip of the Alexander Archipelago along the coast in an arc extending north and west through Prince William Sound to the northeastern part of the Kenai Peninsula. Climate is mild and wet, being largely determined by the relatively warm ocean waters. Within this area, tree growth is usually vigorous in the drained soils at lower elevations. The terrain is interspersed with muskeg resulting from poorly drained soils. As the elevation increases, tree growth is reduced, giving way to low growing shrubs, grasses and forbs above 2,500–3,000 feet (762–914m). Abundant rainfall gives rise to many streams and lakes rich in fisheries, primarily anadromous salmonids. Wildlife species number more than 300, and include deer, moose, mountain goat, Dall sheep, Vancouver Canada goose, river otter, mink, marten, brown bear, black bear, and wolves. The goals and objectives for managing the wildlife and fisheries resources are included within the multiple use requirements of managing the National Forests (USDA Forest Service 1980). The goals were tailored for the National Forests in Alaska as follows:
Goal I. Maintain and enhance when possible the capability of National Forest land and water to produce and sustain the wildlife and fish populations, distribution, composition, and species diversity mutually desired by the Forest Service and the Alaska Department of Fish and Game (ADF&G) in response to public interest and demand.
Goal II. Provide the opportunity for the public to use and enjoy the wildlife and fisheries resources present on the National Forests.
Goal III. Maintain and strengthen communication and coordination with all agencies, organizations and institutions that have responsibilities for management or a strong interest in wildlife and fisheries resources in Alaska.
Goal IV. Develop and implement a Wildlife Habitat Relationships and a Fisheries Habitat Relationships program for the Alaska Region.
Goal V. Encourage wildlife and fisheries research programs that focus on resolving conflicts with other resource management programs and provide opportunity to maintain and/or enhance habitat capability.
Goal VI. Improve the status of threatened and endangered species to a point where they no longer require listing and protection under the Endangered Species Act of 1973 as amended.

We recognize that it may take years to reach some goals, and that others may never be reached. Nonetheless, we believe these are worthwhile beacons to steer toward.

Wildlife and Fish Habitat Management in Alaska National Forests

Virtually every one of the 23 million acres (9.3 million ha) of National Forest in Alaska is habitat for one or more of the 300+ wildlife species. One of the responsibilities is to maintain viable populations of fish and wildlife and plant and animal diversity.

This must be accomplished in the course of managing other resources—timber, minerals, recreation—at levels agreed upon in the planning/allocation process. Considerable effort has been, and is being, put forth to make other resource activities compatible with wildlife and fisheries. We routinely seek Alaska Department of Fish and Game input in such activities as Tongass Land Management Planning (TLMP), Situk Wild and Scenic River Study, timber sale plans, and budget for wildlife and fish habitat improvement. Another major activity in the wildlife and fisheries program is improving habitat productivity, where needed, to support population levels decided upon in the Regional and Forest plans.

In fisheries, the National Forests in Alaska currently yield 134 million pounds (60.8 million kg) annually to the commercial, sport, and subsistence fisheries. Commodity value is $89 million in 1980 dollars. This is net value determined as the price received dockside, minus 30 percent to cover harvest costs to the fishermen. Part of this production, about half a million pounds, (227,000 kg) is the result of some 280 habitat improvements—fishways, etc—developed since 1962, usually in cooperation with the Alaska Department of Fish and Game. A joint planning effort with the Alaska Department of Fish and Game and the aquaculture associations indicates a potential for increasing the annual yield from the National Forests by 30 percent, or another 40 million pounds (18.1 million kg).

Wildlife improvements mainly consist of prescribed burning on the Kenai Peninsula to improve moose habitat by increasing winter browse production. Other improvements include pilot tests of thinning of second growth timber stands in deer winter range to stimulate the growth of forage plants. Several small-scale test burns of wetlands to provide newly sprouted grasses for waterfowl are planned for the coming field season.

Tongass Land Management Plan Decisions

The Alaska National Interest Lands Conservation Act of 1980 (ANILCA) endorsed the resource allocation decisions made in TLMP, which was prepared with input from State and Federal agencies, industry groups, conservation organizations, and private individuals.

TLMP allocated the 16.9 million acres (6.8 million ha) of the Tongass National Forest as follows: Wilderness—5.6 million acres (2.3 million ha); Backcountry—2.7 million acres (1.1 million ha); Multiple Use Areas—7.0 million acres (2.8 million ha); and Unclassified—1.6 million acres (0.6 million ha). Intermediate and key winter habitat for deer in the multiple use areas was estimated at 2.7 million acres (1.1 million ha), which represents 66 percent of all deer winter habitat. Under the allocation made in TLMP, about 40 percent of the intermediate and key winter habitat would be harvested over the 100 year rotation (USDA Forest Service 1979).

Resource Allocation Challenge

The low elevation lands important as deer winter range often are the same acres best suited to growing timber. Climate is more moderate, and soils are deeper and more productive at lower elevations. These conditions enhance tree growth. The stands of larger trees provide greater snow interception than do thinner, smaller stands. Hence, the resource allocation challenge: "How to maintain the current level of habitat productivity and harvest 450 mm bf of timber per year on a sustained yield basis?" A difficult challenge indeed! It appears there will be a reduction in the productivity of the habitat and thus the number of deer available in future years unless:

1. Timber harvest levels are reduced. This would cause a severe blow to local and State economies, a situation opposed by the State of Alaska in the development of TLMP as stated in a letter dated August 4, 1978: ". . . the State cannot and will not support a plan which would result in loss of employment in our timber industry," and later, "The State of Alaska's first goal is that the Tongass Land Management Plan (TLMP) must provide sufficient timber volumes to maintain the present level of employment in our timber industry" (USDA Forest Service 1979).
2. Timber harvest is shifted to areas of low value to wildlife, which are usually the lower volume stands. This is a matter of economics that could greatly increase the cost of harvesting timber and require a sizable government subsidy to make products competitive in the market place. Congress recognized this in ANILCA Section 705 by establishing special funding provisions to maintain the timber supply from the Tongass National Forest at the rate of 4.5 billion board feet per decade. This alternative may place other resources such as soils, water, and recreation in a compromised position by relocating and concentrating the harvest activities.
3. Methods for managing second growth timber for wildlife can be devised and implemented. The possibility is discussed in this paper.

Alternative 1 is contrary to State of Alaska policy and therefore is set aside as being not viable for the time being. Although Alternative 2 holds some promise, the present state of the economy calls for reduced government expenditures. Alternative 3 appears to present the best opportunity for maximizing overall resource productivity from the National Forests.

The characteristics of old growth forest that are valuable for deer are apparently the combination of (1) snow interception by tree crowns, thereby reducing snow depth, and (2) openings in the forest canopy permitting light to reach the ground, thereby providing forage plants (Schoen and Wallmo 1979).

I believe second growth stands of timber can be managed to provide, to a degree, this combination of snow interception and openings for forage plants. The effectiveness of second growth stands in intercepting snow would increase with age, probably up until the age of harvest rotation of 100–125 years. The degree that second growth forests can be made to mimic old growth forests for snow interception and forage production is unknown at this time.

In the early years, say up to age 30, 40, 50, it would appear that the second growth stands would have little capability of providing snow interception and forage. But as the second growth stands age, conditions should become more like those in old growth, so that by age 70 or 80, say, until harvested at 100–125 years of age, snow interception and forage production conditions in second growth might be similar to those in old growth. Based on these assumptions, the predicted reduction in habitat carrying capacity for deer could be mitigated by such management. We are currently thinning 6,000 acres (2,430 ha) each year, one-third of the area logged, to increase tree growth for timber purposes. Through modifications of present management prescriptions, it is possible many of these same areas could be managed as deer winter habitat with only modest cost in terms of timber production. This measure, coupled with the old-growth habitat in wilderness, in backcountry, and in retention acres within multiple use areas, should provide habitat capable of providing populations of deer to meet public demand for hunting—both subsistence and recreational—as well as for viewing and esthetic purposes. Our task is to find the resources necessary to demonstrate the practicality of providing winter habitat in second growth forests in southeast Alaska.

Other measures currently being considered or carried out to address the issue are:

1. Consideration of rescheduling areas to be harvested in the early decades to avoid those with the higher wildlife and fisheries value, thus allowing more time for gathering information. The Alaska Boards of Fisheries and Game in the December 7, 1980 joint resolution #80-80-JB have asked that timber stands of more than 50,000 board feet per acre not be cut and that other volume classes be cut only in proportion to their occurrence. The Alaska Department of Fish and Game has classified areas for wildlife and fisheries value. We in the Forest Service have some flexibility in where, when, and how timber is harvested, but not how much because the harvest level of 4.5 billion board feet per decade was established by TLMP and endorsed by ANILCA. The Alaska Department of Fish and Game and the Forest Service jointly will analyze these possibilities.
2. Develop and apply a demand/supply model for providing productive deer habitat to maintain designated population levels. In 1980, an estimated 5,700 hunters harvested 5,800 deer in southeast Alaska, (Alaska Department of Fish and Game, n.d.) This harvest level is about one-half of the 10,000–12,000 harvested from 1959 to 1968 before severe winters reduced the population (Johnson and Wood 1979).

   Taking into account projected increases in human population growth and demand, the Alaska Department of Fish and Game and the Forest Service should determine the amount of habitat needed to meet public desires at present success rates. Forest Service biologists in Petersburg and Ketchikan have begun to develop such a model and expect to have it completed within the next several months.
3. Continue with the implementation and verification of the Wildlife Habitat Relationships. This process, coupled with an improved resource inventory, will enable us to better predict the consequences of alternative land management proposals on wildlife and fisheries.
4. Continue with the research being done jointly by the Forest Sciences Laboratory, the Alaska Department of Fish and Game, and Alaska Region of the Forest Service on the habitat requirements of wildlife. On-going and planned research includes studies on deer, mountain goat, Vancouver Canada goose, brown bear, black bear, marten, mink, and otter.

These four measures, plus development of methods to manage second growth timber stands for deer winter habitat, will enable us to better display the opportunities and consequences of land management alternatives to the public when TLMP is revised. Perhaps we can harvest timber at current levels and have undiminished populations of deer and other wildlife, or perhaps the information will reveal that tradeoffs must be made that are again unpopular.

Literature Cited

Alaska Department of Fish and Game. n.d. 1981 hunter questionnaire. Alaska Department of Fish and Game, Juneau

Johnson, L., and R. Wood 1979. Deer harvest in southeast Alaska. *In* Sitka black-tailed deer: proceeding of a conference in Juneau, Alaska. Series Report No. R10-48. USDA Forest Service, Alaska Region, Juneau.

Schoen, J. W., and O. C. Wallmo 1979. Timber management and deer in southeast Alaska: current problems and research direction. *In* Sitka black tailed deer: proceeding of a conference in Juneau, Alaska. Series Report No. R10-48. USDA Forest Service, Alaska Region, Juneau.

USDA Forest Service 1979. Tongass Land Management Plan, Final Environmental Impact Statement (Two Parts). Series No. R10-57. Alaska Region, Forest Service, U.S. Department of Agriculture, Juneau, Alaska.

———. 1980. Forest Service policy goals and objectives for wildlife and fish habitat management in the 1980's. USDA Forest Service, Washington, D.C. Unpublished.

Old-Growth Timber and Wildlife Management in Southeast Alaska: A Question of Balance

David T. Hoopes
R. W. Beck and Associates,
Seattle, Washington

Introduction

Successful "multiple-use" management of old-growth timber and wildlife resources on public lands in Southeast Alaska requires both (1) an initial agreement as to the existing situation, its causes and consequences, and (2) a willingness to work together to attain mutually derived and supported management objectives. Can such a seemingly utopian agreement be arrived at to begin with and, once arrived at, will the joint program necessary to attain mutual management objectives be forthcoming, let alone successful? These are important questions because they, in large measure, set the climate in which we must operate as we explore the background leading up to today's management concerns and examine options for establishing the management direction that will at least diminish, if not completely eliminate, future timber/wildlife conflicts.

The practice of fish and game management essentially consists of two basic aspects. The first entails direct population manipulation. Most commonly, manipulation involves reducing numbers to meet commercial or recreational ends. Population manipulation may also include the protection of threatened or endangered species or involve the control of noxious or economically undesirable species. The second aspect involves manipulating the environment in a manner that either enhances or reduces the target species, depending upon the selected management objective. Frequently, the target species is a product of an ecosystem not expressly managed for its benefit. In fact, such ecosystems may be altered substantially by human activities involving other, often unrelated, objectives.

Both of these aspects of wildlife management have relied heavily upon employing population theory to attain management objectives. Selecting desired population levels requires knowing demographic patterns, probable responses to harvest, and a general grasp of the natural regulatory processes controlling the populations in question. Encouraging wildlife populations by environmental manipulation also presupposes knowledge of the ways various environmental factors operate on species of concern.

There are compelling reasons, however, for adopting a more ecosystem-oriented perspective toward managing wildlife species, especially with regard to evaluating a species' dependence upon one or more critical environmental elements. It appears highly likely that most species existing at the periphery of their natural geographic range may react more simplistically to factors in the environment that tend to depress population numbers. Thus, species at the edge of their range are most susceptible to extremes in environmental conditions that result in significant mortality. One cannot always expect that studies of a species thus situated will yield results similar to those of the same species nearer the center of its range.

Historically, studies of deer population dynamics and biology under more moderate climate conditions have indicated that returning vegetative cover to an earlier successional stage by some environmental perturbation, such as fire or lumbering, usually results in an increase in deer numbers, normally attributed to greater food production. Even in regions of relatively severe environmental stress, populations of similar species have burgeoned as a result of increased food, such as moose on Alaska's Kenai Peninsula after the large 1947 burn. Thus, it has been all the more difficult for many people who sincerely believe they have a more than passing acquaintance with the profession of wildlife management to accept the growing body of evidence supporting the concept that leaving old-growth timberland intact rather than cutting it may be necessary to the well-being of certain species, especially Sitka black-tailed deer in Southeast Alaska, when such observations fly in the face of most previous work. Accordingly, acceptance of the vital relationship between deer and old-growth timber in Southeast Alaska has been slow.

The biological basis for concern regarding the role old-growth forest ecosystems play in providing essential habitat for several game and nongame species is growing (Franklin et al. 1981, Wallmo and Schoen 1979, Forsman 1976). Our long-range goal should be to perpetuate the productivity and integrity of the forest ecosystem while still utilizing forest resources (including wildlife) for human use. The research goal should be to understand this system so that we can predict the effects of perturbations and avoid irrevocable changes. An ecosystem approach to wildlife and timber management would endorse a holistic philosophy leading to the management of natural communities rather than individual resources or single species. The desirability of such an approach has been recognized for years, most notably in the Multiple Use-Sustained Yield Act of 1960 (16 U.S.C. 528–531).

Evolution of a Federal Position

Examination of how the concept of multiple use-sustained yield is carried forth on the Tongass National Forest with respect to old-growth timber/deer management begins with an overview of the Federal role in managing public lands. On the surface, the issue seems straightforward enough. Many biologists contend that the old-growth Sitka spruce/western hemlock ecosystem in Southeast Alaska is a nonrenewable resource if cutting continues on the current rotation cycle of 100 to 125 years. The U.S. Forest Service prescribes clearcut silvicultural practices for the Tongass National Forest. The Forest Service has stated that such silvicultural treatment meets all legislative and administrative requirements (U.S. Forest Service 1980b). Furthermore, the Forest Service does not concede that current practices will result in old-growth stands becoming a nonrenewable resource in areas open to clearcut logging. On this point the Forest Service remains somewhat equivocal, but a reasonable interpretation of recent statements leads to the conclusion that the Forest Service does not yet officially adopt the position that cutting trees every 100 to 125 years will effectively prevent the renewal of old-growth stands on cut-over sites. The Forest Service's viewpoint is stated variously as: "The thesis that 'the fact that a climax forest is a non-renewable resource' is still being tested" (U.S. Forest Service 1980a), and, with regard to impacts on wildife:

> We have acknowledged . . . that it is possible that within local areas affected by timber harvesting, some wildlife productivity may be diminished while timber stands mature. Positive steps have been taken to improve understanding of the dimensions of this management concern, so that more positive means may be employed to favor habitat conditions where warranted (Forest Service 1980b).

What then is the Forest Service's position with regard to old-growth timber management in Southeast Alaska, particularly as it pertains to impact on wildlife resources of the Tongass National Forest? To answer this question we must begin by briefly reviewing a selected legislative history at the National level.

The importance of an active management program to conserve wildlife on forest lands has been acknowledged by the Forest Service since the days of Aldo Leopold. Despite such early recognition, wildlife management has not traditionally figured as one of the Forest Service's major concerns. It was not until passage of the Multiple Use-Sustained Yield Act that wildlife management received formal recognition as a valid concern.

"Multiple use" is defined (16 U.S.C. 528–531) as:

> management of all the various renewable surface resources . . . so that they are utilized in the combination that will best meet the needs of the American people; making the most judicious use of the land for some or all of these resources or related services over areas large enough to provide sufficient latitude for periodic adjustments in use to conform to changing needs and conditions; that some land will be used for less than all of the resources; and harmonious and coordinated management of the various resources, each with the other, without impairment of the productivity of the land, with consideration being given to the relative values of the various resources, and not necessarily the combination uses that will give the greatest dollar return or the greatest unit output. . . . Sustained yield . . . means the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the national forest without impairment of the productivity of the land.

Clearly, this Act charges the Federal government with the responsibility to consider the management of wildlife on an equal basis with all other resource values, including timber. Nonetheless, wildlife management has continued to be more of a by-product of other resource management activities rather than a major function. In many instances, the primary role played by Forest Service wildlife managers is that of providing advice and guidance during the development of management actions involving logging, roadbuilding, and other timber-related activities.

The National Environmental Policy Act of 1969 (42 U.S.C. 4321, 4331–4335, 4341–4347) further influenced the direction of forest management in general by requiring: (1) the "full disclosure" of impacts related to major actions affecting the environment, (2) the use of the interdisciplinary approach to resource planning, and (3) laying the groundwork for public involvement in the decision-making process. Any ambiguity in this Act has certainly received clarification through subsequent Council on Environmental Quality (CEQ) regulations implementing the Act and the considerable body of legal opinion stemming from decisions handed down pursuant to its application.

In 1976, the Forest and Rangeland Renewable Resources Planning Act (RPA), 16 U.S.C. 1601–1610, was substantially amended and strengthened by passage of the National Forest Management Act (NFMA) of 1976. This legislation was originally proposed as a direct result of the 1975 Fourth Circuit Court of Appeals affirmation that timber harvesting practices on three timber sales in the Monongahela National Forest constituted a breach of the Organic Act of 1897. Language of the NMFA leaves little doubt as to the intent of Congress with regard to direction given to the Forest Service to adhere to a balanced consideration of all resources during the land management process. The Act recognizes the importance of scientific research and cooperation with State and local governments and places a high priority on public participation during the decision-making process. There are no guarantees, of course, that the Forest Service must respond to comments and advice received as a result of the public involvement process. Of particular interest to Southeast Alaskan resource managers is the requirement made of the Secretary of Agriculture to revise the 50-year timber sale contracts in Alaska to make them consistent with the new guidelines and standards that are being developed pursuant to the Act. Cooperation with State agencies regarding the conservation and rehabilitation of wildlife on National Forest lands is also provided for in the Sikes Act of 1974.

The Alaska Lands Act of 1980 affects Forest Service lands and planning in a variety of ways. Principal among these is direction to the Forest Service to maintain a timber supply level of 4.5 billion board feet per decade on the Tongass National Forest (Sec. 705). The Act also requires periodic reports to Congress on measures instituted by the Forest Service to protect fish and wildlife. The studies required to support these reports are to be conducted in cooperation and consultation with the State, affected Native corporations, the Southeast Alaska timber industry, the Southeast Alaska Conservation Council, and the Alaska Land Use Council.

Additional guidance for managing renewable resources on the Tongass National Forest appears in the *Southeast Alaska Area Guide (Guide),* developed and published by the Alaska Region of the Forest Service in 1977 (U.S. Forest Service 1977). The purpose behind preparing the *Guide* was to notify the public of Forest Service planning and management policies and inform the public of Forest Service intent with regard to resource use on the Tongass National Forest. The *Guide* indicates specifically that the Forest Service will base management decisions concerning wildlife habitat on "sufficient knowledge, information, and data to provide a sound basis for professional judgment" (*Guide,* p. 80). The *Guide* acknowledges that information on the effect of clear-cutting on Sitka black-tailed deer, mountain goats, and brown bear must be obtained or "serious deterioration of wildlife habitat may occur in significant areas of the Forest" (*Guide,* p. 86). Finally, the *Guide* states (p. 89) that the "primary management goal within and adjacent to wildlife habitat will be to protect and enhance wildlife resources and their habitat."

The most recent indication of Forest Service policy toward wildlife management on the Tongass National Forest appears in the Draft Alaska Regional Plan released for public review in August 1981 (U.S. Forest Service 1981a). In the introduction to this plan the Forest Service acknowledges that "good management is founded in a strong forward-looking Forest Service research program." The emphasis in Forest planning will be "on the future and how the Forest can best be used and managed to meet people's needs." A major public issue identified in this draft plan involves the conflict between the harvest of old-growth timber and wildlife habitat (p. 9). The Forest Service has stated that public issues are "the driving force behind the planning process" and, once identified, become management concerns "requiring resolution or that constrain management practices" (Forest Service 1981a). The Area Guide is also cited as forming the foundation for Regional Plan standards and guidelines.

We find, however, (p. 11) that resolution of the conflict between the harvest of old-growth timber and wildlife habitat "is not within the scope of the Regional Plan." The Forest Service is, nonetheless; ". . . fully committed to working with the Alaska Department of Fish and Game (ADF&G) in trying to resolve the issue and will join with the ADF&G in analyzing the consequences of deferring harvest of high volume old-growth timber . . . to allow time for gathering additional information." Furthermore, on page 92 of the Draft Plan, the Forest Service lists a number of goals specific to National Forest resources in the Alaska Region that have been developed to help implement Forest Service policy. These goals include:

1. Maintain and enhance the capability of National Forest lands and water to produce and sustain the wildlife populations, species diversity, and distribution mutually desired by the Forest Service and the ADF&G in response to public demand.
2. Develop and implement a Wildlife Habitat Relationship Program in Alaska.
3. Maintain and improve coordination and communication with all agencies, organizations, and institutions with responsibilities or interest in management of wildlife resources in Alaska.
4. Encourage wildlife research that focuses on resolving conflicts with other resource management programs and provides opportunities to enhance populations and habitat.

Standards and guidelines for implementing Forest Service policy regarding wildlife are listed on pages 120–122 of the Draft Plan, including the following:

1. Give wildlife habitat management needs equal consideration with other resources in all Forest Service programs because the Forest Service recognizes wildlife resources as a major component of the National Forests and the source of numerous important products, benefits and services.
2. Coordinate wildlife habitat surveys, studies, plans and improvement projects with the ADF&G. Use the authorities for cooperative work under the Sikes Act.
3. Establish population objectives for wildlife and identify the amount and quality of habitat needed to sustain the desired population objectives on a joint basis between the ADF&G and the Forest Service.
4. Emphasize management for indigenous wildlife species and natural habitat over other wildlife management approaches, except in cases where the Forest Service and the ADF&G agree upon other alternatives.
5. Provide the habitat management standards necessary to ensure that viable population levels of all wildlife and fish on the Forest are maintained over time despite normal fluctuations in population numbers.
6. Aim habitat management standards for indicator species at supporting populations above the viable population level, as appropriate.
7. Recognize the possibility that alteration of wildlife habitat through a series of projects over an entire range of a species may result in cumulative impacts.

These most recent manifestations of Forest Service policy indicate a clear intent on the part of the Forest Service to work closely with the State of Alaska to solve conflicts arising from the impacts of old-growth timber management on wildlife resources. We need, then, to understand that, while the Forest Service contends it is already fulfilling all legislated and administrative requirements, the door also appears open to further action should the need be demonstrated.

The State's Position

There is little doubt on the part of the State of Alaska that further action is not only warranted but long overdue. The ADF&G has addressed the question of desired levels of wildlife to be maintained on the Tongass National Forest. The ADF&G's goal is to maintain the maximum numbers of wildlife that the existing habitat can support in an ecologically sound manner.

The Alaska Board of Fisheries and the Alaska Board of Game are responsible for regulating the harvest of Alaska's immense fish and wildlife resources. On December 7, 1980, these two Boards unanimously adopted a joint resolution calling for (1) full public disclosure of the known long term and potential impacts of clearcut logging on fish and wildlife habitat and subsequent population levels, (2) more protection for valuable habitat that reflects recent research findings, and (3) a reduction in timber outputs if information is not adequate to ensure the protection of fish and wildlife resources. The Boards also resolved that all future timber sales by State and Forest Service administrators not include timber stands exceeding 50,000 board feet per acre and that other volume classes be cut only in proportion to their occurrence.

This position was further amplified in a decision memorandum from Governor Jay S. Hammond dated June 16, 1981. In his memorandum, Governor Hammond describes the growing problem as one involving the permanent alteration of the natural diversity of plant and animal communities in those old-growth forest stands being logged. If followed, the Governor believes Federal law can provide adequate protection for fish and wildlife on Federal lands. On the other hand, State legislation embodied in the State Forest Practices Act does not address fish and wildlife concerns, thus leaving in doubt just how these resources are to be protected in conjunction with cutting on State and private timber holdings.

The memorandum requests action be initiated in three major areas. First, the memo calls for developing an increased public awareness of the trade-offs involved in timber management by identifying timber harvesting options and their effects on fish and wildlife populations. Second, the memo suggests that existing policy be reviewed and any necessary changes made to minimize impacts on wildlife populations, habitats and user groups. Finally, the memo requests that research programs be provided to assess and mitigate the adverse impacts timber harvesting has on game populations.

Governor Hammond suggests these objectives may be met, in large part, by seeking agency cooperation and industry support for preserving adequate stands of high volume, old-growth timber to provide healthy, viable fish and wildlife populations to meet recreational and subsistence use requirements in areas selected for cutting. He calls for working with the public, the wood products industry and with forest managers to maintain the "natural diversity" of plant and animal communities throughout the forest as much as possible. A series of key steps toward implementing this option is identified in the remainder of the memorandum.

Since this memorandum was prepared and signed, ADF&G has developed what it terms its Forest Habitat Integrity Program (FHIP). This program calls for consolidating habitat to be retained for wildlife into entire drainages having high fish and wildlife values. In this manner, representative habitats for all species occurring in that drainage become permanently preserved. In a special report to the Joint

Boards on December 4, 1981, Region I of the Game Division described the FHIP briefly. Essentially, the program proposes determining the relative value of drainages to fish and wildlife based upon a set of four criteria involving (1) wildlife use, (2) present and future human use, (3) habitat diversity, and (4) the extent of high timber volume, and then ranking them into three broad categories:

1. Those drainages of highest value to fish and/or wildlife, to be designated as permanent retention areas;
2. Drainages of moderate value in which land use decisions will be negotiated on a site-specific basis; and
3. Drainages of lowest value, to be allocated to intensive timber production consistent with the application of basic habitat protection guidelines.

Preliminary calculations, based on current Forest Service timber inventory volumes, indicate the lowest third of the ranked drainages could supply about 7.8 billion board feet of inventory volume, or enough timber to last more than 10 years under current harvest goals. This means that more than one-half of the drainages not currently classified as National Monuments or wilderness lands could remain uncut for nearly 10 years. This concept is similar in nature, though more ambitious in scope, to that proposed by Juday (1978) involving the establishment of old-growth enclaves.

The State proposal essentially takes the Forest Service's land use designation system developed for the Tongass Land Use Management Plan (U.S. Forest Service 1979) and reallocates the units of land termed Value Comparison Units, or VCUs, assigned to each management category or Land Use Designation (LUD) into the three broad categories described above using the four criteria developed to determine the relative value each drainage has for fish and wildlife. Here it might be well to note that the term "LUD" refers to a method of classifying or zoning lands according to a selected combination of various uses and use intensities. Uses or activities are grouped to define, together with a set of coordinating policies, an essentially compatible combination of management activities. For example, logging would not be an accepted activity on all lands (VCUs) assigned the LUD I or II management option, whereas logging would be permitted on lands (VCUs) allocated to LUD III and IV management categories. A Value Comparison Unit (VCU) is a distinct geographic unit that generally encompasses a drainage basin containing one or more large stream systems. Boundaries usually follow easily recognizable watershed divides. These units were established by the Forest Service to provide a common set of areas for which resource inventories could be conducted and resource value interpretations made.

The State's contention is that, while many acres are already removed from the commercial forest base by being placed under either LUD I or II management, much of the most important wildlife habitat falls under LUD III or IV management, where it is subject to logging if not somehow protected even further by some sort of retention system. Consequently, the State program disregards the Forest Service allocation of VCUs to various LUDs because, under the Forest Service plan, only 22 percent of the land designated for LUD I and II management is habitat classified as intermediate or critical deer range, whereas 86 percent of the land placed under the LUD III and IV management designations falls within these habitat categories. Moreover, according to ADF&G biologists, 80 percent of the identified critical deer winter range on the Tongass occurs on VCUs assigned to LUD III and IV management options.

The Industry's Viewpoint

The forest products industry's position on the issue of old-growth timber management in Southeast Alaska has largely been one of adopting a reactive posture toward any threat to continuing a "business as usual" approach. In August of 1976, Senator Walter D. Huddleston chaired a series of hearings in Juneau, Sitka, and Ketchikan before the Subcommittee on Environment, Soil Conservation, and Forestry of the Senate Committee on Agriculture and Forestry. The purpose of these hearings was to collect testimony on National Forest problems in Alaska as a precursor to drafting legislation eventually to surface as the National Forest Management Act of 1976.

Although testimony was presented at these hearings by several representatives of the timber industry, including Donald A. Bell, general manager of the Alaska Loggers Association, Inc. (ALA), several union officials, and both Clarence F. Kramer, Senior Vice President, and James A. Rynearson, Woods Division Manager, of Alaska Lumber and Pulp Company, Inc. (ALP), the old-growth issue was never specifically raised by industry at this time, prior to the 1978 Sitka black-tailed deer conference (Wallmo and Schoen 1979).

A year later, in July 1977, Congressman John F. Seiberling came to Southeast Alaska as chairman of the Alaska Lands and General Oversight Committee of the House Committee on Interior and Insular Affairs. Hearings held at this time focused on settling the long overdue Alaska lands issues, including the proposed designation of, at that time, some 80 million acres (32.4 million ha) as national parks, refuges, wild and scenic rivers, and wilderness areas. It was the term, "wilderness area," that engendered the most concern among members of the wood products industry. They foresaw the inclusion of extensive areas of Southeast Alaska within the National Wilderness System as a major threat to their livelihood. Counter proposals flourished long before the hearings were called to order. In fact, ALP suggested to the State Commissioner of Natural Resources as early as March 23, 1977 that the Forest Service "backcountry" designation would be more appropriate for preserving wildland values in Southeast Alaska than would inclusion of lands in the National Wilderness System. ALP claimed its proposal would end the political polarization arising out of the local reaction toward efforts being made to Congressionally designated wilderness areas in the Tongass. The timber industry's fight to reduce land allocation to the Wilderness System was to continue throughout the acrimonious struggle that finally culminated in passage of the Alaska Lands Act in 1980.

While the wood products industry has historically opposed placing much of Southeast Alaska's timberlands into formal wilderness, some efforts have been made to do more than merely meet proscriptive timber contract and sale requirements related to protecting the environment. One of the foremost of these actions was taken by ALP during May 1977 when this firm contracted a team of consultants to present workshops at their home office in Sitka, at Wrangell, and at eight logging camps under contract to ALP. These workshops included a discussion of the development of the *Guide* and the Forest Service planning process, Forest Service policies affecting logging, with an explanation of their biological basis, and discussions of practical ways of meeting stated policies. Not until the spring of 1979 did the industry's interest begin to zero in on a consideration of the specific impacts to wildlife resulting from removal of old-growth timber. On April 18, 1979, representatives of ALA, ADF&G Game Division, and the Forest Service met to explore ways in which the ALA might become better informed and more involved regarding research on deer and old-growth timber relationships on the Tongass being conducted jointly by biologists from the Forest Service's Forestry Sciences Laboratory in Juneau and the ADF&G. This meeting was followed by an additional meeting on May 22, 1979 and the subsequent presentation of a proposal to the ALA by an independent consultant to conduct an overview study of deer-timber management relationships in Southeast Alaska. This proposal was never acted upon by the Association due, in large part, to a lack of funds. The Association did, however, sponsor two workshops on June 4, 1979 involving issues and concerns related to road building and stream crossings and to log transfer sites.

At about the same time, ALP was completing its alternative proposal for inclusion in the Forest Service's Draft Environmental Impact Statement for the ALP 1981–86 Timber Sale Operating Plan, a 5-year operating plan required as part of ALP's 50-year timber contract. The ALP plan was carefully reviewed by an independent fish and wildlife consultant at ALP's request, and the Woods Division deleted over 10 million board feet of volume in response to the consultant's recommendations regarding fish and wildlife habitat protection. The ALP plan appeared as a separate alternative in the Draft Environmental Statement, but was not considered in any detail in that document. ALP subsequently submitted 47 substantive comments on the Draft Statement, many of which related specifically to fish and wildlife issues. The Final Environmental Impact Statement (U.S. Forest Service 1980a) was filed with the Environmental Protection Agency on April 11, 1980, thereby finally bringing out into the open the long smoldering controversy over old-growth timber management and its far-reaching effects on wildlife populations and habitat in Southeast Alaska.

Before addressing these more recent events and their implications, let us try to summarize the timber industry's position relative to the implications harvesting old-growth timber may have for deer management. Basically, industry has adopted a "wait and see" attitude. Most woods people either do not believe that deer are dependent upon old-growth forest or, if they are, that mitigative measures such as selective thinning will reduce adverse impacts to acceptable levels. The timber industry's reluctance to consider the accumulating biological evidence stems, in large part, from the fear that yet another constraint to timber harvest is being vested upon the industry. Industry is, by and large, more apt to seek a political "solution," such as amending the Alaska Lands Act to make more commercial timberland available for harvest, to its perceived problems than a biological one. The feeling within the industry is that a presently more sympathetic Congress and Administration would look with greater favor upon such proposed changes. In fact, John B. Crowell, Jr., Assistant Secretary of Agriculture, has publicly stated that the Nation has a "heavy excess of old-growth" (*Seattle Post Intelligencer* November 8, 1981). The answer, according to Crowell, is to cut two or three times as many trees out of the National Forests each year as are now being harvested. Such an attitude may encourage the Southeast Alaska wood products industry to continue to "play ball" with the Forest Service and wildlife administrators while hoping to obtain future legislative concessions that would open more land up to harvest.

The Gathering Storm

Confrontations over issues involving old-growth timber management will inevitably lead to management by judicial decree if all interested parties fail to exert the utmost effort toward reaching an equitable accord. The management of valuable natural resources through the courts has usually proven to be both administratively cumbersome and biologically unsatisfactory while, at the same time, often socially and economically unacceptable as well. Perhaps the most recent and well-publicized example of resource management by court edict is that embodied in decisions handed down by the 9th Circuit Court in *United States* v. *Washington,* Phases I and II, in which certain treaty obligations to a number of Pacific Northwest Indian tribes have involved the controversial apportionment of returning Pacific salmon and steelhead trout between treaty Indian tribes and non-Indian fishermen.

Indeed, in Southeast Alaska the legal sparring may have already begun. Strangely enough, the impetus for action has come from a somewhat unusual direction. In May of 1979, the Alaska Chapter of the Wildlife Society distributed a position statement addressing forest practices in Alaska and summarizing the Alaska Chapter's concerns regarding the impacts harvesting old-growth forests were having on wildlife habitat in Southeast Alaska. The statement also offered a number of recommendations, including the suggestion that Forest Service long-term management plans for the Tongass National Forest may be in violation of laws and policies pertaining to fish, wildlife, and their habitats. This position statement was subsequently endorsed by both the Alaska Chapter of the American Institute of Fishery Research Biologists and the Alaska Board of Game.

On April 11, 1980, the Forest Service filed their Final Environmental Impact Statement (FEIS) for ALP's 1981–86 Timber Sale Operating Plan (Plan) for the Chatham and Stikine Areas of the Tongass National Forest. On May 23, 1980, the Alaska Chapter filed a notice of appeal to the record of decision for the FEIS. This notice was followed on June 6, 1980 with reasons for the appeal and relief requested. Simply stated, the Alaska Chapter's reasons were founded upon two basic premises, (1) that the FEIS was inadequate in its treatment of the subject plan's impacts, and (2) that the Plan did not comply with certain legislative and policy directives. The Chapter divided its requested relief into several specific revisions it felt should be incorporated into the FEIS to make it acceptable. These proposed revisions included:

1. Full recognition of the permanent loss of old-growth timber habitat and its diversity and importance to wildlife.
2. Establishment of permanent retention factors based upon the original interdisciplinary team (IDT) recommendations.
3. Adequate evaluation of alternative effects.
4. Bringing the Plan into conformation with the NFMA and the *Guide*.

The Alaska Chapter's appeal was subsequently denied by Chief of the Forest Service, R. Max Peterson, as were a request for oral presentation and a petition for autoptic profference. On November 14, 1980, the Alaska Chapter replied to the Forest Service's Responsive Statement denying the Chapter's appeal. On March 16, 1981, the Alaska Chapter was notified by the Secretary of Agriculture that "recent changes in the appointed officials of the U.S. Department of Agriculture" had delayed the review process.

At that point in time, the Alaska Chapter had three actions before the Secretary of Agriculture that had neither been resolved nor responded to in a substantive manner. They were: (1) The initial appeal, (2) a request to present additional oral and documentary evidence (as per 36 CFR 211.19), and (3) a petition for autoptic profference. On March 18, 1981, the Alaska Chapter requested substantive response from the Secretary, indicating that if such response was not forthcoming, it would seek judicial relief. On May 15, 1981, in a letter signed by Deputy Secretary Richard E. Lyng, the Secretary denied all the Alaska Chapter's requests saying that ". . . the Forest Service has assured that its management policy decisions were informed and that legal requirements for ensuring consideration of environmental concerns in the decision-making process were amply met." Thus, the differences between the Alaska Chapter and the Forest Service appear as yet unresolved.

Pathways to Resolution

Resolution of the conflicts arising between old-growth timber management and wildlife management in Southeast Alaska and elsewhere must begin by all parties concerned agreeing that problems exist. This may seem like a ridiculous statement, but if, as we may conclude from the Forest Service's position on the Alaska Chapter's appeal described above, one party to the controversy adamantly refuses to admit a problem exists, then any further efforts to reach accord would appear doomed to failure.

Thus, the Forest Service and the wood products industry must agree, in principle at least, that old-growth timber is a nonrenewable resource under the present silvicultural practice of clearcutting on a 100- to 125-year rotation. In fact, according to the FEIS for the Tongass Land Management Plan, page 189 (U.S. Forest Service 1979), in LUDs III and IV only 20 percent of the deer range existing today will be left after just 200 years.

The Forest Service and the State of Alaska must come to terms with just what constitutes a "viable" population of a wildlife species as called for in the NFMA. The Forest Service is required to "ensure that fish and wildlife habitats are managed to maintain viable populations of all existing native vertebrate species and to improve habitat of selected species, coordinated with appropriate State fish and wildlife agencies and monitored in cooperation with these agencies, to the extent practicable . . . ," 36 CFR 219.13(b)(8).

The Forest Service defines a viable population as ". . . the number of individuals, adequately distributed throughout their range, sufficient to perpetuate their existence in natural, self-sustaining populations." It would seem desirable to qualify this definition by adding that perpetuation must occur under a natural range of environmental conditions. The goal of the game manager, on the other hand, is to maintain the number of animals that will provide some desired level of harvestable surplus from a population in dynamic equilibrium with the carrying capacity of its range. Thus, if the State assumes a "viable" population requires maintaining existing numbers while the timber industry argues that a reduction in game populations must occur on lands assigned to LUDs III and IV, and the Forest Service still contends that "multiple use-sustained yield" management will permit meeting both timber harvest and game management goals, then a serious difference in interpretation of terms and management philosophy exists.

Beyond the semantics involved, real conflicts in policy implementation may also occur. The Forest Service objective of establishing desired population levels and defining the habitat levels needed to support those populations in concert with ADF&G contains the inherent assumption that the Forest Service and/or ADF&G either "knows," or has the ability to measure, existing wildlife populations in Southeast Alaska. This assumption is invalid. With the notable exception of bald eagles and moose, which are easily censused species, there are few, if any, reliable population estimates for wildlife species in this region of Alaska.

The other major problem with setting desired population levels concerns the need to define and agree upon just what the term "desired" means in a management context. Points that require consideration include:

1. Selected levels will reflect public demand for the resource, but which segment of the public is to be considered? As a national resource, levels should reflect the demands of people nationwide, not just local or regional users.
2. Public demand for wildlife is not static and will quite probably increase in the future. Removal of habitat by clearcutting will, however, permanently reduce the amount of habitat available to support wildlife dependent upon an old-growth ecosystem for survival.
3. Public demand includes both consumptive and nonconsumptive uses of wildlife. While consumptive use can be quantified, how will nonconsumptive uses be evaluated?
4. Wildlife "use" is not readily translated into demand or desired levels. What levels are "desirable" to ensure a reasonable opportunity exists to view or harvest wildlife? To most users, not enough wildlife exists even now.

The ADF&G's policy on "desired" levels is clear: maintenance of the maximum numbers of fish and wildlife that can be supported by the existing habitat in an ecologically sound manner. Whether or not the Forest Service will agree to this goal for National Forest lands remains to be seen. And even should agreement be reached, will the present rate of old-growth timber removal permit such levels to be maintained?

The objective of determining the amount and quality of habitat required to sustain desired levels of fish and wildlife assumes an understanding of wildlife/habitat relationships in Southeast Alaska that is, in reality, still probably a decade or more away. We have a better understanding of deer and their relationship to old-growth forest than for any other species in Southeast Alaska. But what about other wildlife, including bears, goats, moose, wolves, furbearers and nongame species? For these species, little or no information on basic habitat requirements and population levels exists (Longhurst and Robinette (1981).

Political issues and regulatory language remain major impediments to any reduction of differences. Not the least of these is the management dichotomy brought on by the severance of responsibility for habitat and wildlife management between the Federal government and the State. Regardless of the political and historical basis for this separation of responsibilities, the fact remains that management of habitat is basic to the management of any species dependent upon that habitat. In this case, simply stating that Forest Service responsibility extends only to habitat management while the State is responsible only for managing wildlife populations (*Draft Alaska Regional Plan,* pp. 26–27; *Southeast Alaska Area Guide,* p. 90) merely begs the issue, even though the *Guide* states implicitly that "Desirable levels of wildlife will be determined primarily be (sic) the Alaska Department of Fish and Game. . . ."

The argument that the Constitution is silent on the subject of ownership of wildlife and thus its control is within the powers reserved to the States by the Tenth Amendment has been generally upheld in *Geer* v. *Connecticut,* 161 U.S. 519 (1896), until recently. The court decision in *Hughes* v. *Oklahoma,* 99 S Ct. 1727 (1929), overruled *Gerr* v. *Connecticut* and finally established that state wildlife regulation is fully subject to Constitutional constraint. But in this instance, as in *Hunt* v. *United States,* 279 U.S. 96 (1928), the court found Congress was empowered to regulate animals on public lands solely for the "protection of the public lands from damage of some kind." The situation on National Forests is often quite different. In cases involving old-growth timber management, it is the alteration of the environment that affects the well-being of the animals. The courts have yet to look closely at such situations.

If, as we suspect, the availability of critical habitat holds the key to continued species well-being, then inventory becomes absolutely necessary. Several inventory programs and studies either have been accomplished or are underway as part of the Forest Service planning process and the ADF&G's Forest Habitat Integrity Program. The Forest Service's Wildlife Habitat Relationship Program now being initiated on the Tongass depends upon a wide range of biological information that has yet to be obtained in many instances. This program and the ADF&G program may benefit from recent advances in the use of a square grid system for computer estimation of the areal distribution of physical, meteorological, and biological data for entire drainage basins (Solomon et al. 1968, Young 1973, 1976, Tesche and Bergstrom 1978).

Inventory must not be limited to quantification of existing habitat. The volume of commercial timber available for harvest must also be more carefully ascertained. Regardless of statements to the effect that "The timber supply from Tongass National Forest lands is mandated by the Alaska Lands Act" (*Draft Alaska Regional Plan,* p. 12), the question of how much timber production can be sustained from National Forest lands is not answered by a policy decision, it is determined by the capability of the environment to produce wood fiber. An accurate measure of the existing resource is essential to future planning. Currently, there exists no up-to-date information on the areal extent of logging that has already taken place in Southeast Alaska. An independent audit or, at a minimum, an inventory methodology agreed upon by all involved parties should be used to complete such an analysis. Until resource limits have been more accurately defined, all planning remains simply an exercise in futility.

During the inventory period, additional research must be initiated and ongoing research programs strengthened. The recent Oregon Wilderness Coalition appeal to the Chief of the Forest Service involving the northern spotted owl resulted in a requirement that Region 6 provide an "evaluation of needed research" in its Regional Plan. The Regional Forester, R. E. Worthington, in a memorandum to the Chief dated April 1, 1981 (Forest Service 1981b), strongly urged that Forest

Service research efforts be intensified on old-growth as wildlife habitat. Region 6 noted in their research needs assessment that, while the issue of the spotted owl and maintenance of old-growth is the present focus of attention, it is only a symptom of a much larger and more complex issue: "That is the question of old growth as a special or unique habitat for certain species of wildlife" (p. 113). The Draft Alaska Regional Plan also commits the Forest Service to "a strong forward-looking Forest Service research program" (p. 1).

During the inventory and research period, what interim measures can be employed to ensure that statutory and contractual commitments are met without permanently jeopardizing wildlife resources? Without doubt, some modification of the ADF&G Forest Habitat Integrity Program will be necessary to buy the time required to develop a final solution to problems involving permanent conversion of the old-growth ecosystem to one of perpetual secondary succession. Interestingly enough, it was a Forest Service scientist who suggested a similar solution as a necessary element of multiple use and sustained yield in National Forest management. Juday's (1978) suggestion of establishing a network of old-growth enclaves was developed in response to these and other considerations arising as a result of Juday's research. It is also worthy of note that the uses and benefits of old-growth identified by Juday: wood production, water, wildlife, fish, big game range, and recreation are all multiple uses listed in the Multiple Use-Sustained Yield Act. In fact, some of these uses can only be provided by old-growth forests (e.g., specialized research benefitting wood production, greatest aquatic productivity, particular wildlife requirements, and certain forms of recreation). Additional research has identified certain ecological characteristics of old-growth forests that have important implications to fishery, as well as wildlife, managers (Franklin et al. 1981).

Two fundamental criteria must be employed in selecting all old-growth enclaves, key wildlife watersheds, or habitats selected for wildlife retention. Each selected area must represent a landscape unit that will continue to provide old-growth benefits even after all the surrounding land has undergone complete alteration. In such cases, the protectability of the parcel is vital. All regional and forest plans should include an element addressing the management of old-growth timber similar to that in the Draft Pacific Northwest Region Plan (pp. 61–63). The Draft Alaska Regional Plan does not address this issue.

In a May 18, 1981 letter to ADF&G Commissioner Dr. Ronald Skoog, Regional Forester John Sandor included figures for commercial forest land (CFL) in LUDs III and IV showing that only 2.2 million acres (0.9 million ha) are used to calculate timber yields in the Tongass Land Management Plan. From this figure, Sandor states that 273,000 acres (110.565 ha) (including 10,300 acres [4,170 ha] of high volume old-growth forest) has been retained to protect other resources, including fish and wildlife. These data indicate that the proportion of old-growth considered for retention amounts to 12.4 percent of the operable CFL, of which only 1.3 percent runs 50,000 board feet or more to the acre. These values are even lower than those retention figures set forth in the TLMP FEIS (p. 37) of 30 percent of the operable CFL in LUD III and 13 percent of the operable CFL in LUD IV, values "arbitrarily" reduced from interdisciplinary team recommendations of 40 and 18 percent, respectively. Clearly, the problem of retention still remains to be resolved. Indications are that it may prove difficult to meet future harvest commitments while at the same time continuing to maintain acceptable quantities of suitable old-growth wildlife habitat.

Necessary Considerations

Developing a management plan that equitably balances the consumptive removal of old-growth timber with nonconsumptive uses that require its retention remains a still distant goal. Reaching this goal will require honesty, diligence, and a dedication toward the highest degree of professionalism. No simple formula exists and certain caveats warrant consideration along the way:

1. The suggested alternative of seeking Congressional action to release some areas now under Federal wilderness classification as a result of passing the Alaska Lands Act would only delay the inevitable confrontation. First, unless very strong release language is obtained, forest managers can rest assured unpopular decisions will be met with an endless array of appeals, costly litigation, and political action. While such a course of action may seem an expedient way of reaching a short-term goal, it offers no lasting solution to the continuing conflict between wildlife managers and foresters. Too many other applicable laws governing management decisions involving fish and wildlife resources are on the books to attempt to alter each one to favor some perceived advantage to the wood products industry.
2. A balanced management program may require a reduction in the amount of timber to be removed from the National Forests. As distasteful as it may sound, contracts may have to be renegotiated and "mandates" revised. Events of the past few years have clearly shown that even our most venerable laws are not sacrosanct. Witness, for example, the relative ease with which the Organic Act was "widened" to accommodate a right-of-way large enough to allow construction of the TAPS pipeline, or the changes wrought by the Monongahela decision.
3. The ADF&G must face the fact that much of the high-volume old-growth timber transferred to the State under the Statehood Act and to Native corporations under the Alaska Native Claims Settlement Act (ANCSA) will be permanently lost as wildlife habitat. Safeguards might be obtained by amending the State Forest Practices Act, but success is doubtful since strong opposition to stricter provisions will undoubtedly arise from within the private sector. The loss of habitat on private lands, coupled with potentially even greater reductions on National Forest lands as well, may force the State to accept wildlife population levels in areas open to logging lower than those they would normally wish to achieve.
4. Without continued and persistent dedication, both Federal and State administrators will not aggressively pursue a course of action to resolve problems of mutual concern. A possible guarantee that all parties involved will maintain the necessary impetus might be to establish a third, or disinterested, party as a facilitator or mediator to be responsible for supporting the decision-making and negotiation processes. Through the voluntary process of mediation, all parties might jointly explore and reconcile differences to arrive at a mutually acceptable solution. Mediation would reduce the possibility of establishing an adversary setting where positions become polarized and vision narrows. If successful, mediation could also eliminate the need for following costly and time consuming prescribed legal and regulatory procedures for resolving disagreements.

Until we have obtained the information necessary to define and evaluate specific habitat types and desired population levels on a regional or National Forest basis, our goal as resource managers should be to maintain as many naturally occurring habitats (especially climax communities) as possible. Retention of key habitat now will allow future generations to exercise options at least similar to those we have today. If we must err in attempting to balance our management goals of harvesting old-growth timber and maintaining desirable numbers of wildlife, then let our decisions favor conservation. For, if we do, the mistakes we make today will be so much easier to rectify in the years to come.

Acknowledgements

Dr. Donald C. Schmiege, Forestry Sciences Laboratory, Juneau; Dr. R. A. Taber, Institute of Forest Resources, University of Washington, Seattle; Dr. Olof C. Wallmo, Bozeman, Montana; Dr. Donald E. McKnight, Regional Supervisor, Game Division, Alaska Department of Fish and Game, Juneau; and A. R. Griffith, R. W. Beck and Associates, Seattle, provided many helpful comments during the preparation of this manuscript.

References Cited

Forsman, E. 1976. A preliminary investigation of the spotted owl in Oregon. Masters thesis. Oregon State University, Corvallis. 124 pp.

Franklin, J. F., K. Cromack, Jr., W. Denison, A. McKee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. USDA Forest Service General Technical Report PNW-118. Pacific Northwest Forest and Range Experiment Station, Portland, Ore. 48 pp.

Juday, G. P. 1978. Old growth forests: a necessary element of multiple use and sustained yield national forest management. Environ. Law 8:497–522.

Longhurst, W. M., and W. L. Robinette. 1981. Effects of clearcutting and timber management on Sitka black-tailed deer: a report to the Forest Service. Administrative Document Number 103. USDA Forest Service, Alaska Region, Juneau. 36 pp.

Solomon, S. I., J. P. Denouvilliez, E. J. Chart, J. A. Wooley, and C. Cadou. 1968. The use of a square grid system for computer estimation of precipitation, temperature, and runoff. Water Resour. Res. 4(5):919–929.

Tesche, T. W., and R. W. Bergstrom. 1978. Use of digital terrain data in meteorological and air quality modeling. Photogrammetric Engineering and Remote Sensing 44(12):1549–1559.

U.S. Forest Service. 1977. Southeast Alaska Area Guide. USDA Forest Service, Alaska Region, Juneau. 280 pp.

———. 1979. Tongass Land Management Plan: Final Environmental Impact Statement, Part 1. USDA Forest Service, Alaska Region, Juneau. 313 pp. + appendices.

———. 1980a. The ALP 1981–86 Timber Sale Operating Plan, Final Environmental Impact Statement for the Chatham and Stikine areas. Report No. 100. USDA Forest Service, Alaska Region, Juneau. 311 pp.

———. 1980b. Responsive statement to statements of reason in support of appeal from approval of Alaska Lumber and Pulp Company's 1981–86 timber sale operating plan. USDA Forest Service, Washington, D.C. 12 pp.

———. 1981a. Draft Alaska regional plan. Report No. 147. USDA Forest Service, Alaska Region, Juneau. 154 pp. + appendices.

———. 1981b. Draft Pacific Northwest region plan. USDA Forest Service, Pacific Northwest Region, Portland, Ore. 141 pp.

Wallmo, O. C., and J. W. Schoen, eds. 1979. Sitka black-tailed deer: proceedings of a conference in Juneau, Alaska. USDA Forest Service, Alaska Region, in cooperation with the State of Alaska, Department of Fish and Game, Juneau, Alaska. 231 pp.

Young, G. J. 1973. A computer program to describe terrain characteristics of a drainage basin. Scientific Series No. 76. Inland Waters Directorate, Water Resources Branch, Ottawa, Canada. 15 pp.

———. 1976. An approach to glacier mass-balance analysis utilizing terrain characteristics. Scientific Series No. 60. Inland Waters Directorate, Water Resources Branch, Ottawa, Canada. 34 pp.

Effects of Increased Human Populations on Wildlife Resources of the Kenai Peninsula, Alaska

Edward E. Bangs
U.S. Fish and Wildlife Service, Soldotna, Alaska

Ted H. Spraker
Alaska Department of Fish and Game, Soldotna

Theodore N. Bailey
U.S. Fish and Wildlife Service, Soldotna, Alaska

Vernon D. Berns
U.S. Fish and Wildlife Service, Soldotna, Alaska

Introduction

"When in the Kenai Mountains, Alaska, on the 23rd day of August 1897, Mr. Berg and myself while sitting together on the mountain side with the aid of a field glass counted 500 wild sheep, *Ovis dalli,* all within a radius of 6 to 8 miles, 10 here, 6 there, then 20 and 30 in another locality. Can a true hunter or a lover of nature imagine a more beautiful sight?"

This quote is from a letter written by Dall DeWeese in 1902, urging Congress to protect wildlife on the Kenai Peninsula. Thirty years later, reports still requested the protection of wildlife resources on the Kenai Peninsula, but the tone had changed. Quotes from various reports include: "Season should be completely closed on the Kenai Peninsula for mink, foxes, land otters, and beaver, and the closed season enforced for a period of five years. . . ." (Culver 1923); "death blow to furbearers took place some years ago when fur farming was at a boom. Even porcupines were largely killed out. . . . the last caribou was reported seen in 1912. . . . Wolves were destroyed by poison" (Palmer 1938). Statements like these come to mind when discussing human impacts on wildlife especially when a frontier is first explored and developed. During the development of every frontier, the history of wildlife exploitation seems to repeat itself. This portrayed image of human devastation of the environment is often a result of our perception of which species are important, the limited available data base, and the consequences of measuring ecological relationships in terms of a single human life span.

In this paper, we will discuss what has occurred to several wildlife populations on the Kenai Peninsula as the human population increased. By discussing historical impacts, management techniques, and potential human impacts, we intend to show the significance of what occurred and may occur as human populations expand, both on the Kenai and in Alaska.

Study Site

The Kenai Peninsula (Lat. 60° North, Long. 150° West), 10,038 square miles (26,000 km^2) in area, is located in southcentral Alaska, 31 miles (40 km) due south of the city of Anchorage. Connected to the mainland by a 10-mile (16 km) isthmus of rugged mountains and glaciers, the Peninsula is insular. It is bounded by Cook Inlet to the west and north, and Prince William Sound to the south and east.

The rugged Kenai Mountains form the eastern two-thirds of the Peninsula. The southwest-trending peaks reach elevations of 3,000–6,000 feet (1,000–2,000 m) and are separated by valleys and passes 0.625–1.3 miles (1–2 km) wide. The entire mountain range has been heavily glaciated and higher parts of the range are buried in great ice fields from which valley and piedmont glaciers radiate.

The Kenai lowlands form the western third of the Peninsula. This area consists of ground moraine and stagnant ice topography with low ridges, rolling hills, and extensive areas of muskeg. Relief ranges from 60–240 feet (20–80 m) with most of the land less than 600 feet (200 m) above sea level. There are over 4,000 lakes and numerous interconnecting waterways. The two largest lakes, Tustumena, 116 square miles (30,000 ha), and Skilak, 38.6 square miles (10,000 ha), lie in ice-carved basins.

The climate of the Kenai Peninsula is a subarctic mixture of maritime and continental weather patterns. Annual precipitation averages 18.7 inches (48 cm), nearly half of which falls as rain in July, August, and September. Average annual snowfall varies from 54.6–138.4 inches (140–355 cm) at low elevations depending upon location. Snow generally covers the lower elevations from late October to late April, while in the high mountains, snowfall can be expected from September through May and snow-ice cover is, in many areas, permanent. Maximum snow accumulation at lower elevations is usually not over 39 inches (1 m).

The Kenai Peninsula encompasses examples of most other regions of Alaska in terms of vegetation and wildlife. The vegetation types range from coastal to alpine, but the two dominant types are birch-spruce lowland forest (Hudsonian life zone) and Arctic and Alpine life zone. Every native big game and furbearer species found in Alaska except muskox *(Ovibos moschatus),* polar bear *(Ursus mairitimus),* and arctic fox *(Alopex lagopus)* are found on the Kenai Peninsula. There are over 146 species of birds occurring in the area, of which 101 nest locally. Fishery resources include five species of pacific salmon (*Oncorhynchus* spp.), lake trout *(Salvelinus namaycush),* rainbow trout *(Salmo gairdneri),* grayling *(Thymallus arcticus),* Dolly varden *(Salvelinus malma),* and whitefish *(Coregonus clupeaformis).*

Land ownership patterns on the Kenai Peninsula are complex but the majority of the area is under Federal ownership (Figure 1). The breakdown is as follows: Kenai National Wildlife Refuge (USFWS), 3,078 square miles (7,972 km^2); Kenai Fjords National Park (NPS), 1,030 square miles (2,268 km^2); and Chugach National Forest (USFS), 1,679 square miles (4,350 km^2). The remaining lands, 4,019 square miles (10,410 km^2), are divided between State and local government and private ownership. Native corporations are the largest single private landowner.

The recorded history of the Kenai Peninsula began when Vitus Bering sighted it in 1741. The Kenai Peninsula was where much of the initial development on the Alaskan mainland occurred. The first Russian settlement on the Alaskan mainland was on the southern tip of the Kenai Peninsula, and the first gold located in Alaska was found on the Kenai by Russian miners about 1851. In 1882, salmon canneries were built in the Kenai area. Human population levels soared shortly after 1895 when commercial quantities of gold were discovered and hundreds of miners came to the Peninsula. The vast game herds were slaughtered by market hunters during

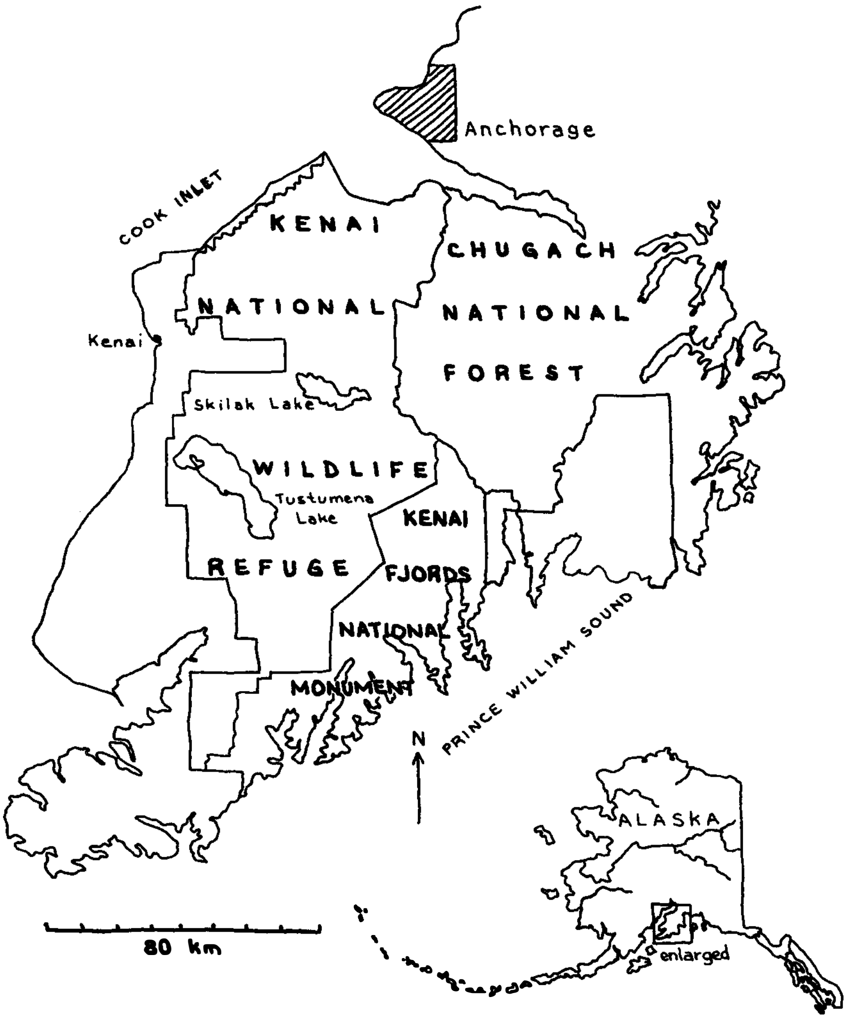


Figure 1. Federal land management patterns on the Kenai Peninsula, Alaska. Areas not labeled are State, borough, and private lands.

this period to provide meat for miners and railroad workers. The gold rush abated about 1905 and the population remained stabilized until the late 1940s, when the Peninsula was opened to homesteading.

The Kenai Peninsula now has approximately 25,000 residents, most of whom live in or near major towns on the western lowlands. Most communities were small and fishing-oriented until oil and gas were discovered in the late 1950s. The population has tripled since 1960. At current growth rates, the population will double by 1995 or sooner, depending on the rate of oil development. The Kenai Peninsula is within 62 miles (100 km) of over one-half of Alaska's total population, is easily accessible by road, and provides the major outdoor recreation area for Alaskan residents and tourists. The Kenai Peninsula receives over 35 percent of the total sport fishing effort in Alaska (Mills 1980). Use of the Kenai as an outdoor recreation area will undoubtedly increase.

Methods

Although the Kenai Peninsula probably has one of the most extensive wildlife information bases in Alaska, data are restricted to mainly game species. Much of the historical information discussed in this paper is taken from early reports by biological survey biologists and are generally limited to observations and general impressions. The first detailed surveys (on a few selected species) began in the late 1950s. Survey, harvest monitoring, and research efforts have steadily increased since that time. Because most of the information was gathered on the western Kenai mountains and lowlands, the Kenai National Wildlife Refuge (formerly the Kenai National Moose Range 1941–1981) will be the focus of discussion. Information is limited to big game species, species of commercial interests, and species once threatened in a portion of their range. Public interests, funding, and personnel levels have determined the level of wildlife monitoring that has occurred on the Kenai Peninsula. Recently, the information base has been expanded by monitoring passerine birds, raptors, and small mammals, with more extensive research conducted on bears and various furbearers, but most of this new information is too recent to be useful in discussing long-term human impacts on wildlife.

Results and Discussion

The history of the Kenai Peninsula appears typical of most frontiers; rapid exploitation resulting in a "boom and bust" economy and sudden changes in the plant and animal communities. Whether these impacts are good or bad is a moral judgment dictated by society's values at the time and subject to change as personal values and commonly held opinions shift.

The perceived impacts to wildlife of the Kenai Peninsula as the human population expanded are undoubtedly biased. Analysis of historical changes relies heavily upon limited data, often gathered in an unobjective manner, on a few species, by a few men who came upon the scene after tremendous impacts had already occurred. With this in mind, we used the best information available to illustrate the wildlife resource problems and solutions that occurred on the Kenai Peninsula as human populations increased.

Caribou *(Rangifer tarandus)*, moose *(Alces alces)*, wolf *(Canis lupus)*, and salmon are examined to assess the impact of consumptive use and habitat disturbance on wildlife. The status of bald eagles *(Haliaeetus leucocephalus)* and trumpeter swans *(Cygnus buccinator)* on the Kenai illustrates how habitat changes and disturbance affect some species.

By examining impacts that have occurred among these species, we demonstrate the limited impact of overharvest, the longer term impacts of habitat changes, and the impacts that can be expected as the human population increases throughout Alaska.

Caribou

Historical records indicate that caribou were once common, but probably not abundant, on the Kenai Peninsula before the 1900s. With an influx of gold miners about 1890, large man-caused forest fires converted vast tracts of mature forest into early successional stages. With much of the important climax vegetation gone, caribou numbers were reduced and the remaining pockets of animals were eliminated by commercial and unregulated hunting (Davis and Franzman 1978). The last recorded sighting of a caribou on the Kenai was in 1912 (Lutz 1956).

Forty-four caribou were reintroduced to the Kenai Peninsula in 1965 and 1966 by the Alaska Department of Fish and Game (ADF&G). These transplants resulted in the establishment of two herds. A herd of approximately 300 animals now inhabits a limited alpine area of public land in the Kenai Mountains near Hope. This herd exhibited excellent production and recruitment initially, but productivity declined sharply during the mid-70s as the herd reached carrying capacity. Sport hunting of these caribou was initiated in 1972 to maintain the herd within the estimated carrying capacity of the area.

The second herd became established in a sedge-grass wetland that surrounds the Kenai airport and is often seen within the Kenai city limits. This herd travels about 25 miles (40 km) east to winter in a large muskeg area. There are between 60 and 80 animals in the lowland herd and it has not increased since 1975. Available data indicate that low recruitment is the most likely cause of the herd's poor growth rate. Predation is suspected when poor recruitment is noticed, especially when initial calf production appears normal. Although black bear *(Ursus americanus)* and wolves are common in this area, results of recent studies (Schwartz and Franzman 1980, Peterson and Woolington 1981) indicate neither is responsible for the majority of calf mortality. A likely cause of calf mortality among caribou is the large number of domestic dogs that roam the area. Dogs have been observed killing both adults and calves and are probably responsible for the low recruitment in this herd.

Kenai Peninsula caribou populations, which were apparently dependent on old age forest, were unable to recover from earlier overharvest and habitat alteration. Although introductions have resulted in two viable herds, both occupy relatively small areas atypical of caribou habitat in other portions of Alaska. The lowland herd, which is exposed to continued human disturbance, has not done as well as the more remote alpine herd. While the problem of past overharvest was corrected, the slow successional rate of boreal forest ecosystems and non-consumptive human activity continue to affect caribou distribution. Caribou are examples of species that use sensitive habitats and are affected by habitat disturbance for several decades.

Moose

"Kenai Peninsula is said to be the best hunting ground for moose in the world." This quote by Milton Whitney in 1916, conveys a different image of the Kenai than the one portrayed by Andrew Berg in 1890. Mr. Berg, a hunting guide in the Tustumena Lake area, stated that, before 1890, "Caribou were plentiful and wolves numerous, there were practically no moose." The difference in moose numbers witnessed by these two men and others (Lutz 1960) was a result of the numerous wildfires around 1900. While wildfires were detrimental to caribou, moose flourished. The moose population, free of wolf predation, virtually unhunted, and having an abundant food supply, increased steadily. By 1920 the Kenai was famous for both the numbers and size of its moose.

The population was reduced in the mid-1920s due to severe overuse of the winter range and harsh winter weather. Moose hunting north of the Kenai River was legally closed in the 1930s, but moose continued to decline. In 1941, primarily due to sportsman and public concern for the declining moose population, the Kenai National Moose Range, now the Kenai National Wildlife Refuge, was established. In 1947 a man-caused fire burned 308,750 acres (125,000 ha) in the northwest portion of the Peninsula and the moose population began to increase. By the early 1950s a limited moose hunt was allowed. The moose population increased steadily throughout the 1950s and 1960s, and by 1970 the population was estimated at nearly 9,000 moose on the refuge. Range quality deteriorated as vegetation in the burn matured. The moose population severely overbrowsed its range (Oldemyer et al. 1977) and, during a series of severe winter weather from 1971 through 1975, declined to approximately 3,500 moose (Bangs and Bailey 1980). Another large wildfire in 1969 (86,450 acres [35,000 ha] has resulted in a current moose population increase. This pattern of growth and decline of moose populations resulted from man's activities and the early successional stages that were created as wildfires and land clearing practices occurred.

The negative impacts of increased human development primarily result from increased incidental mortality. Poaching was a potential problem until effective enforcement and costly penalties controlled it. From 1970 through 1980, approximately 150 moose were reported accidentally killed annually along the road system. This type of mortality will increase as road improvements increase vehicle speed and as the number of vehicles increase. Domestic dogs are reported to kill moose calves near towns each year, but actual numbers are unknown. Sport hunters harvested over 600 bull moose in 1981 during the 20 day season. Despite these mortality factors, moose populations on the Kenai are at moderately high levels and habitat conditions suggest a stable population for the next few years.

A problem in the long term management of moose on the Kenai is that of plant succession. The 1947 fire burned for over a month without attempts to control it. In contrast, the 1969 fire burned for several weeks during which over $20 million were spent for control, and it still burned into the Kenai city limits. Increased development on private land surrounding public land has limited the practice of allowing wildfires to burn. The potential damage to personal property and cost of control efforts has made land management agencies aggressively control all wildfires. Small controlled burns have been successfully conducted on public lands in areas away from settlements and hold some promise as a means of habitat manipulation in remote areas. Mechanical and chemical habitat treatment was conducted on the Kenai National Wildlife Refuge for about 15 years, but increasing costs, changing funding priorities, and other concerns suspended these operations. Habitat disturbance on private land will provide some early successional vegetational stages that benefit moose. Management for moose and other early successional species on government lands will be affected by the high level of fire control needed to protect private property and the relatively high costs of other forms of habitat manipulation.

Moose continue to be the dominant ungulate species on the Kenai, both in terms of numbers and public interest. Although moose populations have been at low densities and experienced the same overharvest problems of other ungulates, they have always recovered rapidly when good habitat was available. Moose have been extremely successful on the Kenai because they are a generalist species that readily adapted to the Peninsula's rapidly growing human disturbance and associated habitat changes.

Timber Wolf

Wolves were reportedly common on the Kenai Peninsula before 1900, but early miners, fearing rabies, immediately set out to eradicate them. The widespread use of poison, along with unregulated hunting and trapping, apparently caused the extirpation of the Kenai wolf by 1915 (Peterson and Woolington 1979). Recolonization by wolves was hampered by the relative isolation of the Peninsula and widespread predator control during the 1940s and 1950s. With the reduction of control efforts in the late 1950s, wolf populations adjacent to the Peninsula increased. In 1962, there was a confirmed wolf sighting and all wolf hunting and trapping was closed on the Kenai Peninsula.

Large packs were sighted in several locations on the Kenai Peninsula by the late 1960s. The wolf population expanded rapidly in the early 1970s, and by 1975 had probably occupied most of the available wolf habitat on the Kenai Peninsula (Peterson and Woolington 1981). Wolf hunting and trapping were opened in 1974 and have remained open since that time. Current harvests are closely monitored by ADF&G and appear to be about 25 percent of the early winter population annually; close to the maximum allowable harvest recommended by Peterson et al. (1981). Man's activities also impact wolves by causing indirect mortality. At least one wolf pack, close to the city of Kenai, was believed to have been reduced by contacting canid distemper from domestic dogs.

Canid abundance on the Kenai appears to have shifted considerably since the 1900s. At the time of initial human development, fox *(Vulpes fulva)* and wolves appeared common, but after 1915 both became rare and coyotes *(Canis latrans)* colonized the Peninsula (Palmer 1938). Wolves and coyotes are now common on the Kenai, but foxes remain rare. Apparently the habitat changes and elimination of wolves during the 1900s benefitted coyotes and were detrimental to foxes (Peterson and Woolington 1981).

Wolves were eliminated from the Kenai by overexploitation, but populations recovered rapidly when given protection. Wolf habitat on the Kenai Peninsula is probably more restricted than in the past because intensively developed lands appear to be avoided by packs. Wolves are an example of a low-density species that can readily colonize available habitat but are susceptible to both consumptive use and non-consumptive human disturbance.

Salmon

Salmon are the most important species of fish for sport, commercial, and subsistance fishing in Alaska. Salmon populations throughout Alaska were heavily exploited by commercial fishing, and salmon runs on the Kenai Peninsula were no exception. Generally, the history of salmon on the Kenai closely parallels that of salmon stocks elsewhere in Alaska (Pennoyer 1979). Starting about 1900, a series of laws were enacted to regulate the salmon fishing industry in Alaska. A limited attempt to have hatcheries increase fish for harvest failed, and the last two Federal hatcheries in Alaska closed in 1934. Predator control measures were also implemented in the 1900s and bounties placed on eagles, seals (*Phoca* spp.), and predatory fish. Poor enforcement of existing laws, limited information on the resource, and lack of gear limitations all resulted in a declining salmon resource. By the early 1950s, runs declined to such low levels that portions of Alaska were declared disaster areas by Presidential decree.

At this time, the importance of sound fishery management became obvious and funds were made available for salmon management and research. Today, many regulations control commercial salmon takes by both foreign and domestic fishermen, and salmon stocks have made a strong recovery.

Sport fishing is a major recreation on the Kenai Peninsula and has increased rapidly since 1970. The Kenai Peninsula provides over 35 percent of the total annual sport fishing effort in Alaska. Due to the tremendous sport pressure, regulations have been implemented to control and more widely distribute the harvest. Examples of the types of regulations include: reduction in daily and yearly limits, elimination of snagging, limited gear (single hook, fly fishing), and reduction in seasons.

Hatchery stock and stream rehabilitation have been used in an effort to satisfy the ever increasing public demand for fish. Most of the salmon spawning and rearing areas on the Kenai are on public lands and are protected from disturbance or development.

Salmon were reduced by commercial harvest occurring on and off the Kenai Peninsula. The high monetary value of this public resource overrode concern for long term population health. When harvest was managed, populations recovered rapidly since the critical spawning and rearing habitat was unaltered. Salmon are an example of species that were once reduced but, through habitat protection and effective management, now provide huge benefits to large numbers of commercial and sport users.

Bald Eagle

Bald eagle nest tree selection, productivity, and food habitats have been examined annually on the western Kenai Peninsula since 1979 (Bangs et al. 1981). Forty-two nest sites have been located, consisting of 48 eagle nests. Trees selected by bald eagles on the Kenai are typical of nesting trees selected by bald eagles throughout North America. Nest trees are typically close to water, have a clear view of water, and are usually the oldest and largest living members of the dominate overstory. The absence of eagle nests in large portions of what appears to be suitable habitat in the Kenai lowlands is most likely attributable to loss of old age trees by fire.

Two years of data (1979 and 1980) on the productivity of bald eagles on the western Kenai lowlands suggest overall eaglet production comparable to other areas in Alaska and above that reported from other areas of North America (Sprunt et al. 1973). The effect of human disturbance on bald eagle nesting success was determined in 1980 by comparing the success of nests subjected to human disturbance to those subjected to little disturbance. Of 13 nests in locations subjected to disturbance, only 3 (23 percent) produced eaglets in either 1979 or 1980, while 16 (88 percent) out of 18 nests subjected to little disturbance produced eaglets in either 1979 or 1980 (Bangs et al. 1981). This information suggests that bald eagles on the Kenai Peninsula are susceptible to human disturbance and that eagles will not reproduce as successfully in areas of high human activity as they will in more remote sites. Hensel and Troyer (1964) reported that nest abandonment was a major factor in influencing nesting success on Kodiak Island. Corr (1978) also commented on bald eagle nest abandonment and suggested that disturbance during egg laying and incubation may have been an important reason for nest abandonment. Most of the human activity on the Kenai classified as disturbance was occasional recreational use such as boating, canoeing, and camping rather than development-oriented activities. Most of the human activity on public land occurs from the end of May to late September and coincides with bald eagle incubation and rearing.

In 1981, two concentrations of bald eagles were located on the Kenai Peninsula lowlands. The largest staging area was below Skilak Lake along the Kenai River. In March, a minimum of 93 eagles (75 adults and 18 immatures) were seen along a 10-mile (16 km) stretch of river. These data indicate that the upper Kenai River is an important staging and/or feeding area for bald eagles. This area is being intensively developed for housing and receives a great deal of boating and fishing activity. In May, over 50 eagles (28 adults and 22 immatures) were seen in a 3-mile (4.8 km) stretch of the lower Fox River at the head of Kachemak Bay. At the same time, 31 active (adult present) nests were surveyed. The high proportion of immatures suggest the Fox River may be an important feeding area for immatures and nesting pairs. This area may be affected by road and transmission lines from the Bradley Lake power project and is currently the site of limited cattle grazing and nearby homesite selection. Since feeding and staging areas are not protected under the Bald Eagle Act, impact of future development on these areas is difficult to predict.

Bald eagles are a nationally significant species whose last secure nesting habitat is in Alaska and Canada. Populations were undoubtedly reduced during the predator control era of the 1900s, but have recovered with protection. This species appears to be tolerant of human activity during certain periods of the year, but not during nesting activities. The bald eagles are examples of species that require specialized conditions to nest successfully and, although protected from consumptive use, are intolerant of human activity while raising young.

Trumpeter Swans

Trumpeter swans were identified on the Kenai during the 1940s and serious investigation began in 1957. At that time, 20 nesting pairs were found during aerial surveys. Nearly all of the trumpeter swan habitat is located on the Kenai National Wildlife Refuge and 80 percent of all nests are located in the northern portion of the Refuge (Richey 1978). The number of nesting pairs fluctuated from 39 in 1965 to 21 in 1972, but has remained at approximately 30 pairs since that time. Trumpeter swan populations in other parts of Alaska have increased several fold during this same time period. Cygnet survival on the Kenai to flight stage has fluctuated yearly for unknown reasons, but has averaged about 70 percent. It is suggested the Kenai swan habitat is fairly well saturated and little growth potential remains for this range. We regularly observe new nests without recording an increase in nesting pairs. Swans are apparently shifting their nest sites, which could be a result of marginal habitat, some unidentified disturbance, or other related factors such as unstable water levels.

On the Kenai, the trumpeter swan population can expect to face continued human disturbance. Since our survey includes some areas adjacent to the Kenai refuge, some loss of nesting sites appears to be associated with increased human disturbance. Some nest site locations in the developing industrial North Kenai area seem to have been displaced eastward onto public land. This movement may provide nesting pairs temporary security from human disturbance. One pair of swans in this area relocated to eight different sites, probably in an attempt to escape human disturbance and find suitable habitat. Observations indicate that when human activity intrudes into swan nesting habitat, swans will move to less disturbed areas.

Swans on the Kenai Peninsula were common at Skilak Lake outlet until 1966. The increased human activity in that area may be the reason that swans abandoned that spring staging area. One of the most important known spring and fall staging areas on the Kenai for swans is near the junction of the Kenai and Moose rivers. The area was declared a critical habitat by the ADF&G and waterfowl hunting is prohibited. Lands surrounding the area are under private ownership and are currently being subdivided for housing development. Many swans that nest on the Kenai winter near the Skagit River in Washington and on Vancouver Island. Birds banded on the Kenai have been illegally shot in Alaska and lead poisoning of Kenai swans has been diagnosed in Washington.

Trumpeter swans were once an endangered species due to commercial overharvest on their wintering areas. Much of the swan's nesting habitat has remained undisturbed, and swan populations have recovered when given protection. Trumpeter swan nesting habitat seems to be affected by human activities and development. Trumpeter swans are examples of species that were almost reduced to extinction by overharvest, but recovered after protection because their nest sites were in areas protected from human disturbance.

Conclusions

Resource problems experienced on the Kenai Peninsula are similar to those that resulted from development of other frontiers. The typical patterns of unplanned habitat alteration and wildlife exploitation dramatically altered plant and animal communities on the Kenai Peninsula. Species of immediate value to man, such as caribou, salmon, or trumpeter swans, were overexploited. Species believed to compete with man for resources, such as wolves and eagles, were persecuted. Generalist wildlife species, such as moose, benefitted from unplanned habitat alterations, but species with specialized habitat requirements or that are intolerant of human activity declined as the Kenai Peninsula was developed. Of the changes that occurred to wildlife on the Kenai Peninsula, those related to habitat alteration have had the most lasting effect. Changes in wildlife communities caused by past exploitation were generally corrected within a short time span. Currently, there are no known endangered or threatened species on the Kenai Peninsula.

Adequate legal mechanisms exist to regulate exploitation, human caused disturbances, and habitat quality. These should control man's impact on resident and some migrating wildlife species on public lands and avoid the dramatic changes of the past. However, management of public lands is constrained by funding levels, appropriate management planning, the surrounding private land, and demands for other non-wildlife-oriented uses, such as logging, energy and mineral development, hydroelectric development, and numerous recreational pursuits.

Wildlife management practices were eloquently described by Aldo Leopold (1946) when he stated: "The practices we now call conservation are, to a large extent, local alleviations of biotic pain. They are necessary, but they must not be confused with cures. The art of land doctoring is being practiced with vigor but the science of land health is yet to be born." Wildlife management programs on the Kenai Peninsula are currently evolving into more enlightened, scientifically based management schemes that will ultimately lead to land health.

Problems likely to develop in the future are more complex than those identified in the past. Besides the anticipated political tradeoffs that will require lands to be intensively managed for maximized human benefits, other problems currently outside resource management authority will arise. How will increased industrial development affect water quantity and quality and fish production? Are the population levels of low density species high enough to maintain genetic integrity? What are the long term impacts of the species specific enhancement programs that society demands? How can species that travel outside protected habitats be best conserved? How can disease and predation from domestic animals be controlled on public lands? Solutions to these types of problems will primarily depend upon innovative resource management techniques and the importance that society places upon the value of wildlife and wildlands.

Acknowledgements

We thank the many wildlife biologists and resource managers who collected much of the information used in this report. R. Delaney, S. Eide, P. Fencl, R. Johnston, W. Regelin, K. Schreiner, and C. Schwartz provided numerous comments that greatly assisted in preparing this manuscript.

Literature Cited

Bangs, E. E., and T. N. Bailey. 1980. Interrelationships of weather, fire, and moose on the Kenai National Moose Range, Alaska. Proc. N. Amer. Moose Conf. and Workshop 16:255–274.

Bangs, E. E., T. N. Bailey, and V. D. Berns. 1981. Ecology of nesting Bald Eagles on the Kenai National Wildlife Refuge, Alaska. Pages 47–54 *in* Proc. Symposium and Workshop on Raptor Manage. and Biol. in Alaska and Western Canada.

Corr, P. O. 1974. Bald Eagle *(Haliaeetus leucocephalus alaskanus)* nesting related to forestry in Southeastern Alaska. M.S. Thesis. Univ. Alaska, Fairbanks. 144 pp.

Culver, W. G. 1923. Report of moose on Kenai Peninsula. Unpubl. Report, Kenai National Wildlife Refuge files, 18 pp. typewritten.

DeWeese, D. 1902. Protect Alaska Game. Congressional Record, House. 3843–3844.

Davis, J. L., and A. W. Franzmann. 1979. Fire-moose-caribou interrelationships. Proc. N. Amer. Moose Conf. and Workshop 15:80–118.

Hensel, R. J., and W. A. Troyer. 1964. Nesting studies of the Bald Eagle in Alaska. Condor 66(4):282–286.

Leopold, A. 1949. A Sand County Almanac. Ballantine Books. New York. 295 pp.

Lutz, H. J. 1960. History of the early occurrence of moose on the Kenai Peninsula and in other sections of Alaska. Misc. Publ. No. 1. Alaska Forest Research Center, U.S. Forest Service. 25 pp.

Mills, M. J. 1980. Alaska State-wide Harvest Study. Federal Aid and Restoration and Anadomous Fish Study, Vol. 22, July 1980–June 30, 1981. 107 pp.

Oldemeyer, J. L., A. W. Franzmann, A. L. Brundage, P. D. Arneson, and A. Flynn. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41(3):533–542.

Palmer, L. J. 1938. Kenai Peninsula moose. Research Project Report, Bureau of Biological Survey—Sept.–Oct. 1938. Unpubl. report, Kenai National Wildlife Refuge files, 24 pp, typewritten.

Pennoyer, S. 1979. Development of management of Alaska's fisheries. Proc. Alaska Science Conf. 29:17–25.

Peterson, R. O., and J. D. Woolington. 1979. The extirpation and reappearance of wolves on the Kenai Peninsula, Alaska. Proc. Portland Wolf Symposium. In press.

______. 1981. Wolf-moose investigations on the Kenai National Wildlife Refuge. Final Report. USFWS Contract No. 14-16-0007-81-5202.

Peterson, R. O., T. N. Bailey, and J. D. Woolington. 1980. Wolf management and harvest patterns on the Kenai National Wildlife Refuge, Alaska. Proc. Wolf Symposium. In press.

Richey, R. A. 1978. Status of the trumpeter swan on the Kenai National Moose Range. Presented at 6th Trumpeter Swan Society Conf. Anchorage, Alaska. Sept 7–12.

Schwartz, C. C., and A. W. Franzmann. 1980. Black bear predation of moose. Vol I. Project Progress Report. Federal Aid in Wildlife Restoration Projects. W-17-11 and W-21-1, Job No. 17.3R.

Sprunt, A., IV, W. B. Robertson Jr., S. Postupalsky, R. J. Hensel, C. E. Knoder, and E. J. Ligas. 1973. Comparative productivity of 6 bald eagle populations. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 38:96–106.

Whitney, M. 1916. Reconnaissance of the Kenai Peninsula, Alaska. USDA Field Operation of the Bureau of soils. 18th Report. Government Printing Office, Washington, D.C. 1921. P. 35.

Wildlife and Fishery Allocation in Alaska, 1982: Allocations for Subsistence, Commercial, and Recreational Uses

Gregory F. Cook
Douglas, Alaska

Allocation of fish and wildlife resources has become one of the major challenges confronting Alaska's resource managers.[1] Increasing competition among users and a diminishing resource base have combined to create a situation in which managers now find themselves focusing less attention on species and habitat conservation to deal with the plethora of social and political questions involved in allocating harvestable surpluses among competing groups of potential users. Biologists in Alaska find this particularly frustating since only a decade ago many biological surpluses went unharvested for lack of users. Since resource allocation in Alaska now requires discrimination among state residents,[2] biologists, politicians, and the general public now agree that competition for Alaska's wild resources has suddenly become very intense.

Without advocating any of the various interests involved, this paper will describe current problems with wildlife and fishery allocations in Alaska. Initially, I will look at the legal context in which allocation occurs, citing specific laws and using case histories. Allocation itself will then be discussed using specific examples of regulatory and judicial actions to describe the events that have led to the situation Alaska faces today. A look to the future and an examination of how events in Alaska may affect resource management in other states will conclude this paper.

One of the primary reasons for focusing attention on allocation is the emergence of "subsistence" harvests as a distinct statutory objective of fish and game management. Responding to different political constituencies, the Alaska State Legislature in 1978 and Congress in 1980 enacted laws mandating a "priority" allocation for "subsistence uses."[3] Implementation of the state's subsistence law is now fairly well developed, albeit incomplete. Federal subsistence implementation is embryonic. At this time, it is only possible to highlight major points and suggest areas of compatibility and conflict between federal and state laws.

Article VIII, Section 4 of the Alaska Constitution reads:

> Fish, forests, wildlife, grasslands, and all other replenishable resources belonging to the State shall be utilized, developed, and maintained on the *sustained yield principle, subject to preferences among beneficial uses* (emphasis added).

Consonant with this Constitutional provision, Alaska's 1978 subsistence law requires a specific allocation system for wildlife and fish:

[1]See, for example, Mitchell, "Bitter Harvest," p. 125 *Audubon Magazine*, Nov. 1979, and *Kenai Peninsula Cooperative Fishermen's Marketing Association, Inc., v. State of Alaska* 628 P2d 897 (Alaska, 1981).

[2]See, generally "Note: Nonresidents Are Not Guaranteed Equal Access to a State's Recreational Resources" 53 Tulane L. Rev. 1524 (1979).

[3](Ch. 151, SLA 1978 codified in AS 16.05; the Alaska National Interest Lands Conservation Act, ANILCA, 16 USC 3101 *et seq.*).

> Whenever it is necessary to restrict the taking of game to assure the maintenance of game resources on a sustained yield basis, or to assure the continuation of subsistence uses of such resources, *subsistence use shall be the priority use.*[4]

State law defines subsistence in this way:

> (26) "subsistence uses" means the customary and traditional uses in Alaska of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools or transportation, for the making and selling of handicraft articles out of non-edible by-products of fish and wildlife resources taken for personal or family consumption, and for customary trade, barter, or sharing for personal or family consumption; for the purposes of this paragraph, "family" means all persons related by blood, marriage, or adoption, and any person living within the household on a permanent basis;
>
> (27) "barter" means the exchange or trade of fish or game, or their parts, taken for subsistence uses
>
> (A) for other fish or game or their parts; or
>
> (B) for other food or for non-edible items other than money if the exchange is of a limited and noncommercial nature.[5]

Alaska's subsistence law meticulously avoids mention of race. Instead it refers to "uses" of wildlife and fish rather than referring to racial characteristics of users. To do otherwise would almost certainly violate Alaska law.[6]

A series of recent lawsuits has produced case law interpreting Alaska's newly mandated allocation system. Each case has been resolved at a level lower than the Alaska Supreme Court; consequently their precedential value is limited.[7] Nevertheless, a review of those cases provides much insight into today's allocation problems in Alaska.

The Board of Fisheries is the state regulatory authority for fish matters. *Village of Tyonek v. Alaska Board of Fisheries* #3AN 80–3073, Civ., Anchorage Superior Court, 1980, arose when the Board of Fisheries declined to adopt a proposed regulation to allow the harvest of 3,000 king salmon by gillnet in late May and early June in the vicinity of Tyonek, an Athabascan Indian village on the east shore of Cook Inlet. Tyonek villagers had caught king salmon for generations at that location and season of the year until 1963 when an early season closure was ordered by the (then) Board of Fish and Game as a result of years of commercial overfishing and decimation of the Susitna king salmon stocks.[8]

The court required the Alaska Department of Fish and Game (ADF&G) to allow the harvest requested by Tyonek. The decision was based on an assessment that Tyonek's past king salmon fishing constituted "customary and traditional" sub-

[4]AS 16.05.255. For the parallel provision governing fishery resources see AS 16.05.251. See also Letter of Intent, House Journal 1153, May 12, 1978.

[5]AS 16.05.940.

[6]Ak. Const. Art. 1, Sec. 1,3; AS 18.80.255; Alaska A.G. Op. Jan. 21, 1981, "Constitutionality of State Implementation of Native Exemption". As to discrimination among "uses" see *Kenai Peninsula, supra,* note 1, at p. 903.

[7](See, generally, "Department of Law Presentation to the Boards of Fisheries and Game" Dec. 5, 1980).

[8]Fishing re-opened in late June directed at other stocks, yet allowing an incidental harvest of Susitna kings at the tail end of the run.

In 1975, the Board of Fish and Game was split to form two separate Boards, the Board of Fisheries and Board of Game. AS 16.05.221.

sistence activities. (*Tyonak* transcript, p. 4) The time of year and location for the fishery were also reinstated since they were found by the court to be material elements of the village's subsistence. No evidence was adduced by the State of Alaska to show that the requested level, time, place, or method of harvest would be so biologically imprudent as to require continued restraints on village residents seeking to harvest early run Susitna king salmon.

Judicial intervention at Tyonek was founded on these key points: (1) the Board of Fisheries has an affirmative statutory obligation to adopt subsistence fishing regulations; (2) the Board failed to state on the record why Tyonek's fishery was not "customary and traditional" or why a sustained yield of Susitna River kings (the stock involved) would be jeopardized if the fishery took place; (3) for the previous two years the Board had re-opened the freshwater recreational fishery that targets on Susitna kings, setting a guideline harvest level of 11,000 fish; and (4) commercial fishermen were allowed to catch and retain Susitna kings caught incidentally in other fisheries that opened in late June.

Francis v. Alaska Department of Fish and Game #3KN 80–546 Civ., is a 1980 stipulated settlement involving new residents of Alaska's Kenai Peninsula. Plaintiffs protested Board action closing a certain beach to subsistence fishing and substituting a different beach where access is extremely difficult. The stipulated settlement re-opened the old beach, which had been left open only to sport and commercial fishing. A key reason for the State's concession and settlement was the lack of biological evidence on the Board meeting record that subsistence fishing would interfere with the sustained yield of the late run coho involved.

Gjosund v. Alaska Department of Fish and Game #3 HO 80–92 Civ., is a 1980 Homer Superior Court case. In *Gjosund,* a group of non-Native residents of Cook Inlet's Kachemak Bay succeeded in invalidating certain gear and closed water restrictions newly imposed on subsistence fishermen targeting mainly on coho salmon. The Board of Fisheries' action limiting subsistence was a response to an increase in the number of subsistence fishing permits in the area (from 35 in 1969 to 202 in 1979). Court action invalidating the Board's regulations rested on these salient points: (1) a finding that plaintiffs were "customary and traditional users" who "relied in varying degrees on their catch for personal or family consumption;" (2) a finding that the Board's action was unnecessary for biological purposes since no such purposes were articulated on the record of the Board's regulatory action; and (3) the areas of Kachemak Bay closed by the Board for subsistence fishing were left open to sport and commercial fishing.

State v. Ewan #3GL 80–21–23, Crim., is a 1980 Glennallen District Court criminal case and is, as yet, the only Alaska judicial decision based on subsistence hunting.[9] Mr. Ewan, an Athabascan Indian, killed a caribou from the Nelchina herd near his cabin during the closed season. At the time Mr. Ewan was arrested, hunters wishing to utilize the Nelchina caribou herd applied for permits issued on a lottery basis. Alaska residents competed for permits on an equal basis with non-Alaskans. The court found Mr. Ewan to be a customary and traditional subsistence

[9]*State v. Tanana Valley Sportsmen's Association* 583 P2d 854 (Alaska, 1978) did not reach the merits of the subsistence issues raised. The holding rested on procedural aspects of subsistence caribou hunting regulations.

user, and further found that it was not practical for Mr. Ewan to travel to an area where the season was open at the time of year he needed caribou for food. The District Court held the Board of Game's permit system for Nelchina caribou failed to satisfy the legal priority for subsistence and Mr. Ewan was not convicted.

The most significant federal law dealing with resource allocation in Alaska is also the newest—Alaska National Interest Lands Conservation Act (ANILCA).[10] ANILCA defines subsistence use in a way that closely parallels the State's definition with two major exceptions: (1) only *rural* Alaska residents benefit from the federal subsistence priority,[11] and subsistence is made the priority *consumptive* use, i.e., subsistence does not necessarily take priority over non-harvesting uses such as viewing or photography.[12]

A complete review of the subsistence provisions of ANILCA is beyond the scope of this paper. At the risk of considerable oversimplification, these key points emerge:

1. only "rural" Alaskans (Native and non-Native) benefit from the subsistence priority;[13]
2. three criteria of perplexing amorphism are given for discriminating among subsistence users;[14]
3. the State of Alaska may retain management of the subsistence priority on federal lands if certain conditions are met,[15] otherwise the Secretary of Interior is specifically authorized to manage resident fish and wildlife to achieve the subsistence priority;
4. a cause of action in Federal District Court with special provision for expedited hearing is established for persons aggrieved by either a State or Federal failure to provide for the subsistence priority;[16]
5. planning and evaluation of subsistence impacts must occur for all uses of Alaska public lands, including findings to support final decisions affecting subsistence;[17]
6. access is ensured for rural subsistence users on public lands;[18]
7. all National Parks and Park Monuments are closed to taking wildlife "except for subsistence uses to the extent specifically permitted";[19]
8. the subsistence priority is made applicable to all federal lands in Alaska, not merely those withdrawn under ANILCA.

Other federal statutes act to allocate wildlife in Alaska among different groups. The Marine Mammal Protection Act (MMPA)[20] generally prohibits taking of nine species of marine mammals, yet still provides for subsistence taking by Alaska

[10]*supra*, note 2.
[11]16 USC 3113, U.S.N.P.S. Reg. 36 C.F.R. 13.42 and U.S.F.W.S. Reg. 50 C.F.R. 36, p.31818, Fed. Reg. June 17, 1981. c.f. Alaska A.G. Op. Dec. 2, 1981 regarding Alaska law and rural residency.
[12]16 USC 3112.
[13]16 USC 3113, 3114, and note 11, *supra*.
[14]16 USC 3114: (1) dependence on the resource as a mainstay of livelihood; (2) local residency, and (3) availability of alternative resources.
[15]16 USC 3115 (d).
[16]16 USC 3117; House Report 97–228 to accompany HR 4084 at pp. 20–30.
[17]16 USC 3120.
[18]16 USC 3121.
[19]16 USC 3126.
[20]16 USC 1361–62, 1371–84, and 1401–07.

Natives.[21] The 1981 MMPA amendments include important modifications in the subsistence provisions. The change of potentially greatest import may be in the operation of the term "priority."[22] The discussion of the law's effect on the decision reached in *Togiak v. United States* 470 F. Supp. 423 (D.D.C, 1979), is also significant. The 1981 amendments and their legislative history may provoke accusations of revisionism regarding the reasons for federal non-management of marine mammals since the MMPA was passed in 1972.[23]

The Endangered Species Act[24] (ESA), like the MMPA, contains special treatment for subsistence but provides less protection for subsistence than the MMPA. Under the ESA, the Secretary may restrict Alaska Natives who take endangered or threatened wildlife after a finding that "such taking materially and negatively" affects the species.[25]

Recent attempts to modify treaties affecting migratory waterfowl to achieve new treatment of subsistence waterfowl hunting are important to waterfowl managers nationwide.[26]

Subsistence and Federal Trust Responsibilities

It has been argued in a variety of fora that the federal government owes a duty to protect subsistence activities of Native Alaskans as a result of federal trust responsibilities.[27] Whatever status the trust responsibility over subsistence may have had prior to 1971, it definitely has been affected by passage of ANCSA, the Alaska Native Claims Settlement Act, Sec. 4.[28] One can state with confidence that the extent to which trust responsibilities for subsistence uses have survived ANCSA has been and will continue to be hotly contested.

The current state of the law indicates a narrow federal trust responsibility over subsistence, i.e., only those responsibilities explicitly appearing in statutes are cognizable. *North Slope Borough v. Andrus* 642 F2d 589 (D.C. Ct. of Appeals, 1980) concerned Outer Continental Shelf leasing in the Beaufort Sea. The court in that case held federal trust responsibilities over subsistence were satisfied by

[21] 16 USC 1371 (b), 1379 (f). See also 43 ALR Fed. 599 and House Report 97–228 to accompany HR 4084 at pp. 20–30.

[22] House Report 97–228, *supra*, at p. 28.

[23] House Report, *supra*, p. 13, c.f. Gottschalk, "The State Federal Partnership," p. 293 *Wildlife and America*, Brokaw, Ed., Council on Environmental Quality, 1978.

[24] 16 USC 1531–43.

[25] 16 USC 1539 (e) (4). See also Memorandum, Office of the Solicitor, Department of Interior, October 16, 1980, "Application of the Endangered Species Act to Native Americans with Treaty Hunting and Fishing Rights."

[26] See generally 16 USCA 703–711 and Convention for the Protection of Migratory Birds, Aug. 16, 1961, United States-Great Britain 39 Stat. 1702, T.S. No.628; Convention for the Protection of Migratory Birds and Game Mammals, Feb. 7, 1936, United States-Mexico, 50 Stat. 1311, T.S. No. 912; Convention for the Protection of Migratory Birds, Mar. 4, 1972, United States-Japan, 25 U.S.T.3329, T.I.A.S. No.7990. See also Kelso, "Subsistence Use of Fish and Game Resources in Alaska: Considerations in Formulating Effective Management Policies." 47 *Transactions of the North American Wildlife and Natural Resources Conference* 630 (1982).

[27] *State of Alaska v. Udall* 420 F2d 938,940 (9th Circ. 1969); *United States v. Unalakleet* (1969) 188 Ct. Cl. 1, 411 F. 2d 1255; and *Edwardsen v. Morton* 369 F. Supp. 1359 (D.D.C., 1973); see generally 41 ALR Fed. 468, and *Cook v. Watt*, J. 82–0006 Civil, (D. AK, 1982).

[28] ". . . any oboriginal hunting or fishing rights that may exist are hereby extinguished. See S. Rep. #1163, at p. 15 (1957) and H.R. Rep. #625 at p. 2 (1957) See also De Vleming, "The Aboriginal Hunting Right: Is the Only Good One an Extinguished One?" 13 Idaho L. Rev. 403 (1977).

federal compliance with ESA and NEPA and by direct consideration given to subsistence in the EIS. "Without an unambiguous provision by Congress that clearly outlines a federal trust responsibility, courts must appreciate that whatever fiduciary obligation otherwise exists, it is a limited one only."[29]

Alaskan User Groups

Competition among user groups for wildlife usually involves rural hunters operating fairly close to home versus urban hunters benefitting from the mobility of air transportation. Often, each group hunts for the primary purpose of putting meat on the table. Depending on how one interprets the federal and Alaska definitions of "subsistence," some meat hunters are subsistence users, the rest are recreational or "personal use" users. Trophy hunters as a group occasionally overlap with the two former groups when hunting moose, caribou, or Dall sheep, since an individual animal may be prized for its meat or its trophy equally.

Other wildlife user groups that are less prominent include professional guides, trappers, and non-harvesters. There are presently 38 Master Guides licensed statewide and over 300 Registered Guides restricted to specific portions of Alaska. In 1981, over 23,000 state trapping licenses were sold in Alaska. Although non-harvesters have not yet been as active in wildlife management issues as hunters or trappers, their visibility is expected to increase since a non-game program was established within the Alaska Department of Fish and Game in 1982.

Competition among user groups is more intense for Alaskan fisheries than for wildlife. Each substantial fishery has a unique combination of gear conflicts, user group conflicts, management difficulties, and allocation problems. The Alaska Board of Fisheries now spends over 60 days and evenings annually in regulatory sessions attempting to resolve these Gordian allocation conflicts.

Subsistence fishermen harvest for personal use in the nearshore marine and freshwater areas of Alaska. They often use the identical resource of commercial fishermen, e.g., herring, or sport and commercial users, e.g., salmon, halibut and sheefish.[30] Many sport fishermen consider their personal use of fish to be no different from that of individuals fishing under subsistence regulations. In fact, the method of harvest or bag limit is often the sole visible distinction.[31] There are, of course, catch-and-release and trophy fishermen in the sports group also.[32] Many subsistence users hold commercial fishing licenses and harvest additional fish under subsistence privileges.

Competition among commercial fishermen is intense: foreign fleets compete with Americans, Alaskans compete with non-Alaskans, and competition exists among different gear groups.

[29]*North Slope Borough, supra,* p. 612. See also *Adams v. Vance* 570 F2d 950 (D.C. Ct. of Appeals, 1978 and *Togiak, supra,* p.11. c.f. Verges, McClendon, "Inupiat Eskimos, Bowhead Whales, and Oil: Competing Federal Interests in the Beaufort Sea" 10 UCLA Alaska L. Rev. 1, 17–30, (1980).
[30]AS 16.05.940 (17); AS 16.05.930.
[31]5AAC 01.010 (g).
[32]AS 16.05.940 (16).

Examples of Allocation

How allocation laws operate in the real world of resource management requires a look at specific examples of allocation. Passage of the 1978 Alaska subsistence law did not revolutionize Alaska's hunting regulations. The Alaska Board of Game continues to avoid distinctions between "sport" and "subsistence" users. Their approach is ". . . whenever possible, the subsistence priority should be achieved by existing regulatory techniques, such as open and closed seasons, bag limits, control of methods and means of take, and controlled use areas."[33]

Caribou

In response to the decision in *Ewan,* the Board of Game adopted new caribou hunting regulations after receiving testimony from local Fish and Game Advisory Committees and ADF&G biologists. The new regulations treat all Alaska residents as traditional and customary subsistence users and grant additional privileges to a narrowly defined group of Alaskans. Discrimination against urban Alaskans in this instance is not made in the manner that federal law now demands. The Board's regulations discriminate among Alaskans on the basis of the state's statutory criteria required to be used when "further restriction is necessary":

1. dependence on the resource as the mainstay of one's livelihood;
2. local residency; and
3. availability of alternative resources. (AS 16.05.255)

Since 1981, no more than 5 percent of the Nelchina caribou permits may go to non-Alaskans, all of whom are non-subsistence hunters. All other permits are for subsistence. Additionally, if wild meat is and has been a major part of his diet for five years and he lives in a household with an annual income of less than $12,000, an Alaskan who is a resident of Game Management Unit (GMU) 13 and GMU 14 (except GMU 14C, which includes Anchorage) now qualifies for a special drawing for a permit to hunt during either of two seasons: August 20–September 20 or in January and February.[34] The fall hunt is not available to any hunters except the narrow group of local, more needy susbsistence hunters.

"Priority" under the Nelchina caribou regulations is demonstrated by the Board's action in reserving 95 percent of the harvestable surplus for Alaskans, all of whom were treated as subsistence users, and by allocating 9 percent of the total permits available for Nelchina caribou for use by those meeting the more restrictive subsistence criteria described above. In adopting this sytem, the Board was careful to articulate on the record the biological constraints of harvest and what uses the Board concluded are customary and traditional subsistence uses. Even this may not satisfy the legal standards of federal law.

Brown Bear

Although relatively insignificant as a subsistence species compared to moose, caribou, deer, or salmon, some brown bear are used for subsistence. Those uses

[33]Joint Boards Policy Statements on the Subsistence Utilization of Fish and Game, March 28, 1979 and December 5, 1981; see also ADF&G Memorandum, R. Hinman to G. Cook, May 27, 1981.
[34]5AAC 81.055(C) (3); 81.320(5).

have recently been documented by the Subsistence Division, ADF&G, in the Lake Iliamna region (GMU 17). However, in April 1981, the Board of Game declined to establish new regulations for GMU 17 to discriminate among resident brown bear hunters. The Board's action, articulated on the record, was based on the low level of subsistence use of brown bear and the lack of any showing that subsistence needs were unmet under the existing regulatory structure. In contrast, black bear seasons and bag limits are extremely liberal in almost all Game Management Units in Alaska, partly because of the high level of subsistence use of black bears.[35]

Deer

In Southeast Alaska, caribou are totally absent and moose populations occur in only a few isolated drainages. The primary subsistence species of game is the Sitka black-tailed deer. The Board of Game has adopted a complex regulatory system for deer.[36] Current policies of the U.S. Forest Service encourage clearcut logging of low elevation, high-volume, old-growth forest and promise to result in serious reductions of deer populations through habitat destruction[37]. As critical winter habitat for deer is eliminated through continued large-scale clearcutting, deer populations will decline permanently. Allocation conflicts for deer have not yet been serious, but declines in deer numbers, increased human populations, increased human mobility, and loss of habitat may produce conflicts in the near future.

Susitna King Salmon

The shores of Cook Inlet, where almost three-quarters of Alaska's population lives, have been the site of a bitter, long, and unfinished allocation battle. The battle is being waged between subsistence, sport, and commercial users before the Board of Fisheries, the Legislature, and in the courts. The prize? The privilege of fishing for Susitna River king salmon. The solution to the Susitna River king salmon problem attempted by the Board of Fisheries in 1978 was to allocate virtually all of the run to sport fishermen on the freshwater tributaries of the Susitna, leaving the tail end of the run in saltwater for Tyonek Indian villagers. Additionally, some of the run was to be caught incidentally by commercial gillnetters, both drift and set. Chum and sockeye runs close to the village were allocated to subsistence use for Tyonek. This system was nullified in Anchorage Superior Court for failure to comport with the State subsistence law.[38] Tyonek villagers may now gillnet up to 4,000 early run Susitna king salmon in Cook Inlet, where stocks are mixed. Biologists have been unable to detect any diminution in numbers of upstream spawners.[39] No correlative decrease in sport fishing success has occurred, either.[40]

[35]5AAC 81.320 (1).
[36]5AAC 81.320 6.
[37]Wallmo, O.C., and J.W. Schoen, "Response of Deer to Secondary Forest Succession in Southeast Alaska," *Forest Sci.*, 26(3):448–462
[38]See *Tyonek, supra.*
[39]5AAC 01.560.
[40]Report to the Board of Fisheries, December 1981.

Although the Susitna king run appears healthy and continues to rebuild, no observer could fail to note the escalating acrimony that has ensued over the *Tyonek* saga. As a direct result of this allocation battle, bitter lines have been drawn between Natives and sportsmen's groups, unusually vituperative confrontations have broken out in the Legislature, and an Initiative[41] to repeal the state subsistence law has been submitted to Alaska's Lieutenant Governor.

As a result of the *Tyonek, Gjosund,* and *Francis* cases discussed in this paper, the Board of Fisheries adopted a list of criteria for evaluating fish uses in Cook Inlet.[42] These standards are used by the Board in determining what uses should be deemed "customary and traditional subsistence uses." The guidelines themselves are now the issue of new court challenges.[43]

Summary: Alaska Fish and Wildlife Allocation

In viewing Alaskan allocation decisions, a key point to keep in mind concerns the measure of discretion available to Alaska's Boards of Fisheries and Game. A comparison with the well-known Multiple Use-Sustained Yield Act (MU-SYA) of 1960[44] may help.

One team of commentators has said that "management of either multiple use or dominant use lands to provide recreational opportunities while protecting other values and allowing other uses is a delicate, unenviable task in the best of circumstances."[45] The same statement could be applied to allocation of Alaskan fish and wildlife: it is a delicate balancing process that often leaves all user groups less than fully satisfied in spite of the fact that Alaska allows more public participation in rulemaking proceedings for fish and game than any other State in the Union.[46]

A key difference between multiple use management and subsistence management is the relative amount of discretion allowed the Boards. Whereas MU-SYA provides nearly unlimited discretion in the allocation of land to particular uses, managers of Alaska's wildlife and fisheries must, by statute, treat subsistence use as a priority use.[47]

Alaska's Boards are required to balance the interests of all user groups and create a harvest system that provides a priority for subsistence. Interpretation of the term "priority" will be a key area of litigation for the future.[48] How much of an advantage is enough? Present interpretations by the Boards allow for recreational and commercial uses along with subsistence uses in many instances. Since the passage of ANILCA, the state system must now also demonstrate a priority acceptable to federal managers if the state is to retain management prerogatives

[41]AK. Const. Art. XI, Sec. 1–4.
[42]Board of Fisheries policy #80–81.
[43]*Madison v. Skoog* #3KN81–532 Civ., (1981) and *Gjosund v. State, supra.*
[44]16 USCA 528–531.
[45]Coggins, Wilkinson, *Federal Public Land and Resources Law,* 1981, p. 672.
[46]See 5 AAC 95, 96.
[47]Most commentators prefer a level of discretion in MU-SYA actions not yet adopted by courts. See *Sierra Club v. Butz* (9th Circuit, 1973) unpublished order at 3 ELR 20292. See also: Dolgin, Guilbert, *Federal Environmental Law,* pp. 566–568.
[48]See House Report 97-228, *supra,* note 19 at pp. 28–29.

on federally owned public lands and, perhaps, also on a penumbra of state and private lands.

The two Boards probably possess a great deal of discretion in interpreting and applying the state subsistence law.[49] Any action taken by the Boards must meet these standards: (1) it must be consistent with the law; (2) it may not be arbitrary; and (3) it must be reasonably necessary to carry out the law's purposes.[50]

It is important to realize that neither Board was well-equipped to integrate into their allocation decisions the statutory definition of subsistence formulated by the Alaska Legislature. Terms such as "customary and traditional," "direct dependence," "availability of alternative resources," and "local residency" temporarily baffled both Boards. Before 1978, the Boards needed only to consider "conservation and development."[51] The lexicon of subsistence was unfamiliar and perceived by many Board members, perhaps correctly, as an assault on the social justice of some of their past allocation decisions.

A few years of experience administering the subsistence law has benefitted the Boards and the Alaska Department of Fish and Game. There have been successes and failures. There will be more of each. Overall, however, Alaska is making steady progress implementing its subsistence law and dealing with the ongoing competition among increasing numbers of users who wish to use limited resources. In evaluating Alaska's record, observers should bear in mind that never before in the American legal history of fishery and wildlife management has there been comparable legislation dealing with allocation.

Conclusion

Just as ". . . wildlife law is in its flexible, cantankerous adolescence,"[52] so is the law of fish and wildlife allocation. A number of crucial questions remain unresolved in Alaska. The answers to these questions will affect fish and wildlife users throughout the United States who come to Alaska and may even presage management directions and issues outside Alaska.

A key tenet of modern resource management is that no harvest is allowed unless a surplus is known to be available.[53] Since *Tyonek,* it is arguable that judicial interpretations of Alaska's subsistence law have now shifted the burden of proof to the State to show that subsistence harvest will interfere with a sustained yield before the state may restrict subsistence.

Both Boards continue to be faced with the complex task of determining what uses of wildlife and fish are "customary and traiditonal," over a geographically vast and culturally disparate state of legendary faunal diversity. The Boards also need to determine the nature and level of dependence on subsistence; whether areas used for subsistence can be changed by regulation; to what extent harvest

[49]Sands, Sutherland *Statutory Construction* Sec. 65.01–.03, 71.14; *Nathanson v. State* 554 P2d 456, 458 (Alaska, 1976).
[50]AS 44.62.030; *Kelly v. Zamarello* 486 P2d 906 (Alaska, 1971).
[51]AS 16.05.221,.251,.255
[52]Coggins, "Federal Wildlife Law Achieves Adolescence: Developments in the 1970's" 1978 Duke L.J. 753, 764 (1978).
[53]Wright, "Contemporary Pacific Salmon Fisheries Management" *North American Journal of Fisheries Management* 1:29–40, (1981).

levels for subsistence must be allowed to increase as rural populations increase; whether the subsistence priority applies permanently to a specific fish stock or wildlife population; what level (if any) of past subsistence use by an individual is necessary to legitimately claim the direct benefits of the subsistence priority; how far from home a subsistence hunter may reasonably be required to travel for game; and finally, perhaps the toughest interpretive issue of all: what regulatory advantages are sufficient to satisfy the statutory priority in the legal sense.

Resolution of these administrative questions is complemented by equally serious legislative and judicial issues. If Alaska acts to repeal its subsistence law, either by Initiative or normal legislative processes, must the Federal government assume fish and wildlife management on the public lands? In order to adopt all regulations necessary to implement the subsistence priority of ANILCA, what regulation of hunting, fishing, access, or other land use on state or private land will be required? Like it or not, federal power to regulate activities on non-federal lands and waters rests on a sturdy legal foundation that has been recently affirmed, and is expanding in scope.[54] Species such as caribou and salmon travel great distances, recognize no diffference between United States, Alaskan, or Canadian control, and figure prominently in subsistence uses. It takes very little imagination to conceive of the potential for "extra-territorial" federal regulation of these species, followed by legal battles and judicial decisions that may affect the relationship between state and federal resource managers throughout all of America.

Fishery and wildlife managers and users throughout the United States will almost certainly be directly affected by the way Alaska and the Federal government deal with allocation among subsistence, commercial, and recreational users. Although allocation decisions made outside Alaska may not be identical to those made in Alaska, they will be influenced by Alaskan decisions.

Access to land and water for hunting, trapping, and fishing has turned into a major issue in Alaska. It does no good for the Boards to allocate a certain harvest to various user groups if those groups have no realistic opportunity to use the land where harvsting takes place. Access issues will be heavily litigated. ANILCA ensures access over public lands for rural subsistence users, yet many rural and urban Alaskans are worried. Why? ANILCA and ANCSA both withdrew millions of acres of land and water. Native corporations are now the most important private land owners in all Alaska. The State of Alaska has a very active land disposal program whereby private individuals may buy state-owned land. The issue of trespass is suddenly important. It is unclear whether the public has retained anything like an implied easement for hunting, trapping, or fishing on these once-public lands.[55]

[54]See *United States v. Brown* 552 F2d 817 (8th Circ., 1977), *United States v. Lindsey* 595 F2d 5,6 (9th Circ., 1979), *Kleppe v. New Mexico* 426 US 529, 538 (1976), *National Association of Property Owners v. United States* 499 F. Supp. 1223, 1261 (D. Minn., 1980). Coggins, "Wildlife and the Constitution: The Walls Come Tumbling Down" 55 Wash. L. Rev. 295, 303, 353 (1980), Wilkinson, "Public Land Law: Some Connecting Threads and Future Directions" 1 Public Land L. Rev. I (1980).

[55]See generally *Analysis of Laws Governing Access Across Federal Lands,* Office of Technology Assessment, 1979; *Leo Sheep Co. v. United States* 440 U.S. 668 (1979); 35 AM Jur 2d, Fish and Game Sec. 16; and Tiffany, *On Real Property* Sections 339,471.

Alaska is about to begin a massive program of hydroelectric development. What effect will this have on wildlife and fish habitat? Will it encourage an increase in the human population of Alaska and at the same time reduce fish and wildlife populations, exacerbating existing allocation conflicts and creating new ones?[56] These questions may be answered in the immediate future before many people have even considered the trade-offs.

Maintaining adequate amounts of good quality habitat is basic to maintaining productive populations of fish and wildlife. Today, habitat for Alaska's big game, in particular, is shrinking while offshore oil development and inland hydroelectric development reduce fish habitat and threaten its future.[57]

The State of Alaska is rapidly developing her natural resources. Population growth ineluctably accompanies development. Both combine to place more pressure on scarce resources, especially in the Cook Inlet area and Kenai Peninsula where Alaska's population is concentrated.[58] Although such generalizations are dangerous, fish and wildlife habitat in Alaska is shrinking in size and deteriorating in quality.

What lessons should we draw from these allocation struggles? Unless subsistence, recreational, commercial, and non-harvesting users of Alaskan wildlife and fish join together to work for clean rivers flowing in adequate volume, clean air, non-acid rain[59], retention of low elevation, high-volume old-growth forests, responsible oil, gas, and mineral exploration, rational hydroelectric and agricultural development, and other uses of land and water that avoid violence to replenishable fishery and wildlife resources, there may come a day in Alaska when there won't be enough left to allocate or fight over.

Subsistence users and others must recognize the need for allies in the fight to preserve habitat. "Conventional benefit cost analyses do not always result in sound conservation decisons."[60] "Economic efficiency does not always result in conservation of a resource."[61] Alaskans need to be far-sighted enough and creative enough to pursue prudent development that does not destroy fish and wildlife or their habitat. Serious racial polarization now current in Alaska will have to subside in favor of the common goals shared by all users of fish and wildlife. Alaskans must seek accommodation in the allocation process so that no group of users feels disenfranchised to the point where loss of a fish stock, stream, old-growth forest, or wildlife population appears not to matter. It would be tragic to see Alaska flush with petrodollars but unwilling to conserve its priceless wildlife and fishery resources.

[56]On the related topic of federal reserved water rights, see Brooks "Reserved Water Rights and Our National Forests" 19 Nat. Res. J. 433 (1979); Ranquist, "The *Winters* Doctrine and How It Grew" 1975 BYU L. Rev. 639, 679; *United States v. New Mexico* 438 US 696 (1978), especially the dissent by Powell and fn 5, and Tarlock, "No Water for the Woods: A Critical Analysis of *United States v. New Mexico*" 15 Idaho L. Rev. 590 (1978).

[57]See, generally, Denney, "Managing the Harvest" in *Big Game of North America*, Stackpole Books, 1978, p. 396.

[58]See, Bangs et al., "Effects of Increased Human Populations on Wildlife Resources of the Kenai Peninsula" 47 *Transactions of the North American Wildlife Natural Resources Conference* 000 (1982).

[59]See, generally, Haines, "Acidic Precipation and its Consequences for Aquatic Ecosystems: A Review" p.66 Vol. 110 No.6, Nov. 1981, *Transactions of the American Fisheries Society*.

[60]Loesch, "Multiple Uses of Public Lands—Accommodation or Choosing Between Conflicting Uses," 16 Rocky Mtn. Min. L. Inst. 1 (1971).

[61]*Id.*

Acknowledgements

I wish to thank Dr. Don McKnight and Bob Hinman, Game Division, ADF&G, Dr. John Gissberg, Department of Law, and Griffin Quinton, Alaska Board of Fisheries for their critical review of drafts of this paper. Any errors or omissions are my own.

Addendum

Several days after this paper was presented, the Alaska Boards of Fisheries and Game jointly adopted a new regulation specifying their approach to implementing the State of Alaska's and the Federal Government's subsistence priorities. The new regulation can be found at 5 AAC 99.010.

Subsistence Use of Fish and Game Resources in Alaska: Considerations in Formulating Effective Management Policies

Dennis D. Kelso
Division of Subsistence
Alaska Department of Fish and Game
Juneau

Background

The Subsistence Priority in State and Federal Law

In 1978, the Alaska Legislature enacted a statutory priority for subsistence uses of Alaska's fish and game resources.[1] Congress adopted legislative language in 1980 for the Alaska National Interest Lands Conservation Act (ANILCA), which is similar in most respects to the definition and priority established by state law.[2] In addition, ANILCA provides, in part:

> It is hereby declared to be the policy of Congress that—(1) consistent with sound management principles and the conservation of healthy populations of fish and wildlife, the utilization of the public lands in Alaska is to cause the least adverse impact possible on rural residents who depend upon subsistence uses of the resources of such lands; . . . (2) nonwasteful subsistence uses of fish and wildlife and other renewable resources shall be the priority consumptive uses of all such resources on the public lands of Alaska. . . .[3]

This strong statement is in keeping with the ANILCA provisions that require federal land use decisions to include evaluation of potential impacts on subsistence uses and resources.[4]

Research on Subsistence Uses and Their Importance

Both state and federal laws recognize the need for research on subsistence uses of resources.[5] The Alaska Legislature directly addressed this need by creating a new section in the Department of Fish and Game. The task assigned to the Division of Subsistence was necessarily broad because so little scientific research data on subsistence were available. The legislative mandate stated in part:

> The section of subsistence hunting and fishing shall . . . compile existing data and conduct studies to gather information, including data from subsistence users, on

[1]*See* Ch. 151, 1978 Alaska Session Laws.
[2]*See* U.S.C.A. §§3113,3114 (1980 Laws Special Pamphlet).
[3]16 U.S.C.A. §3112 (1), (2) (1980 Laws Special Pamphlet).
[4]16 U.S.C.A. §3120 (1980 Laws Special Pamphlet).
[5]ANILCA, 16 U.S.C.A. §3122 (1980 Laws Special Pamphlet), provides:
"The Secretary, in cooperation with the State and other appropriate Federal agencies, shall undertake research on fish and wildlife and subsistence uses on the public lands; seek data from, consult with and make use of, the special knowledge of local residents engaged in subsistence uses; and make the results of such research available. . . ."

all aspects of the role of subsistence hunting and fishing in the lives of the residents of the state.[6]

In addition to conducting applied social science research, the Division of Subsistence performs diverse policy-related roles but does not have authority to make regulatory decisions, to manage resources, or to enforce regulations. The Division is the only agency engaged in comprehensive research on subsistence uses of resources, and the demand for these studies has increased exponentially. Previously unavailable data have enabled the Alaska boards of fisheries and game to apply the subsistence priority (Thomas 1981) in their regulatory decisions and also have been used extensively in evaluating major land and water management issues (Veltre and Veltre 1981).

Understanding the Nature and Significance of Current Subsistence Uses of Resources in Alaska

The development of subsistence policy has been hampered by inaccurate assumptions about the nature of the resource uses involved. There are some well-known myths about fishing and hunting for subsistence. One is that subsistence activities are pursued using "primitive" technologies such as spears, bolas, and bows and arrows. Another myth is that subsistence refers to bare survival of persons in rural settings. A third myth is that the presence of cash transforms subsistence into something that does not require the harvest of fish and game. These erroneous notions make rational policy development more difficult by obscuring the true complexity and adaptability of subsistence systems. Research by the Division of Subsistence is directed toward providing a more accurate portrayal of current subsistence uses in Alaska.

Alaska's human history is entwined with the use of wild renewable resources. Among northern aboriginal peoples, adaptations directly related to patterns and cycles of resource availability are among the key elements of sociocultural differentiation. After contact with western society, the harvest, distribution, and use of locally available food and raw materials have continued to provide essential economic, nutritional, cultural, and social benefits to a large number of communities and households. For non-Native residents as well, the use of fish and game has satisfied similarly important needs.

Today both Natives and non-Natives participate in subsistence economic sys-

[6]AS 16.05.094 (1). Other duties described in the legislative mandate require that the Division of Subsistence:

(2) quantify the amount, nutritional value, and extent of dependence on food acquired through subsistence hunting and fishing;

(3) make information gathered available to the public, appropriate agencies, and other organized bodies;

(4) assist the department, the Board of Fisheries, and the Board of Game in determining what uses of fish and game, as well as which users and what methods, should be termed subsistence uses, users, and methods;

(5) evaluate the impact of state and federal laws and regulations on subsistence hunting and fishing and, when corrective action is indicated, make recommendations to the department;

(6) make recommendations to the Board of Game and the Board of Fisheries regarding adoption, amendment and repeal of regulations affecting subsistence hunting and fishing;

(7) participate with other divisions in the preparation of statewide and regional management plans so that those plans [recognize] and incorporate the needs of subsistence users of fish and game.

tems. These economies are systems of production, distribution, and consumption that are based upon the harvest of renewable resources. Within subsistence economies, a substantial portion of the goods produced are for direct local consumption rather than for export and sale on external markets. Modern subsistence systems have some cash flow, but the cash sector is generally limited, seasonal, and tenuously linked with exogenous economic systems (Lonner 1980). Even in towns having viable non-subsistence sectors of production and exchange, subsistence production and distribution nevertheless may be functional and vital to the entire community at certain times of the year, especially for subcommunities, groups, or households within the town that rely on subsistence harvests. Recent data suggest that, in many rural Alaska communities, the "commercial" and "subsistence" sectors of the economy are complementary and mutually supportive (Wolfe 1981: 88–96, 1979: 264–266, Ellanna 1980: Vol I).

Subsistence uses of locally available resources often provide substantial community and family self-sufficiency. In much of Alaska, the absence of reliable alternatives means that subsistence may be the only stable economic base. This is not to suggest that subsistence should be viewed as a less desirable alternative than the commercial economies which typify most other areas in the United States. Indeed, because connections to commercial markets are limited, it has been argued that subsistence economic systems tend to be "buffered" against the vagaries of inflation and other external economic effects (Lonner 1980).

Use of locally available resources—although dynamic—is so well established in many areas of Alaska that human communities may properly be viewed as integral parts of the ecosystems in which they participate. Accordingly, much of the Division's current research is, in effect, addressed to questions about human ecology. The presence and distribution of human populations as well as their social and cultural forms are viewed as beneficial adaptations, developed over time, in response to natural environments of fish and wildlife resources (Steward 1972, Cohen 1974, Vayda 1969, Lee and DeVore 1968).

Ethnohistorical data as well as information on current practices and use patterns are important in developing this picture of ecological relationships over time. Historic sites used for harvest or other subsistence activities provide a chronicle of relative resource abundance and movements (Fall 1981a, 1981b: 3–8, Table 1, Map No. 1). Traditional names also provide valuable information on resource use (Kari, cited in Fall 1981b: Table 3). For example, the Dena'ina name for Point McKenzie near present day Anchorage in Cook Inlet, *Dilhi Tunts'del'ust Beydegh* ("hooligans are transported point"), derives from the significant trade in eulachon oil that occurred here during April and May (Fall 1981b:8). Similarly, names of sites, seasons, and activities offer keys to understanding the annual cycle of subsistence resource uses and, concomitantly, the resources upon which the local economy depended.

In order to assess current uses, a variety of well-established social science methods are employed by the Division of Subsistence. The Division has conducted research using literature reviews, oral histories, participant-observation methods, informal interviews, interview surveys, mail surveys, and combinations of these techniques. In addition, particular field studies may require stratified sampling, selection of index study communities, comparative approaches, longitudinal designs, and other specialized applications. After data have been gathered in the field, analysis involves standard quantitative and descriptive treatments. Quantitative information is evaluated using accepted statistical computer programs. Where appropriate, geographic data are mapped in order to facilitate their use in land and water management decisions.

Considerations in Subsistence Policy Formulation

Reliable research data on subsistence uses in Alaska are extremely limited; indeed, comprehensive research efforts are just beginning. Nevertheless, studies completed to date and current field experience permit generalizations indicating certain components essential for effective management of subsistence resources.

For purposes of evaluating the factors to be considered in formulating management policy, I shall assume that a fundamental management goal is to maintain the productivity of the resource base so human use may continue. In addition, I shall assume that the word "subsistence" does not refer to resource uses that are characterized by "primitive" methods or limited to bare, physical survival. Instead, subsistence involves the use of locally available resources primarily for local consumption as part of the complex economic systems described earlier.[7] Although other views of "subsistence" have been articulated based upon various configurations of political values, the assumptions offered here have the advantage of being consistent with available research data concerning resource uses in Alaska.

The following discussion draws upon research findings, field experiences, and other current developments related to diverse Alaskan subsistence uses.

Cooperation Between Managers and Users in Development of Reliable Data and Management

Effective management of wild renewable resources can be achieved only if resource managers have reliable data and if resource users cooperate in the implementation of the desired management regime. Of course, user cooperation is necessary in order to obtain high quality data on harvests and other aspects of subsistence use. However, accurate harvest data are of only limited utility if harvest timing or other features of the harvest are inconsistent with the management plan. Neither reliable data nor other types of cooperation are likely to result unless users are assured that their interests are recognized and their uses are protected. Because use of wild resources is so important to many communities and households, unrealistic regulations may virtually compel uses outside the regulatory system (Collins 1982, Stickney 1981). If this occurs, the users may feel extremely uneasy[8] and reluctant to provide information.

[7]Alaska law provides a technical definition:

> '[S]ubsistence uses' means the customary and traditional uses in Alaska of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation, for the making and selling of handicraft articles out of non-edible byproducts of fish and wildlife resources taken for personal or family consumption. . . .

AS 16.05.940(26). The definition appearing in federal law is substantially similar but includes the limiting language, "by rural Alaska residents". 16 U.S.C.A. §3113 (1980 Laws Special Pamphlet).

[8]This discomfort is not merely due to anxiety about possible arrest. Many subsistence users strongly desire to comply with societal standards but believe they cannot do so and still provide for their families (Davidson 1974). In addition, some rural residents attempt to comply with ill-suited regulations simply from a sense of deference to the legal system, frequently absorbing significant losses and hardships in the process.

For example, Robert J. Wolfe conducted his initial research on food production in a village near the mouth of the Yukon River in 1978 (Wolfe 1979). Village residents recognized that regulations did not reflect certain characteristics of their harvest activities, such as spring take of waterfowl. Accordingly, local representatives insisted upon guarantees of confidentiality at the outset, in addition to the anonymity that Wolfe had already built into his design. Limitations on that portion of the research data dealing with waterfowl were imposed as preconditions to his conducting any research in the village (Wolfe, pers. comm. 1982). Representatives of Yukon Delta residents feared adverse enforcement attention if details of waterfowl use on the Delta were published and they took action consistent with this concern.

By contrast, a different regulatory climate existed on the Delta when Wolfe conducted additional research during 1981. In the interim, federal enforcement policy had moderated, and proposals to amend migratory bird treaties had been made.[9] There was less fear among Delta residents that information presented about their use of migratory birds would result in damage to their communities, and their representatives approved the reporting of important harvest and use data (Wolfe, pers. comm. 1982). The resulting research product provided previously unavailable insight into the complex socioeconomic systems of the Yukon Delta (Wolfe 1981).

Subsistence uses in rural communities can be expected to continue regardless of whether harvest regulations are consistent with the realities of local practice. Quite simply, users will take the actions they believe necessary to provide for their families and communities. If seasons, bag limits, or other limitations are inconsistent with these practices, they will be perceived as irrelevant and are unlikely to be effective.

For example, the migratory bird treaty with Canada prohibits the taking of most migratory birds between March 10 and September 1. This would eliminate virtually all use of these resources in northern and western Alaska because they are not present prior to March 10 and are migrating again at the time the treaty would

[9]Migratory birds are addressed in bilateral treaties between the United States and Canada, Japan, Mexico, and the Soviet Union. The most recent agreement, signed with the Soviet Union in 1976, authorizes the United States to set seasons which permit the taking of migratory birds and their eggs by indigenous inhabitants of Alaska for their own nutritional and other essential needs, but the seasons must provide for the preservation and maintenance of the migratory bird stocks. *See* Convention Concerning the Conservation of Migratory Birds and Their Environment, Nov. 19, 1976, United States - Union of Soviet Socialist Republics, 19 U.S.T. 4647, T.I.A.S. No. 5604. The treaty with Japan contains provisions allowing harvests by Eskimos and Indians for food and clothing. *See* Convention for the Protection of Migratory Birds in Danger of Extinction and Their Environment, Mar. 4, 1972, United States - Japan, 25 U.S.T. 3329, T.I.A.S. No. 7990. The treaty with Canada prohibits the hunting of most migratory birds during spring and summer, with certain exceptions. *See* Convention for the Protection of Migratory Birds, Aug. 16, 1916, United States - Great Britain (signatory for Canada), 39 Stat. 1702, T.S. No. 628. The treaty with Mexico does not refer to subsistence hunting. *See* Convention for the Protection of Migratory Birds and Game Mammals, Feb. 7, 1936, United States - Mexico, 50 Stat. 1311, T.S. No. 912. When the Migratory Bird Treaty Act was amended to implement the Soviet treaty, 16 U.S.C. §712 (Supp. III 1979), Congress indicated its intention that the language of the Soviet treaty should be followed in amending the treaties with Canada, Japan, and Mexico to provide consistency among provisions governing subsistence. *See* S. Rep. No. 1175, 95th Cong., 2nd Sess., reprinted in 1978 U.S. Code Cong. & Ad. News 7641, 7645.

Negotiations with Canada produced a protocol amendment signed by both parties on January 30, 1979. A request for negotiations on similar amendatory language was made by the Department of the Interior in late 1979. However, these negotiations have not been concluded; nor has the protocol amendment with Canada been ratified.

allow harvests in the fall. Of the species excepted, many are neither readily available nor commonly used throughout much of Alaska and Canada. Obviously, subsistence use of migratory birds is not likely to occur without violating these limitations.

Similar problems have arisen because of inconsistencies between regulations and social or cultural roles of subsistence. For example, the usual "bag limit" concept in wildlife management allows a licensed hunter to fill his bag limit for the day or season and then to take no more animals. In rural Alaska, however, one hunter may be responsible not only for supplying his own immediate family but also for a system of community sharing with elders and others who need meat but cannot hunt. A hunter with those responsibilities may "overharvest" according to the bag limit; but when considered in light of the distribution among family and community members, the average individual use may be well within the established bag limit. In such circumstances, the regulatory intent actually may be met but the hunter and his social responsibilites are in conflict with the letter of the law (Skoog 1980).

Major discontinuities between management regulations and local practices may, in some instances, produce total lack of management effectiveness. Our research suggests, for example, that in some interior Alaskan communities where regulatory measures have shown great inconsistencies with local practice, the regulations are considered to be applicable only to other users; in fact, to follow such regulations would, from the perspective of local residents, be irrational, since it would make long-established harvest strategies ineffective (Stickney 1981). Instead, it is their belief that the Board of Game could not have intended the regulations to apply to subsistence uses or else the provisions would have been drafted differently. The practical effect of this discontinuity is that parallel systems now exist: codified management regulations and enforcement, and non-codified local practice and social control.

An additional problem for wildlife managers arises if this divergence is not recognized. Because most managers are accustomed to a system of regulatory restraints, it is easy to assume that regulations have direct effects in controlling harvest; that is, changes in bag limits or seasons are presumed to produce corresponding changes in behavior. Where this is not the case but management nevertheless proceeds without modifying the assumption, serious management shortcomings may result.[10]

Harvest Levels Based Upon the Ability of Resource Populations to Sustain Take Rather Than Upon Arbitrary Limits

Because subsistence economic systems in Alaska are both diverse and dynamic, demand for resources should not be regarded as a constant. Indeed, variability in species selection and in food output over short and long-term cycles may be one

[10]The significance of this effect should not be overstated, however. Harvest practices and cycles of activity are long-established in many areas. As a result, managers' assessments of population status may unknowingly take into account unreported harvest or other use characteristics that may affect resource abundance and distribution.

defining characteristic of subsistence economies. Demand for wildlife, like other products, is not static but is affected by many factors, including:

1. the availability of the resource; (seasonal, annual, or longer-term fluctuations occur and populations are often subject to impact by "non-consumers" such as industrial development);
2. the relative expense, in time, effort, and money, required to harvest a resource;
3. the relative utility of a product in comparison with other products, including other species; and
4. the relative perceived need for the resource.

(Wolfe 1979:214–244). Each of these is influenced by a number of other factors, such as resource population size, geographic distances of resources from a user group, levels of harvest for other species during a year, monetary income during a year, restrictions placed upon methods of harvest and harvest seasons, competition among user groups, climatic and geophysical conditions (such as ice conditions), and other considerations. Many of these variables may fluctuate from year to year. It is clear that regulations are only one factor, and in many cases not a signficant one, affecting demand for resources and harvest levels.

Because of these dynamics, arbitrary harvest limits have no place in a sensible management program. A static ceiling is not responsive to cycles of harvestable resources that often occur over long periods. If an arbitrary ceiling is imposed, it may lead to inhibition or distortion of harvest patterns associated with these resources and may cause unanticipated changes in other parts of the annual harvest cycle. The net effect could be impairment of both subsistence use patterns and management plans. An alternative approach would be based upon potentially flexible harvest levels or ranges derived from longitudinal data on resource populations and harvests by humans. Such an approach would allow for possible variation in use without adversely affecting the population base.

Management in Light of All Relevant Factors—Not Overemphasizing Harvest by Humans

Harvest by people is only one of many variables affecting abundance and distribution of resources. Wildlife management analyzes the dynamics of a species by means of population data (census, distribution and composition), fecundity and recruitment, mortality factors (including losses to predation, disease, weather, and harvest), and habitat condition (Skoog 1980). Overemphasis on the influence of the "human harvest" factor may lead to a mischaracterization of overall ecosystem dynamics and potentially ineffective management methods.

Similarly, evaluation and prediction of the subsistence use component of this harvest should not rely solely on quantified harvest data for particular species. Research on the dynamics of social and biological systems interacting over time can provide much better indices of resource demand than single species harvest data. This is not to denigrate the importance of harvest data but merely to recognize its limitations for predicting future changes in subsistence practices.

Effective Mutual Education About the Desirability of Management and the Significance of Local Conditions

Accurate subsistence harvest data can be obtained only if users understand the purposes for which the data are being sought and if they perceive those purposes as consistent with desirable ends. In the field work conducted by the Division of Subsistence, evidence has been found repeatedly that management concepts, procedures, and agencies are poorly understood in much of rural Alaska. Few distinctions are drawn between management or enforcement agencies such as the U.S. Fish and Wildlife Service, the Alaska Department of Fish and Game, and the Division of Fish and Wildlife Protection (Alaska Department of Public Safety). In addition, the processes by which regulations are developed, the uses of research data, and the reasons for management choices tend to be much more mysterious to local users than resource managers frequently assume.

Division of Subsistence field staff have noted that taking of fish or game frequently occurs outside the regulations—not because participants wish to break the law but because they perceive that the regulations are irrelevant to their long-established practices. In some areas the harvesters may be only vaguely aware of the regulations, harvest reporting requirements, or uses of management data. Even if the regulatory requirements are known, some residents have virtually no choice; to provide for their families is the major directive. Accordingly, if management is to be effective, a sensitive program of mutual education must be undertaken, in which each party seeks to understand the orientation of the other for their common benefit. This is particularly important where compulsory rules and regulations are not elements of the indigenous culture.

Meaningful Involvement of Users in Development of Regulations

Regardless of the quality of data gathered through field observations, local users consistently have additional information about production and exchange practices and resource conditions. The users typically have unique insight into what management measures are likely to be acceptable. Because effective management fundamentally depends upon voluntary compliance,[11] it is desirable to build these dimensions of user experience into the regulations.

Cooperation by users in implementation of management measures also is made more likely if the users have a meaningful role in formulating regulations. Effective participation means more than simply receiving information. Instead, it requires that user representatives be involved in understanding the problem to be addressed and in identifying management options. One potential component of this process is creation of a formal participation role such as the local advisory committee and regional council system established by the Alaska Boards of Fisheries and Game.[12]

[11]It is unrealistic to assume that enforcement activity will be adequate to assure compliance with regulations. For example, the Yukon-Kuskokwim Delta contains more than 55 separate villages and many additional summer fish camps. Enforcement of fish and game regulations throughout this large area is obviously impractical unless most users comply voluntarily.

[12]On March 1, 1982, there were 67 local advisory committees recognized by the Boards; several petitions for new committees also were pending. The committees perform a variety of functions, including development and evaluation of regulatory proposals. *See* 5 AAC 96.050.

The Boards also have designated six regions within which operate councils composed of advisory committee representatives. The regional councils are intended to facilitate communication among local committees, to provide a forum for resolving disagreements about management issues, to make recommendations to the Boards, and to perform a variety of other authorized functions. *See* 5 AAC 96.250. The importance of the regional council and advisory committee system also is recognized by federal law. *See* 16 U.S.C.A. §3115 (1980 Laws Special Pamphlet).

Another opportunity for strengthening cooperative relationships between managers and users is the employment of local field staff.[13] In this way, local people can be involved in resource assessment activities that provide insight into the issues of concern to regulatory authorities. After regulations have been adopted, local field staff can make unique contributions to the implementation phase, in part by conveying information to other members of the community.[14]

Local resource users have shown great interest in the management of fish and game. In several instances, user representatives have formed organizations to facilitate their participation in management. For example, coastal communities that utilize marine mammals have formed the Eskimo Walrus Commission (EWC). In addition to sharing information and advising on management matters, the Commission for two years has conducted studies, under grants from the Alaska Legislature, on uses of marine mammals.

In support of the Commission, the Pacific Walrus Technical Committee (PWTC) was created at the suggestion of the U.S. Fish and Wildlife Service. The Technical Committee includes scientific and management personnel from federal and state agencies as well as commission representatives. The PWTC provides technical information and liaison to the Commission. Together, the EWC and the PWTC provide a direct user-manager dialogue and a means for shared management discussions. They also represent a significant initiative by local users in developing a meaningful management role.[15]

Summary and Conclusions

Effective wildlife management in Alaska requires an approach reflecting the realities of today's subsistence way of life. Otherwise, management will be hampered by a significant data shortfall, possibly producing virtual inability to manage. Wildlife managers have a real opportunity to gather reliable data and to achieve local cooperation. Because subsistence use data have not previously been available to managers, even a relatively small investment in the necessary research has produced a substantial return of usable information. The potential benefits include both better management decisions and more effective execution of management programs.

[13]The Division of Subsistence has enjoyed considerable success in employing local and bilingual staff in professional resource specialist positions and in technical assistant roles. Their contributions to field data and analysis have been substantial (*See, e.g.*, Stokes and Andrews 1982). The Division views the technician responsibilities as valuable experience which may lead to higher level program positions. The U.S. Fish and Wildlife Service also has employed local staff in gathering subsistence use data (*See* Copp and Smith 1981).

[14]Management approaches sometimes have encountered resistance because they attempt to impose unfamiliar forms of social control that conflict with long-established local mechanisms. Traditional methods of encouraging socially acceptable behavior may help provide effective limits for use in fish and wildlife management. Indeed, it has been argued that such methods offer far greater potential for success than the Anglo-American codifications used in the United States (*See* Worl Associates 1978, Worl 1979, *see also* Hallowell 1955).

[15]Other users have established organizations with similar purposes. The Alaska Eskimo Whaling Commission is involved directly in monitoring bowhead whale harvest quotas, through a cooperative agreement with the National Marine Fisheries Service, U.S. Department of Commerce. Similarly, rural Alaskan users of the Porcupine Caribou Herd have joined with their counterparts in the Yukon Territory to form the International Porcupine Caribou Commission.

Short-term results may include not only better maintenance of the resource base but also continuation of opportunities for non-subsistence use. Wildlife users outside of Alaska may benefit directly from this improved management. In the context of migratory birds, for example, more reliable harvest and use data could lead to projections of take which, in turn, could produce more accurate assessments of harvestable surplus.

Plans for better research and management probably will be ineffective, however, if users perceive management to be either antithetical or irrelevant to their interests. To increase the probability that management will be effective, several specific measures have been suggested:

1. Cooperation between managers and users in development of reliable data and management.
2. Harvest levels based upon the ability of resource populations to sustain take rather than upon arbitrary limits.
3. Management in light of all relevant factors—not overemphasizing harvest by humans.
4. Effective mutual education about the desirability of management and the significance of local conditions.
5. Meaningful involvement of users in development of regulations.

These steps are mutually supportive and should not be considered in isolation.

Because subsistence economic systems are dynamic, research data should include all aspects of system functioning—not merely harvest data. Only in that way will predictive ability be developed, since harvest data alone, even when suggesting historical trends, do not identify causal factors. In addition, existing data are inadequate in most parts of Alaska to allow reliable estimates of current harvests. Even if such information were available, resulting estimates would not provide an adequate basis for management because current harvest levels, lacking both longitudinal data and analysis of system dynamics, are not meaningful as projections for the future.

The potential rewards of realistic management policies for subsistence include long-term benefits as well. Wise harvest allocation policies will enable subsistence-reliant communities to retain the economic base that best meets their needs—including nutritional, social, and cultural components. To the extent these communities continue their subsistence way of life, concern about wildlife populations and habitats will be an important theme of local and regional planning decisions. As with improved management, users in Alaska and in other places stand to benefit.

The value of using fish and game as part of the self-sufficiency base is, at best, difficult to quantify, but its importance to Alaskan communities and households is clear. Managing in recognition of subsistence realities can protect these opportunities while maintaining the resource populations that all user groups value.

References Cited

Cohen, Y. A., ed. 1974. Man in adaptation: the cultural present. 2nd ed. Aldine Publishing Co., Chicago.

Collins, R. 1982. Upper Kuskokwim Fish and Game Advisory Committee, Testimony before the Alaska Board of Game, Anchorage.

Copp, J., and M. Smith. 1981. A preliminary analysis of the spring take of migratory waterfowl by Yupik Eskimos on the Yukon-Kuskokwim Delta, Alaska. U.S. Fish and Wildlife Service, Yukon Delta National Wildlife Refuge, Anchorage, Alaska.

Davidson, A. 1974. Does one way of life have to die so another can live? Yupiktak Bista, Bethel, Alaska.
Ellanna, L. J. 1980. Bering-Norton petroleum development scenarios and sociocultural impacts analysis, volumes I and II. Technical Report No. 54. Bureau of Land Management, Alaska OCS, Anchorage, Alaska.
Fall, J. 1981a. Patterns of Upper Inlet Tanaina leadership, 1741–1918. University Microfilms, Ann Arbor, Mich.
———. Traditional resource uses in the Knik Arm area: historical and contemporary patterns. Division of Subsistence, Alaska Department of Fish and Game, Juneau.
Hallowell, A. I. 1955. Culture and experience. University of Pennsylvania, Philadelphia.
Lee, R. B., and I. DeVore, eds. 1968. Man the hunter. Aldine Publishing Co., Chicago.
Lonner, T. D. 1980. Subsistence as an economic system in Alaska. Division of Subsistence, Alaska Department of Fish and Game, Juneau.
Skoog, R. 1980. Letter to Keith Schreiner, Area Director, U.S. Fish and Wildlife Service, May 23, 1980. On file at Alaska Department of Fish and Game, Juneau.
Steward, J. H. 1972. Theory of culture change: the methodology of multi-linear evolution. University of Illinois Press, Urbana.
Stickney, A. 1981. Subsistence resource utilization: Nikolai and Telida—Interim Report II. Division of Subsistence, Alaska Department of Fish and Game, Juneau.
Stokes, J., and E. Andrews. 1982. Subsistence hunting of moose in the Upper Kuskokwim Controlled Use Area. Division of Subsistence, Alaska Department of Fish and Game, Juneau.
Thomas, D. 1981. Norton Sound-Bering Strait subsistence king crab fishery. Division of Subsistence, Alaska Department of Fish and Game, Juneau.
Vayda, A. P., ed. 1969. Environment and cultural behavior. University of Texas Press, Austin.
Veltre, D., and M. Veltre. 1981. A preliminary baseline study of subsistence resource utilization in the Pribilof Islands. Division of Subsistence, Alaska Department of Fish and Game, Juneau.
Wolfe, R. 1979. Food production in a western Eskimo population. University Microfilms, Ann Arbor.
———. 1981 Norton Sound/Yukon Delta sociocultural systems baseline analysis. Technical Report No. 72. Bureau of Land Management, OCS, Anchorage, Alaska.
Worl Associates. 1978. Beaufort Sea Region. Sociocultural Systems. Tech. Rep. No. 9. Bureau of Land Management, Alaska Outer Continental Shelf Office, Anchorage, Alaska.
Worl, R. 1979. Sociocultural assessment of the impact of the 1978 International Whaling Commission quota on Eskimo Communities. University of Alaska, Arctic Environmental Information and Data Center, Anchorage.

Interstate and International Management Implications of Salmon Hatchery Production

Robert S. Roys
Alaska Department of Fish and Game, Juneau

Pacific salmon ranching, both natural and artificial, is a topic that one encounters with increasing regularity in the literature, periodicals newspaper, and TV. Recently, a TV program was aired in Alaska called "Salmon on the Run," which popularized some of the issues facing salmon managers in the Pacific Northwest—Indian ownership, corporate ownership of hatcheries, loss of habitat, user group conflict (e.g. sport, commercial, cultural) and a brief review of natural versus artificial production. The magic of national TV has arrived to assist responsible persons in solving salmon management problems by bringing "facts" to the attention of the public. TV - presented analyses, coupled with judicial edicts, should immeasurably assist harried salmon managers in Washington, Oregon, and California in solving extremely complex biological, cultural, and economic problems.

The purpose of this paper is not to discuss pro's and con's of media analyses and the salmon management implications of judicial findings. But rather the purpose is to suggest that national attention must now be focused on long-range problems associated with massive enhancement activities contemplated by the dominant salmon harvesters—Alaska, Japan, and the U.S.S.R., instead of just short-term problems associated with minor producers such as California, Oregon and Washington.

That Alaska, U.S.S.R, and Japan *are the major salmon harvesters* is illustrated by Figure 1, where 5-year moving average catches since 1930 have been plotted. During the late 1930s, the Asian salmon catch (Japan and U.S.S.R) averaged about 219 million, Alaska was about 97 million, and the rest of North America (British Columbia, Washington, Oregon and California) was about 30 million, for an average annual harvest of about 346 million during that period.

Converting these data to a percentage of all Pacific salmon harvested in those years shows that Asian catches averaged 63 percent of the Pacific salmon harvested during the late 1930s, Alaska averaged 28 percent, and the rest of North America, about 9 percent.

In the mid-1970s, Asian salmon harvests averaged about 121 million, Alaska 45 million, and the rest of North America was about 29 million, for a total of 195 million. Average catch percentages were somewhat similar to the late 1930s, with Asia estimated at 62 percent, Alaska 23 percent, and the rest of North America about 15 percent.

The United States commercial Pacific salmon industry usually ranks first or second in landed value of all U.S. finfish fisheries ($413 million ex-vessel catch value and $2.8 billion retail value in 1979) (R. Simpson pers. comm. 1982). There are more United States fishing vessels (20,000) and more citizens engaged in Pacific salmon commercial fishing (30,000) than any other commercial fishing activity in the nation.

In 1980, $904 million, 53 percent of the U.S. edible fisheries exports, came from Pacific salmon. The Alaska salmon industry produced 83 percent, or $345 million,

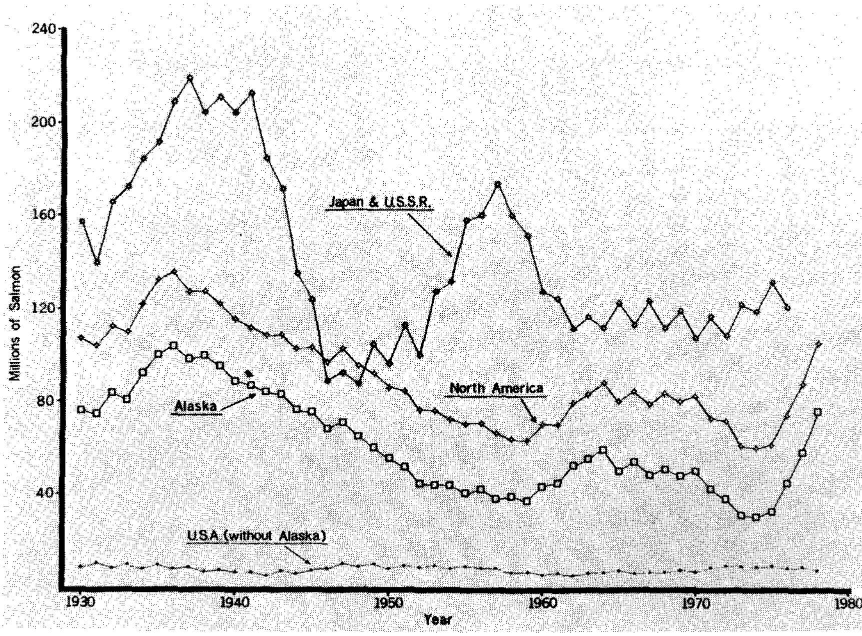


Figure 1. Five-year moving average of commercial salmon harvests in the North Pacific Ocean, 1930–1978.

of the national salmon ex-vessel value in 1979. Of Alaska's share, some 59 percent, or $204 million, was harvested by Alaskans

In 1979, the non-resident catch of Pacific salmon in Alaska was worth $141 million, slightly more than twice the $68 million in the ex-vessel values of catches originating in California, Oregon, and Washington. There are more than a million Pacific salmon sport anglers in the United States with effort being concentrated in Washington, Oregon and California. Alaska's Pacific salmon sport industry is exploding, with Anchorage serving as "jumping off place" for foreign sportsmen. Thousands of private vessels and hundreds of charter boats worth millions in capital investments are engaged in the Pacific salmon sport fishery, which was conservatively estimated to be worth $246 million in 1980. From the foregoing statements, it is reasonable to conclude that Pacific salmon are internationally important species that contribute to a multi-billion dollar industry in the United States.

There is one common denominator in the North Pacific salmon area—whatever one country does affecting pricing, production, and marketing undoubtedly will affect the other countries politically, biologically and economically. Obviously, the possibility exists that the greater the change from the status quo the greater the effects may be.

There are proposed changes in the status quo that carry great potential for impacting the salmon industry. The impacts will be brought about by significant production increases stemming from rapidly expanding enchancement efforts in the U.S.S.R, Japan, Alaska and British Columbia. These enhancement efforts are summarized in Figure 2 as enchancement goals.

The U.S.S.R. plans to construct 52 new hatcheries and release 4.97 billion salmon fry into the North Pacific rearing areas by the year 2000 (Konovalov, 1980a). About half of the released fry will be pink salmon and another 2.1 billion will be chum salmon. Assuming an ocean survival rate of 1 percent, approximately 49.7 million adults could result from the Soviet releases by the year 2005.

In a report published in 1980 (Government of Japan), the Japanese government predicted that 2.3 billion salmon fry (mostly chum) will be released from public and private hatchery facilities in Japan in 1983. The average rate of return for chum salmon released from Hokkaido Island hatcheries during the period of 1969–1974 has been 2.28 percent, while the Honshu Island average survival has been 0.86 percent during the same period. Assuming an overall 1.5 percent survival, the predicted 1983 release could result in the production of 34.5 million adult salmon by 1988. That is an increase of 11.1 million adults over the return announced by the Japanese Fishery Agency (Anon. 1981) for 1980.

The Canadians (Canadian Department of Fisheries and the Environment) published a document in January 1978 that stated their goals in British Columbia were to increase the salmon catch by 190 million pounds (86.2 million kg) annually. Achievement of this goal would require the release of approximately 1.78 billion fry and should result in the return of approximately 27.1 million adults by 1993. This would be an increase of 22.3 million adults over what is expected from the releases of 1980.

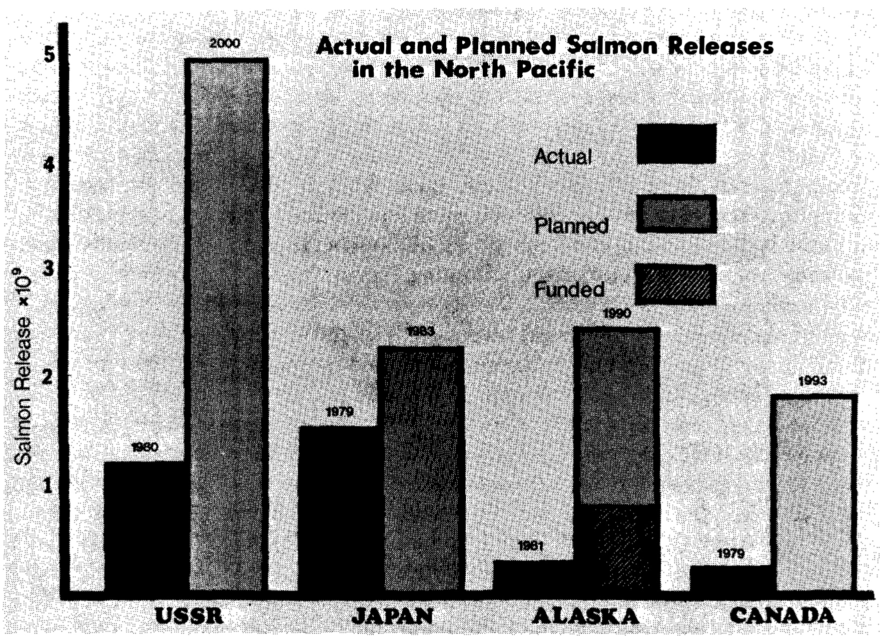


Figure 2. Enchancement efforts and goals of the Soviet Union, Japan, Alaska, and Canada.

The Alaska Salmon Fisheries Plan published by the Alaska Department of Fish and Game in 1975 called for an increase of 47.6 million adult salmon to be achieved by supplemental production facilities by 1995. Present (1982) hatchery design capacity for the public and private sector in Alaska is about 700 million fry or about 12 million adults. Efforts are primarily concentrated on pinks and chums, but sockeye are considered a high priority species for hatchery research and development. The Alaska program has stalled out at a goal of 12 million adults because of a short-sighted, urban-controlled legislature.

Collectively, Washington, Oregon, and California presently release approximately 400 million salmon annually. Most of these are chinook and coho. At this time I am not aware of any planned increases in hatchery production in those states that will measureably impact the international status quo.

Thus, by the beginning of the twenty-first century, if all enchancement goals are achieved, and the Alaska plan is reinstated, approximately 121 million (after removing 10 million adults for brood stock) additional salmon may be harvested, a percentage increase over recent average harvest levels (195 million) of about 62 percent. If natural production at the beginning of the twenty-first century is similar to that of the 1930s, the percentage increase of enchancement produced harvests will still be significant—approximately 35 percent.

What unknowns do we in Alaska foresee as this tremendous enhancement effort is launched in Asia but curtailed in Alaska—an effort that will add more salmon to the world markets than all natural and artificial production conceived for British Columbia, Washington, Oregon, and California combined? First there are a series of economic questions. As Asian salmon harvests increase, will Alaska's traditional markets (such as Europe) be captured by Asian salmon? Will Japan increase investments and expand control over Alaskan processing plants commensurate with production, or will she maintain the status quo? Some analysts claim she now controls most of the Alaskan salmon processing industry. Will the U.S.-owned processing industry be satisfied with present processing capacities and production, or will it seek reinstatement of enchancement goals and expansion of Alaskan processing capability and develop new markets? Will Alaskan salmon fishermen continue to accept processor-imposed catch limits because prerequisite processing capacity is not available, or will they seek new outlets for catches? Secondly, there are many biological questions confronting North Pacific Rim countries as the enhancement effort accelerates. Will competition for food in the marine areas become significant as recruitment increases? Will the incidence, transference, and distribution of diseases change in esturarine and marine rearing areas as stocks are intensively cultured and released? Will ocean rearing areas occupied by Asian juveniles and immatures expand and encroach on traditional North American rearing areas? Are the North Pacific salmon pastures undergoing physical changes that will increase or decrease salmon carrying capacities? Perhaps high exploitation rates of other species associated with salmon in the North Pacific will induce changes in carrying capacities either positively or negatively.

Questions posed in this paper are not original and have been raised at practically every technical salmon aquaculture meeting in the North Pacific countries. Literature pertaining to the subject is appearing with regularity. Symposia and workshops are being organized with many topics discussed, but one question often encountered is: where and how do we begin to answer some of these critical questions?

Konovalov (1980b) stated, "With consideration of such peculiarities of Pacific salmon biology as stock mixing in the marine period of life and complicated problems facing populations biology, it is necessary to come over to intersdisciplinary planning of research, creating a material and technical basis for investigations and drawing upon the cooperation of many scientists of various specialties. Consequently, the organization of research in population biology requires long-term planning, investments for many years and creation of large, temporary working teams on a national and, in a number of cases, on a international basis."

Peter Larkin (1980) addressed international salmon research problems in the following manner in the first of the McKernan lectures:

> This leads me naturally into what I see as the great hope for the future based on the great accomplishments of the past. Many of you here will remember that in 1950 we knew very little about the oceanography of the North Pacific and virtually nothing of the seaward migrations of Pacific salmon. As a consequence of the investigations conducted under the rubric of the International North Pacific Fisheries Commission, we greatly enchanced our understanding, and the magnificence of the natural spectacle of Pacific salmon migrations began to unfold. Since 1965, or perhaps, to be charitable, 1970, we have added little new. The scale, scope and intensity of international cooperation has faded rather than grown. For many years Japan, Canada and the United States cooperated in INPFC enterprises, while Japan and the U.S.S.R. annually negotiated the high seas catches of Asian stocks. From time to time there have been visitors from the U.S.S.R. to North America, and vice versa, but only rarely have the four countries collaborated on large-scale scientific studies. For reasons that I would personally summarize as a lack of imagination and enterprise at the highest levels of government, we have collectively failed to pursue the great promise of joint international undertakings.

And he further stated, "It is my passionate hope that the next two decades will be characterized by new and exciting international investigations that will bring our knowledge of Pacific salmon and of the North Pacific Ocean to levels of understanding that would be enriching to all mankind."

Soviet, Japanese, Canadian, and American scientists recognize the need for coordinated international salmon research. That research should commence near the beginning of the enchancement effort, not after the fact.

What recent statements or action has our Federal Government taken under the New Federalism to assist Alaskans and other citizens who fish her waters as major international enchancement efforts commence with awesome biological and economic implications? Perhaps it is first useful to look at what the Federal Government has been doing the past 20 years following Statehood and in response to developments in circum-Pacific salmon enchancement capabilities.

After passing responsibility for coastal salmon management to the State of Alaska, the Federal Government has maintained a declining salmonid research presence, including a pitifully small shore-based aquaculture research program in Alaska. The significance of North Pacific salmon enhancement and aquaculture developments to the Federal Government is best exemplified by the recently passed and meaningless National Aquaculture Act. That fiasco, a hallmark of bureaucratic and petty infighting between government departments (Interior, Agriculture, and

Commerce) clearly shows the Feds are far more interested in private-profit domestic aquaculture activities, such as catfish in ponds and crawdads in sloughs, than any real concern over what is happening to Pacific salmon—a truly national and international species with major commercial, cultural and sport values. In fact, there is strong doubt that, outside of a few Northwest and Alaska locals, the Federal Government even understands in the broadest context the political, social and economic ramifications of major application of ocean ranching concepts by Russia, Japan, and Canada.

To paraphrase the old cowboy range boss—the north pasture is out there, and although the fences are biological, not barbed wire, they are potentially just as effective. It's not a simple question of white hats or black hats, good guys or bad guys, but the other group—Japan, the Soviet Union, and Canada—is giving a lot more attention to putting salmon in those pastures and establishing even stronger grazing rights than we, as a nation, are.

The 200-mile (322 km) limit, Marine Fisheries Conservation and Management Act (MFCMA) of 1976 was, in part, designed to at least reduce high seas harvesting of North American salmon. In practice this act has many loopholes and sizeable defects. While open-ocean gillnetting of the magnificent cyclic Bristol Bay sockeye runs has been partially contained, we depend on a plethora of foreign draggers in the North Pacific groundfish fishery to assure us they incidently catch only insignificant numbers of salmon. Net marks on Southeast Alaska troll-caught chinook and coho salmon indicate that incidental encounters with foreign nets on the high seas result in the capture or death of numbers of fish equal to that taken in some domestic U.S. fisheries.

Ask any troller or charter boat operator from any West Coast state what the MFCMA has done for them lately and you will sense what the Feds are doing about the North Pacific pasture and salmon. But, of course, in this era of tight budget we still have tobacco subsidies and liberal catch quotas and ridiculously small fees for foreign draggers off our coast, so we can really say the Feds are concerned.

Federal concern for the Alaska salmon fisheries has recently been expressed in two general ways. The first, as manifested by the U.S. Fish and Wildlife Service and the National Park Service, is to prevent the construction of enhancement facilities or prohibit nearly any enhancement activities on lands administered by those two agencies unless it is "naturalistic."

The second expression of Federal concern emanates from budget projections for Fiscal Year 1983 for NOAA, and more specifically NMFS, where projected budget cuts are 11 percent and 30 percent, respectively, Furthermore, the research arm of NMFS in the North Pacific, the Northwest and Alaska Fisheries Center, suffered a 35 percent reduction while the Auke Bay Laboratory based in Alaska was eviscerated. The Auke Bay budget was cut an unbelievable 74 percent and funds for all of the salmon aquaculture research were eliminated.

A tremendous amount of Federal, State and private financial, legal, and verbal effort was expended, and is still being expended, to protect the so called National Crown Jewels and promote sound development of lands, minerals, and waters in Alaska. Those land withdrawals were heralded as necessary for future generations. If those land withdrawals were the Crown Jewels to environmentalists, then our fishery jurisdictions in the North Pacific, Bering and Chukchi Seas must be considered our National Fisheries Treasure. There is of course a major difference. We are practically giving away those fisheries to foreign nationals or allowing them to establish dominance in the salmon pastures of the North because of indifference and inactivity on our part.

We know that some scientists in the Soviet Union believe that in the future we will be negotiating salmon fry-fingerling and smolt recruitment rights in those finite pastures—but they will have the data upon which to base negotiation, not us.

What are we to do in Alaska—proceed on our own like a foreign nation and attempt to seek answers that will at least require: high seas research vessels, international interdisciplinary working teams, sophisticated equipment, and long-term funding commitments? The State of Alaska and her citizens cannot afford the venture nor should they be asked for such largesse to protect not only Alaskan rights but the rights of other states' citizens also.

What is the solution to our dilemma? Is it secession, as some Alaskans have proposed? Is it establishment of an Alaska Region for resources not divided into different federal departments? Is it the establishment of a National Fisheries policy, including North Pacific salmon, that is based upon U.S. interests and not bureaucratically defined and defended territories? I don't know the answers, but I do know this: U.S. National Fisheries Treasures adjacent to Alaska warrant at least a Special Assistant to the Secretary of Commerce similar to the Special Assistant in the Department of Interior for Alaska lands. And that Special Assistant should be charged with developing and recommending policy and program direction to the Secretary that will:

1. Establish policies to guarantee a strong U.S. position of fisheries utilization in the North Pacific, Bering and Chukchi Seas for future American generations.
2. Develop an aggressive national research policy that will ensure and protect vital U.S. interests in salmon in these northern seas.
3. Promote cooperative research between States, the Federal Government, British Columbia, Japan, and the U.S.S.R.

National attention must be focused on the importance and the value of the Fisheries Treasures in the Northern Seas adjacent to Alaska's coastline. To do less is to yield to inevitable and perhaps irrevocable domination of this treasure by foreign interests.

Literature Cited

Anonymous. 1981 Japan Update. Pacific Fishing Magazine. Sept. 1981, p. 31.

Canadian Department of Fisheries and the Environment, Fisheries and Marine Service. 1978. The Salmonid Enchancement Program. Canadian Dep. Fish. and Environ., Ottawa. 86 pp.

Government of Japan. 1980. Japanese Salmon Catch 1965–1979. Japan Government Report, Tokyo. 32 pp.

Konovalov, S. M. 1980a. U.S.S.R.: Salmon ranching in the Pacific. Pages 63–89 *in* J. E. Thorpe, ed. Salmon ranching. Academic Press, London.

———. 1980b. The main problem of the population biology of Pacific salmon. Pages 324–325 *in* W. J. McNeil and D. C. Hepworth, eds. Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis.

Larkin, P. 1980. Pacific salmon scenarios for the future. Washington Sea Grant. University of Washington, Seattle 23 pp.

Chairman:
CLAY SCHOENFELD
Chairman
Environmental Communications Center
University of Wisconsin, Madison
Cochairman:
TOMMY L. BROWN
Senior Research Associate
Cornell University
Ithaca, New York

Historical Trends In American Animal Use and Perception

Stephen R. Kellert
School of Forestry and Environmental Studies
Yale University
New Haven, Connecticut

Miriam O. Westervelt
Division of Program Plans
U.S. Fish and Wildlife Service
Washington, D.C.

Introduction

The presumption of most historians is that contemporary Americans are more concerned about wildlife than ever before. Do we perhaps presume too much? Is our age truly distinctive in its degree of environmental and wildlife awareness, at least among ordinary Americans? Do the many legislative changes in environmental law and protection since World War II actually reflect substantive shifts in the average person's perceptions of animals? The passage of laws can often reflect more the attributes of power and persuasiveness of special interest groups than the pressing concerns of the general public.

The purpose of this paper is to review the results of a study of historical trends in American animal use and perception during the twentieth century. Three interrelated objectives guided this research, including: (1) assessing the extent of change in American animal use and perception during the twentieth century; (2) reviewing this change among diverse groups in American society; and, (3) determining the rate and progress of this change.

This paper is based on a much longer report (166 pp.) that can be obtained either from the authors or from the U.S. Fish and Wildlife Service. This report is the fourth in a series of studies on American attitudes, knowledge and behaviors toward animals funded by the U.S. Fish and Wildlife Service.

Methodology

An analogous study in Canada by Bos et al. (1977) suggested analyzing the content of newspaper articles over a period of time as a good indicator of public perceptions and uses of animals. Despite the tendency of newspapers to report on primarily "newsworthy" events, a numbers of factors recommended its use. First, newspapers tend to be oriented to local constituencies. Second, if judiciously selected, newspapers can reflect urban, rural, as well as regional differences. Third, by selecting newspapers in continuous publication throughout the century, historical changes can be examined relatively undistorted by interpretive recall. Finally, because of their local and continuous publication, newspapers can reflect the experiences and concerns of a large fraction of the general public.

Various reference books were used to identify possible newspapers for this analysis, including the *Ayers Directory of Publications* (1977) and, to a less important extent, the *American Newspaper Market's Circulation* (1978) and *Newspapers in Microform U.S.* (1973). Twenty newspapers (7 urban and 13 rural) were identified as possibilities. Four were eventually selected representing two rural, two urban, and altogether four regional locations. The two urban newspapers were the *Los Angeles Times*—representing the Far West—and the *Hartford Courant*—the Northeast. The two rural papers were the *Buffalo Bulletin* (Buffalo, Wyoming)—the Rocky Mountain Newspaper—and the *Dawson News* (Dawson, Georgia), representing the South.[1]

The considerable time required for this type of analysis necessitated a random sampling of newspaper issues. Seventeen issues were chosen in a single year, with two to three year intervals between annual reviews. Every third year starting with 1900 was selected for the analysis except for critical historical periods, when every other year was chosen. The two-year interval periods included the wilderness cult/ Teddy Roosevelt era from 1900–1906, World War I, the Depression, and World War II. Thus, 31 years were included in the analysis.

Seventeen to eighteen newspaper issues were selected for a single year, yielding approximately 550 issues for each newspaper analysis. Using the perpetual calendar of the *World Almanac* (1977), starting dates in each year were randomly identified, with issues chosen each successive third week. In consecutive weeks, the following day of the week was selected to assure a roughly equal sampling of days.

Time constraints necessitated a smaller sampling of the *Hartford Courant*. Specific issue selection for this newspaper was based on the *Los Angeles Times* sample, with the date of every third *Los Angeles Times* issue included in the *Hartford Courant* sample. This sampling procedure resulted in 86 *Hartford Courant* issues based on six editions per year.

The most critical and difficult methodological step was the development of a standardized, empirical procedure for recording the content of the animal-related articles. An acceptable content analysis procedure necessitated seven formats being drafted, reviewed, and modified before a final system evolved. Seventeen

[1]Buffalo (population, 3500) is in east-central Wyoming on the edge of the short-grass prairie, some 108 miles from the urban area of Casper, Wyoming. Dawson (population 5500) is in central-western Georgia, some 60 miles from the metropolitan area of Columbus on the Alabama border.

types of information were collected. Basic descriptive information included the newspaper in which the article occurred, the issue date, the location of the article, its relative importance (in relation to the issue and in general), the geographic scope of the article (e.g., local, national, international), and the type of article (e.g., general news, column, etc.). Information on specific animals in the article included the taxonomic identity of the animals; if appropriate, the type of wild animal (e.g., terrestrial mammal, songbird, etc); the relationship of the animal to human beings (e.g., game, pet, livestock, etc.); if the animal was wild, its population status (e.g., endangered, rare, etc.); the geographic location of the animal (e.g., region of the U.S., country); and the exotic/native status of the animal relative to the United States. Detailed information on 31 separate animal-related activities was gathered, including such activities as hunting, fishing, trapping, animal-related fashion and art, bird-watching, animal-related food gathering and processing, non-consumptive wildlife use, animal-inflicted damage, animal ecology, animal rights and welfare, pet-ownership, wildlife management, etc..

The final information collected considered attitudes toward animals. A typology of 10 attitudes was used, based on a system developed previously (Kellert 1976). One-sentence definitions of each attitude are provided in Table 1, although more lengthy descriptions are available elsewhere (Kellert 1980a). The strength or intensity of the attitudes was measured on a 1 to 10 scale, with 1 indicating the most intense expression and, 10, the attitude as present but only in a peripheral or marginal way. At least one attitude was coded for each article, although this attitude was not necessarily coded as strongly present. For example, if an article consisted of a short descriptive statement of an animal, it might receive a neutralistic code of 10 with no other attitude cited. On the other hand, more than one attitude was often present in an article and sometimes each received strongly present codes.

Five persons were trained to analyze and record the content of the articles. Each coder analyzed at least 50 articles before being allowed to work on the sample newspaper issues. Despite extensive coder training, the interpretive requirements of content analysis render the technique difficult to standardize and completely remove from subjective bias. A large sample size, careful coder training, and the use of only a few coders may have minimized these problems.

Table 1. Attitudes toward animals.

Aesthetic:	Primary interest in the artistic and symbolic characteristics of animals.
Dominionistic:	Primary interest in the mastery and control of animals, typically in sporting situations.
Ecologistic:	Primary concern for the environment as a system, for interrelationships between wildlife species and natural habitats.
Humanistic:	Primary interest and strong affection for individual animals, principally pets; regarding wildlife, primary focus on large animals with common anthropomorphic associations.
Moralistic:	Primary concern for the right and wrong treatment of animals, with strong opposition to exploitation or cruelty toward animals.
Naturalistic:	Primary interest and affection for wildlife and the outdoors.
Negativistic:	Primary orientation a dislike or fear of animals.
Neutralistic:	Primary orientation a neutral relation to and emotional detachment from animals.
Scientistic:	Primary interest in the physical attributes and biological functioning of animals.
Utilitarian:	Primary concern for the practical and material value of animals or the animal's habitat.

Results

A total of 4,873 animal-related articles were analyzed for the 75-year period. An average of 157 articles occurred per year, or 2.74 per newspaper issue.

Somewhat unexpectedly, no discernible trend appeared toward increasing numbers of animal-related articles during the century (Figure 1). The greatest number of articles in a single year was 275 in 1964, although 1921, 1927, 1930 and 1967 also had more than 200 articles (Table 2). When the 75 years were distinguished by critical historical periods, three periods had an average of more than 200 articles per year—1921–27, 1930–1936 and 1961–1967. The periods with the fewest number of articles were the two world wars—1916–1918 and 1940–1944—each averaging less than 115 articles per year.

Interestingly, the periods with the greatest number of animal-related articles were among three of four eras identified by Rose (1971) as major conservation periods of the twentieth century. The most important conservation-related influence of the 1920s was a technological development—the automobile—that markedly stimulated public interest in wildlife and the outdoors (Trefethen 1976). National parks and wilderness areas became, for the first time, readily accessible to tourists, campers, and sportsmen and, as a consequence, an unprecedented demand for recreational use of natural resources occurred. The 1930s, on the other hand, focused the nation's attention on the results of grossly unwise resource use and depletion, accompanied by the first large-scale Federal attempts at wildlife and public land management. Additionally, the 1930s remained a period of extensive recreational interest in wildlife and the natural environment. Finally, the 1960s witnessed the emergence of broad public concern for wildlife conservation, symbolically marked by the occurrence of "earth day" as the decade drew to a close.

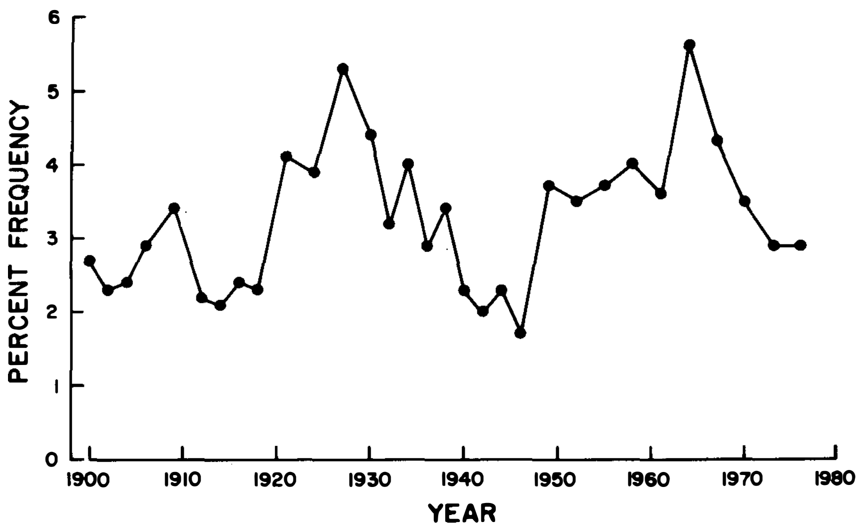


Figure 1. Frequency of animal-related newspaper articles, 1900–1976.

Table 2. Frequency of articles by year, 1900–1976.

Year	Frequency	%	Year	Frequency	%
1900	130	2.7	1936	142	2.9
1902	111	2.3	1938	166	3.4
1904	119	2.4	1940	111	2.3
1906	140	2.9	1942	98	2.0
1909	164	3.4	1944	110	2.3
1912	109	2.2	1946	82	1.7
1914	106	2.1	1949	181	3.7
1916	119	2.4	1952	173	3.5
1918	114	2.3	1955	178	3.7
1921	200	4.1	1948	196	4.0
1924	190	3.9	1961	174	3.6
1927	259	5.3	1964	275	5.6
1930	213	4.4	1967	210	4.3
1932	157	3.2	1970	170	3.5
1934	196	4.0	1973	139	2.9
			1976	141	2.9

Total number of articles = 4,873
Average number of articles per year = 157
Number of issues = 1,777
Average articles per year = 2.74

The two world wars, in contrast, shifted the country's attention away from environmental concerns, as the imperatives of a nation in conflict focused concern on the suffering and needs of people.

The animal-related articles were also distinguised according to broad stylistic categories. The general news category was, by far, the most common, accounting for 63 percent of all animal-related articles during the century. On the other hand, this type of article decreased significantly from 79 percent of the total from 1900–1915 to 55 percent in 1961–1976. Pictorial stories were second in overall frequency, but increased dramatically from just 3.4 percent of the total at the beginning of the century to nearly 19 percent since 1960. Similarly, hunting and fishing columns increased markedly, from not occurring at all in 1900–1915 to accounting for 4 percent of the total from 1961–1976. Animal-related feature stories accounted for nearly 11 percent of the total and remained relatively constant during the initial and final 15 years examined, although decreasing markedly from 1946–1960. Animal-related editorial page articles accounted for just 2 percent of the total, although increasing in recent years.

One of the most interesting analyses considered the frequency of the attitudes toward animals. The relative percentage and rank of each attitude during critical periods and for the entire 75-year period are summarized in Table 3 and Figure 2.

The greater occurrence of the utilitarian attitude was especially impressive (Figure 3). The preponderance of this attitude during the war periods was particularly striking, notably World War I when the utilitarian perspective accounted for a remarkable two-thirds of all attitude classifications. On the other hand, a substantial decline in the utilitarian attitude in recent decades also occurred. Illustrative of this decrease, just 12 percent separated the utilitarian attitude from the next most frequent attitude (the neutralistic) from 1970–1976, compared to a 36 percent difference when contrasted with the second most frequent attitude (the humanistic) in 1900–1906. This decrease in the utilitarian attitude was quite pronounced in the *Los Angeles Times,* declining from a high of over 50 percent during World War I to just over 20 percent since 1970.[2] In striking contrast, the utilitarian perspective decreased slightly in the rural newspapers and, in the *Dawson News,* this attitude still accounted for nearly two-thirds of all attitudes classifications from 1970–1976.

The humanistic attitude was the second most frequent attitude during the century; found in approximately 16 percent of the articles examined, although its relative rank dropped to fourth by 1961–1976. The humanistic perspective achieved its greatest prominence during World War II, when 26 percent of the articles included this attitude. Like the ultilitarian attitude results, very pronounced urban/rural differences were observed. In the *Los Angeles Times,* the humanistic perspective substantially increased and, since World War II, occurred in nearly 30 percent of this newspaper's articles (Figure 4). In contrast, this attitude decreased so precipitously in the rural newspapers that, by 1961–1976, it was observed in only 3 percent of the Dawson and Buffalo newspapers. Thus, the rural newspapers were characterized by a marked decline in the humanistic perspective in addition to the continuing importance of the utilitarian attitude. *The Los Angeles Times,* in

[2]The *Hartford Courant* results are excluded from this discussion due to insufficient sample size.

Table 3. Percentage and relative rank of basic attitudes toward animals by historical periods (Rank in parentheses).

	Naturalistic	Ecologistic	Humanistic	Moralistic	Scientific	Aesthetic	Utilitarian	Dominionistic	Negativistic	Neutralistic
1900–1906	3.8 (8)	6.6(6)	16.2(2)	4.6 (7)	10.6 (4)	6.6(6)	52.2(1)	6.6(6)	11.4(3)	8 (5)
1909–1915	6.8 (6)	5.5(9)	17 (2)	4.2(10)	9.2 (5)	6.5(7)	47.2(1)	12.3(4)	16.8(3)	5.7(8)
1916–1918	3.9 (6)	5.2(5)	9.1(3)	2.1 (9)	5.2 (5)	2.5(8)	65.9(1)	3.5(7)	17.5(2)	7.8(4)
1921–1927	2.5 (9)	6 (6)	15.1(2)	1.5(10)	7.5 (4)	5.9(7)	61.8(1)	3.7(8)	12.9(3)	6.6(5)
1930–1938	3.1 (9)	6.6(7)	18.1(2)	2.4(10)	8.5 (6)	9.1(5)	47.2(1)	5.8(8)	12.5(3)	10.6(4)
1940–1944	2.1 (8)	3.2(7)	26.1(2)	1.5 (9)	2.1 (8)	10.7(4)	49.8(1)	6 (6)	13.2(3)	10.3(5)
1946–1958	2.1(10)	5 (7)	15.4(3)	3 (9)	4.8 (8)	8.3(6)	46.8(1)	9 (5)	9.5(4)	18.5(2)
1961–1967	3.8 (9)	9 (6)	13.3(4)	2.6(10)	8.9 (7)	10.5(5)	37.2(1)	14 (3)	5.2(8)	23.8(2)
1970–1976	4 (9)	13.4(4)	14.2(3)	4.9 (8)	2.1(10)	9.9(5)	38.9(1)	8.5(6)	6 (7)	27.5(2)
Overall *X* 1900–1976	3.4 (9)	6.8(8)	16.1(2)	2.9(10)	6.9(7)	8.1(5)	48.5(1)	7.9(6)	11 (4)	13.9(3)

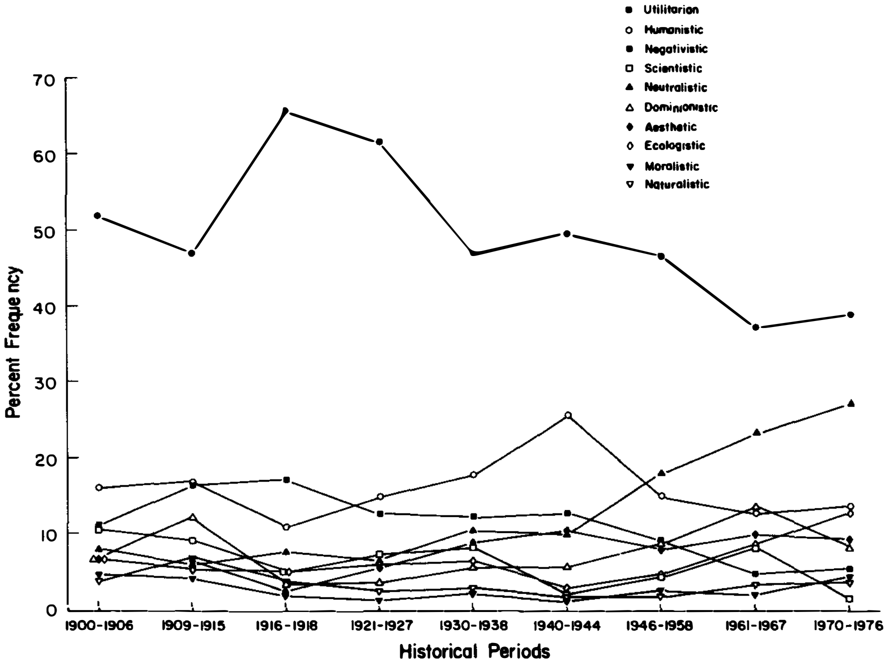


Figure 2. Frequency of ten attitudes toward animals, 1900–1976.

contrast, revealed the opposite pattern, with substantial decreases in the utilitarian perspective being accompanied by major increases in the humanistic attitude. This urban/rural difference was also reported in a 1978 survey of 3,107 Americans (Kellert and Berry 1981).

The neutralistic attitude ranked third in overall frequency of occurrence. Additionally, this attitude steadily increased during the 75-year period, particularly since World War II, and ranked second after 1970 (Figure 5). An increase in the neutralistic attitude was especially pronounced in the rural newspapers. In the *Buffalo Bulletin,* prior to 1930, this attitude occurred in 6 percent of the articles but, since 1960, in over 40 percent. In contrast, in the *Los Angles Times,* the neutralistic attitude appeared in 18 percent of the articles from 1946–1960, but just 8 percent since 1961.

The negativistic attitude decreased markedly, although this attitude ranked fourth overall and occurred in 11 percent of the articles (Figure 6). From 1900–1946, the negativistic attitude was found in approximately 14 percent of the articles but, since World War II, in just 7 percent. This attitude dramatically declined in the rural newspapers, although only gradually in the *Los Angeles Times.*

The more frequent occurrence of the utilitarian, humanistic, negativistic, and neutralistic attitudes paralleled results reported in the 1978 national survey (Kellert 1980b). Percentage differences among the attitudes, however, were substantially larger in the historical than national survey studies.

The aesthetic attitude was the fifth most frequently occurring attitude, although found in less than 10 percent of the articles. This attitude increased slightly during

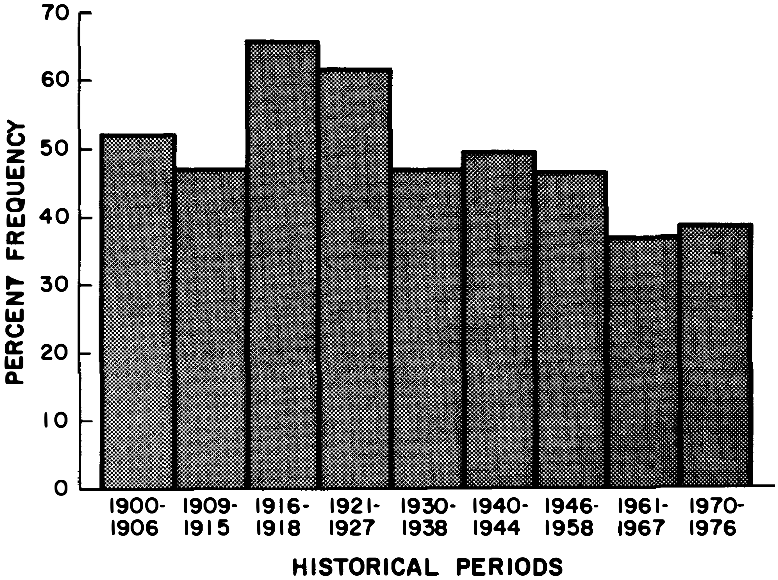


Figure 3. Frequency of utilitarian attitude, 1900–1976.

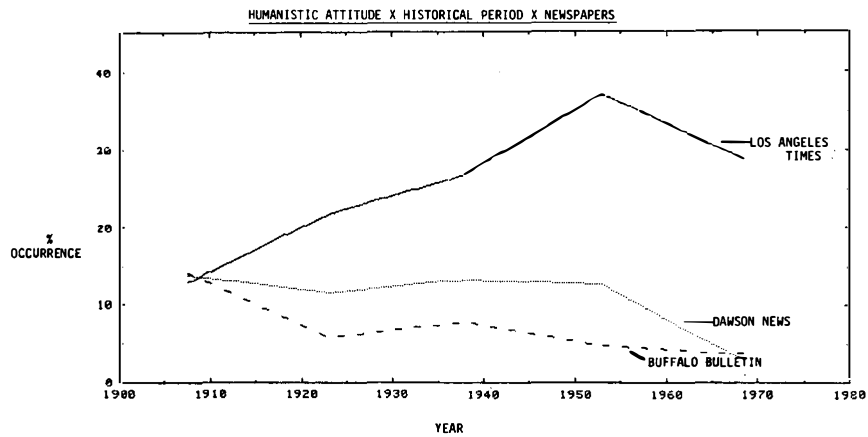


Figure 4. Humanistic attitude by historical period by newspapers.

the 75-year period—occurring in 5.6 percent of the articles prior to 1930, but nearly 10 percent since that time. The aesthetic perspective was far more prevalent in the *Los Angeles Times* than in the rural newspapers in recent decades (Figure 7). This result further suggested that an appreciative, emotional, and less pragmatic perspective of animals was more typical of urban than rural areas, especially since World War II.

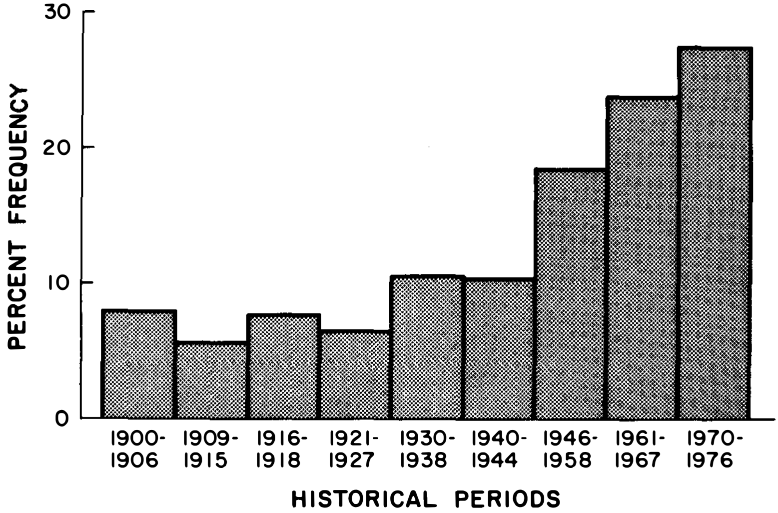


Figure 5. Frequency of neutralistic attitudes, 1900–1976.

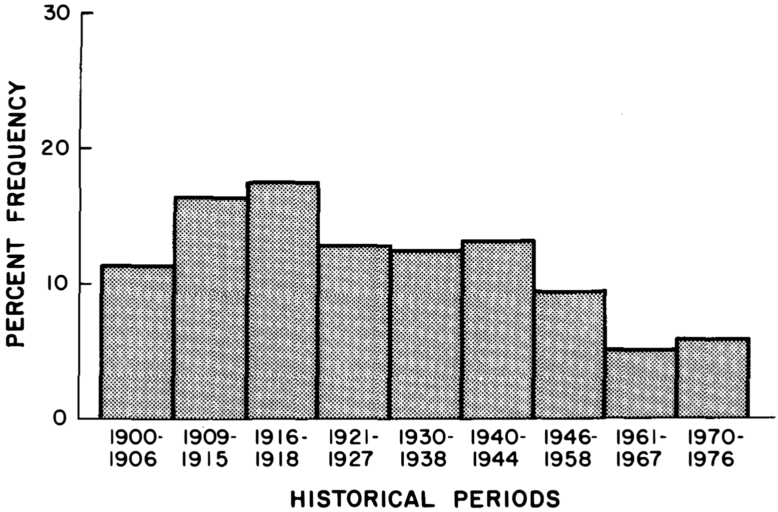


Figure 6. Frequency of negativistic attitude, 1900–1976.

The dominionistic attitude was present in approximately 8 percent of the articles and ranked sixth during the century. It erratically occurred, however, with no trend clearly evident. This attitude appeared more often in the *Los Angeles Times*, particularly since 1960.

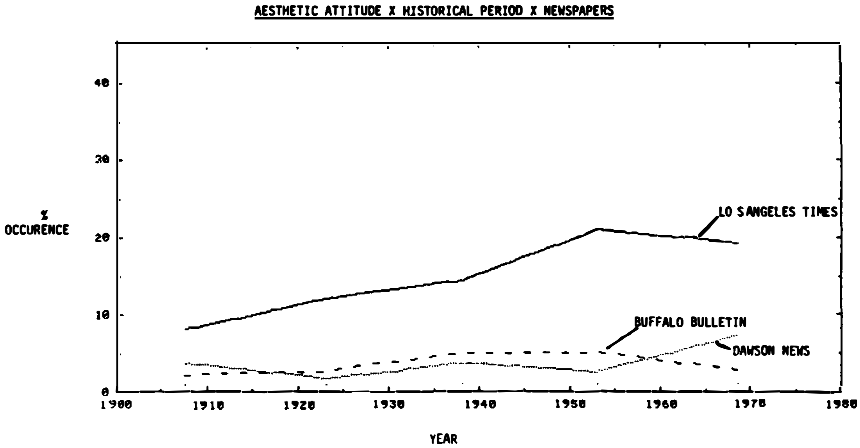


Figure 7. Aesthetic attitude by historical period by newspapers.

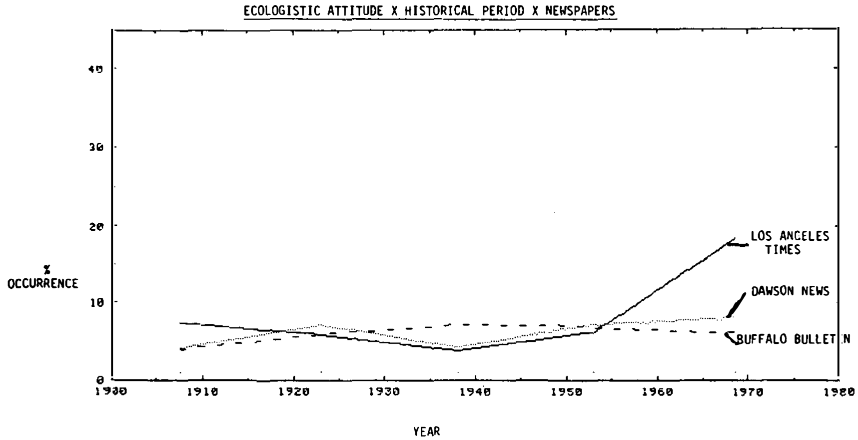


Figure 8. Ecologistic attitude by historical period by newspapers.

The ecologistic attitude occurred in 7 percent of the articles and ranked seventh overall. This attitude significantly increased since World War II, however, and, by 1970–1976, ranked fourth, appearing in over 13 percent of the articles reviewed. This growth was especially evident in the *Los Angeles Times,* as the ecologistic attitude increased from occurring in 6 percent of this newspaper's articles prior to 1960 to over 18 percent since that time (Figure 8). The ecologistic perspective only slightly increased in the rural newspapers.

The scientistic attitude ranked eighth overall and was found in approximately 7 percent of the articles. This perspective substantially decreased during the century. Until 1927, the scientistic attitude ranked fourth or fifth in frequency of occurrence but, since 1970, was the least common attitude, occurring in just 2 percent of the articles. Newspaper differences were slight after 1940 although, prior to that time, the scientistic attitude occurred far more often in the rural newspapers.

The naturalistic attitude was rarely encounterd throughout the century. In recent years, this attitude was more prevalent in the *Los Angeles Times,* but still found in only 8 percent of this newspaper's articles since 1960.

Finally, the least frequently occurring attitude was the moralistic, present in just 3 percent of the articles. Moreover, this attitude changed only slightly and appeared in no more than 5 percent of the articles during any time period. This result was especially surprising as the moralistic perspective was among the four most prevalent attitudes in the 1978 national survey (Kellert 1980b). This disparity of historical and survey analysis reflects the difficulty of comparing findings based on widely varying methodologies. Nevertheless, the historical findings do suggest the limited importance of animal cruelty and rights considerations as newsworthy events during the century. This result was particularly evident in the rural newspapers, where the moralistic attitude was practically nonexistent since World War II. In marked contrast, the moralistic perspective occurred far more often in the *Los Angeles Times,* present in 8 percent of this newspaper's articles since World War II. This urban/rural difference was similar to results reported in the 1978 national study (Kellert 1980b).

The frequency of various animal-related activities and types of animals was also examined. Farming and livestock production were the most frequent activities during the century, accounting for some 25 percent of the total. Farm and livestock activities significantly decreased, however and, since 1960, represented just 15 percent of the total (Table 4). Relatedly, livestock declined from 42 percent of all animal classifications prior to 1946 to approximately 25 percent since 1960 (Table 5). During World War I, livestock accounted for a remarkable 63 percent of all animal citations. These shifts were especially pronounced in the *Los Angeles Times* with farming declining from 13 percent of this newspaper's activity classifications during 1900–1915 to just 5 percent since 1961. Corresponding declines in the *Buffalo Bulletin* were 22.5 percent to 16.4 percent but, in the *Dawson News,* farming actually increased from 32.7 percent to 42 percent during the same time periods.

Hunting and fishing activities and game animal classifications increased significantly during the century. From 1900–1946, the proportion of game animals remained relatively unchanged, accounting for roughly 15 percent of the total; hunting and fishing activities each consisted of approximately 6 percent of the activity classifications. From 1946–1960, however, game animals increased to approximately 25 percent of all animal citations and, even more dramatically, from 1961–1976, this proportion climbed to 39 percent of the total. Additionally, since 1960, game animals for the first time displaced livestock as the most frequent classification. Relatedly, the proportion of hunting-related articles increased significantly although, somewhat unexpectedly, fishing changed slightly. Hunting increased to 12 percent of all activity classifications from 1946–1960 and to 17 percent from 1961–1976 (for the first time, replacing farming and livestock as the most frequent activity).

Table 4. Animal relationship activities by 15-year periods.

	1900–1915	1916–1930	1931–1945	1946–1960	1961–1976
Hunting	6.5%	5.7	7.7	11.6	17.1
Fishing	7.6	4.0	6.8	7.6	9.4
Fashion	1.1	1.4	0.9	0.9	1.7
Nonconsumptive use	1.3	0.5	1.0	1.4	1.9
Animal damage	12.5	8.7	8.9	6.7	4.2
Study/ecology	5.4	4.8	3.9	3.6	3.9
Wildlife management	1.5	2.0	2.3	2.8	2.1
Farming	22.0	39.1	23.4	27.1	15.5
Disease	1.9	2.8	2.7	2.3	1.4
Protection/rights	0.9	1.0	0.8	1.0	1.2
Pets	10.3	7.4	13.5	9.5	9.3
Work/protection	3.8	3.3	3.5	2.2	1.0
Illegal acts	3.0	2.6	2.8	3.5	3.9
Entertainment	7.8	8.9	13.2	15.0	13.4
Zoo/parks	1.6	1.0	2.0	1.4	1.9
Humor/human interest	5.7	4.7	4.0	1.7	1.4
General description	7.0	2.2	2.8	1.7	10.8

$x^2 = 540.18; P = <.001$

Table 5. Animal relationship by 15 year period.

	1900–1915	1916–1930	1931–1945	1946–1960	1961–1976
Furbearer	1.5%	1.3	1.0	1.1	2.4
Game	18.4	12.9	18.5	25.3	39.0
Livestock	39.9	50.1	36.7	37.2	24.5
Pest	11.5	14.9	8.6	6.1	4.5
Pet	17.4	13.4	24.4	16.6	15.9
Predator	3.8	2.3	2.8	1.8	1.6
Show/circus	6.3	4.1	6.5	10.5	11.0

$x^2 = 384.04; P = <.001$

Fishing, on the other hand, increased from 6 percent to a little over 9 percent of activity classifications during the same periods.

Animal-related entertainment (e.g., shows, circuses) experienced fairly rapid growth during the century. This activity accounted for an unexpected 12 percent of the activity classifications and increased from 8.5 percent of the total prior to 1930 to over 14 percent since World War II. Relatedly, show/circus animals grew from 3.5 percent of all animal classifications from 1900–1916 to a high of 11 percent since 1960.

Pet animal classifications changed slightly during the century and accounted for roughly 10 percent of the total. Paralleling the decline in livestock-related activities, the animal-damage category decreased from 12 percent of the total from 1900–1915 to 4 percent since 1961. Nonconsumptive wildlife-related activities and wildlife study and ecology comprised only a small proportion of the activities and, surprisingly, changed slightly during the century. For example, nonconsumptive wildlife use accounted for just 1.3 percent of the activities from 1900–1915 and a mere 2 percent since 1961. Finally, general descriptive articles concerning animals comprised 5 percent of the activity classifications and increased from 2 percent of the total prior to 1960 to nearly 11 percent since 1961.

The frequency of specific animals was also recorded but, for brevity's sake, these data will be presented in a limited manner. The dog, horse, and cow were the most numerous animals (Table 6). The most common wild animal was the deer, ranking eighth overall. Interestingly, pets, livestock and game animals included all ten of the most frequently occurring animals. Among vertebrate classes, mammals accounted for two-thirds of the animal citations, birds for 14 percent, fish for 8 percent and reptiles and amphibians, 3 percent. Invertebrates comprised 9 percent of the animal classifications.

The great majority of animal-related articles focused on local issues and native animals, and this parochial tendency increased during the century. Nearly 75 percent of the articles emphasized local considerations, 8 percent were regionally-oriented, 13 percent had a national emphasis, and just 4 percent focused on international matters. Additionally, the proportion of locally-oriented articles increased from 55 percent of the total from 1900–1915 to a remarkable 88 percent since 1960. In contrast, articles of national significance decreased from over 20 percent of the total to approximately 6 percent during the same periods. This trend toward a more local emphasis was especially evident in the rural newspapers. In the *Buffalo Bulletin,* locally-oriented articles increased from 28 percent of the total from 1900–1915 to an incredible 99.8 percent since 1961. The proportion of local articles in the *Los Angeles Times* changed slightly from 69 percent to 73 percent during the same periods.

Articles on native wildlife accounted for 84 percent of all wildlife classifications,

Table 6. Thirty most frequently occurring animal categories, 1900–1976.

Rank	Animal	*N*	Rank	Animal	*N*
1.	Dog	549	16.	Ducks/waterfowl	69
2.	Horse	370	17.	Unspecified bird	53
3.	Cow	360	18.	Unspecified mammal	48
4.	Fowl/poultry	213	19.	Mule/burro/donkey	46
5.	Unspecified livestock	208	20.	Antelope/bear	45
6.	Pig	197	21.	Nonpoisonous snake/elephant	44
7.	Sheep	121	22.	Hare/rabbit	39
8.	Deer	116	23.	Rattlesnake/unspecified insect	38
9.	Unspecified game fish	106	24.	Grasshopper	35
10.	Trout	96	25.	Rat	34
11.	Fish	90	26.	Lion/monkey	30
12.	Unspecified game animal	88	27.	Wasp/bee	26
13.	Weevil	86	28.	Fox	25
14.	Elk	82	29.	Fly/turkey	24
15.	Cat	73	30.	Shark/tuna fish	23

and increased from 74 percent of the total from 1900–1915 to over 91 percent since 1960. Finally, articles concerning rare, endangered, or extinct animals were infrequently encountered, appearing in just 1.6 percent of the articles. The greatest proportion of articles on endangered or threatened species occurred during the initial and latter parts of the century.

Summary and Policy Implications

Possible policy and management implications of the results include:

1. The absence of any trend toward increasing number of animal-related articles during the century suggests some caution regarding greatly expanded programs based on the presumption of rapid growth in wildlife and natural area interest.
2. Major increases in hunting, fishing and other wildlife-related activities suggest a shift toward more recreational and appreciative interests in wildlife. These results qualify the initial policy implication and may indicate the need to plan for more leisure-oriented wildlife demands.
3. The frequency of wildlife-related interest during the 1920s—possibly due to the impact of the automobile—reflects the value of anticipating the effects of changing technologies (e.g., off-road vehicles, air travel) on the future demand for wildlife resources.
4. The 1930s results suggest the difficulty of presuming that periods of economic downturn, even depression, will result in diminished interest and demand for wildlife-related experiences.
5. The greater frequency of animal-related articles during the 1960s, and the lack of a trend since that time, may indicate the need for caution when reacting to the pressures of a period marked by ideological fervor.
6. Major increases in animal-related pictorial articles represent a significant public awareness challenge when one notes the visual ease of communicating the plight of, for example, baby harp seals, compared to the difficulty of visually depicting the consequences of habitat loss, particularly when invovling obscure and aesthetically unappealing creatures (e.g., the snail darter).
7. The greater frequency of the utilitarian attitude during the century indicates that a pragmatic relationship to animals remains a dominant perspective in American life. On the other hand, substantial declines in this attitude, particularly in the urban areas, suggest a decrease in materialistic orientations to animals.
8. Major increases in the aesthetic and humanistic attitudes in the urban newspapers intimate the growth of a more appreciative and emotional perspective of animals among city residents. Additionally, a pronounced increase in the ecologistic attitude in the urban areas suggests a more protectionist attitude toward wildlife and natural habitats among urban residents. Significant contrasts with the rural areas on these attitude dimensions intimate major urban/rural differences in the decades ahead.
9. Although the utilitarian attitude remained dominant in the rural areas, a marked decline in the negativistic and substantial increase in the neutralistic attitudes implied a more positive view toward animals among rural residents.
10. The infrequent occurrence of the moralistic perspective throughout the century reflects the limited importance of animal cruelty and rights considerations as newsworthy issues, especially in the rural areas.

11. Far greater emphasis on locally-oriented animals, on native wildlife, and an infrequent consideration of rare and endangered species issues suggest a strong parochial bias among most Americans. These results indicate the need for Federal programs to be locally and regionally relevant.

Considerable refinement of the research methods and a broadening of the data base will be required before a clear historical picture of American animal use and perception emerges. Historical studies are necessarily fraught with uncertainty, particularly when novel, empirically-oriented techniques are employed. Nevertheless, the need to understand the past in attempting to avoid previous mistakes when planning for an uncertain future rationalizes the effort. Hopefully, this exploratory study will lead to other empirical attempts to understand the role of animals in American history.

References Cited

American Newspaper Market's Circulation 1977–1978. 1978. American Newspaper Markets, Inc., Malibu, California.

Ayers Directory of Publications 1977. 1978. Ayer Press, Bala Cynwyd, Pa.

Bos, W., L. Brisson, and P. Eagles. 1977. A study of attitudinal orientations of central Canadian cultures toward wildlife. Project No. 702-17. Waterloo Research Institute, University of Waterloo, Ontario.

Kellert, S. R. 1976. Perceptions of animals in American society. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 41:533–546.

______. 1980a. Contemporary values of wildlife in American society. *In* W. W. Shaw and E. H. Zube, eds. Wildlife values. Center for Assessment of Noncommodity Natural Resource Values.

______. 1980b. Public attitudes toward critical wildlife and natural habitat issues. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 45:111–124.

______, and J. K. Berry. 1981. Knowledge, affection and behaviors toward wildlife and natural habitats. National Technical Information Service, Accession Number PB-81-173106.

Newspapers in Microform: U.S. 1948–1972. 1973. U.S. Library of Congress, Catalog Publication Division, Washington, D.C.

Rose, H. M. 1971. Conservation in the United States. *In* G. H. Smith, ed. Conservation of natural resources. John Wiley and Sons, New York.

Trefethen, J.B. The American Landscape: 1776–1976—two centuries of change. The Wildlife Management Institute, Washington, D.C.

World Almanac and Book of Facts. 1977, 1978. Newspaper Enterprise Association, New York.

The Influence of Hunter Density on Firearm Deer Hunters' Satisfaction: A Field Experiment

Thomas A. Heberlein, John N. Trent, Robert M. Baumgartner
Department of Rural Sociology
University of Wisconsin
Madison

Recreational experiences for humans are one of the major products of wildlife management. Managers modify the physical environmental by manipulating habitat and the social environment by regulating season and hunting methods to produce sustained recreational opportunity. The outcome of such management is to provide wildlife that is essential for a hunting experience where seeing, and then shooting and bagging, game species are basic elements in hunting satisfaction. Hendee (1974) and others (cf. Decker et al 1980, Gilbert 1977) have noted the multiple satisfactions beyond seeing, shooting, and bagging that are sought by hunters. Some of these factors, such as companionship, are not amenable to management, while others, such as being close to nature, are automatically provided in most settings.

Beside game related management, hunter density has been manipulated in certain areas. Usually this is done to limit wildlife harvest, but the number of hunters also directly affects other aspects of the recreation experience. High density may produce competition for game or hunting opportunities that can lead to crowding, interpersonal conflict, poor sportsmanship, and practices that waste game. Available evidence on the effect of hunter density on success, satisfaction, and attitudes presents conflicting results.

In one study (Miller et al. 1977), Colorado deer hunters disliked increased hunter densities in the areas they hunted. When presented hypothetical situations on surveys, increased hunter density led to a 25-percent decrease in willingness to pay among all sportsman license holders.[1] On the other hand, decreasing hunter density did not decrease willingness to pay as might be expected. This suggests that hunters oppose increases, but are indifferent to decreases in the units in which they choose to hunt. Miller et al. also found that for specialized groups, such as muzzle loaders, doubling density had a larger negative effect than could be offset by doubling the success ratio (minus 43 percent for increased density versus plus 25 percent for increased success).

In an actual field study, Kennedy (1974) found Maryland deer hunters were satisfied with their hunting experiences with very high hunter densities (2.9 ha per hunter on opening day) and low success (3 percent over a 7-day season). In spite of these conditions, 62 percent of the hunters reported having a good or excellent hunting trip, while only 14 percent reported a poor or very poor experience. This is a much higher level of satisfaction than found by Cue (1978) in Michigan, where

[1]Miller et al. do not present the actual hunter densities used in their survey. High and low hunter densities were based on the actual management unit hunted during the 1974 season. High density was the actual density + 0.55 − 0.45 actual + 0.005 actual^2, while low was the actual density minus this same equation. Actual densities ranged between 1 and over 23 hunters per square mile.

45 percent of the firearm deer hunters sampled reported a poor or very poor trip. Vaske et al. (1982) also report much lower levels of satisfaction among four hunting populations. Kennedy argues that there may be positive effects of high hunter density because more hunters are supposed to move deer, as well as negative effects due to competition and safety concerns. His data show that as hunter density increased the percentage of hunters reporting being "bothered" increased. But even in these high density conditions a majority (53 percent) felt there were not enough others to move deer.

Cue and Langenau (1979) and Cue (1978) studied hunter densities on eight Michigan quarter-townships for six years and found the hunter evaluation that "there were too many other hunters" had no effect on hunter satisfaction after buck kill, and deer seen were statistically controlled. Highest hunter densities and negative evaluations by hunters occurred in the units with high buck kills and high hunter satisfaction. It appears from their data that the increased levels of seeing, shooting and bagging override the negative effects of hunter density.

One problem with interpreting data from these three studies is that hunters are self-selected to areas. Kennedy (1974) and Cue (1978) both note that hunter preferences for contacts vary, with some hunters preferring large numbers of hunters to "move deer," and others preferring low numbers to achieve solitude. Wisconsin data show that while 20 percent of the deer hunters prefer to see no other hunters, 18 percent prefer to see 11 or more others (Heberlein and Laybourne 1978). Hunters themselves may also move to areas of higher deer concentrations. It is further difficult to compare the overall satisfaction levels across different studies and areas because hunters have different backgrounds and experience. Kennedy's highly satisfied deer hunters were largely urban hunters from Baltimore, Maryland. These potential confounds could be eliminated and the effect of density more systematically studied in a controlled experiment where deer hunters are randomly assigned to low and high density cells with cover types and deer densities held constant and approximately equal in each cell. Such random assignment would, within statistical limits, equalize expectations and preferences. The present research reports that findings from such an experiment for Wisconsin firearm deer hunters in an enclosed area during a two day managed antlerless deer hunt. This paper will explore the effect of density on seeing, shooting and bagging deer, as well as hunter interference and overall satisfaction.

Study Area

The Sandhill Wildlife Area is located about 27 km (17 miles) southwest of Wisconsin Rapids, Wood County in central Wisconsin. The area contains about 3,705 ha (9,155 acres) and is enclosed by a 27 km (17 miles) of 3-meter (10-foot) high deer-proof fence. Sandhill was operated as a private game farm from 1938 until 1962. It is now managed by the Wisconsin Department of Natural Resources (DNR) as an experimental and demonstration area emphasizing habitat management and quality hunting techniques.

The main soil types at Sandhill are loamy sands and sedge peat overlaying very fine sands. Topography is generally flat with large marshes and low islands. Sixteen impoundments and a 50 km (31 mile) system of plugged drainage ditches are dominant features of the area.

Aspen (*Populus tremuloides* and *P. grandentata*) and oak (*Quercus elipsoidalis* and *Q. alba*) dominate, with 65 percent of the upland forest in pole-sized stands. The remaining 35 percent of the upland forest has been logged or treated to benefit forest wildlife. A more detailed description of the area is located in the Sandhill Master Plan (Haug et al. 1977).

Wildlife species common to lowland marshes and disturbed upland forests occupy the area. White-tailed deer (*Odocoileus virginianus*) are the only cervids and are intensively managed. In 1972, the white-tailed deer population within Sandhill was eliminated and new individuals were admitted in 1973. Beginning in 1979, Sandhill deer have been managed for production of trophy bucks (Kubisiak 1980), which included two seasons of anterless deer hunting only. About 450 deer were in the area when this experiment was conducted.

Public hunts for white-tailed deer at Sandhill have been conducted intermittently since 1963. These hunts have had experimental and demonstration objectives, including manipulation of the deer population, use of unconventional firearms, and controlled levels of hunter density. In the interests of promoting a quality recreational experience for hunters, property managers have held numbers of participants to a hunter density of approximately 22 hectares per hunter (12 hunters per square mile). Hunter density in the area outside the Sandhill is approximately 7 hectares per hunter (39 hunters per square mile) during the regular gun season for deer in Wisconsin.

Methods

Hunt Administration

Sandhill is divided into four administrative compartments labeled northwest, northeast, southeast and southwest for deer hunters. All four compartments are roughly equivalent in gross size, net huntable hectares, and kilometers of driveable access roads (Table 1).

Hunters are checked into each hunting compartment through separate gates. Each compartment is designated by signs and road gates restricting hunters to their assigned compartment when hunting. A common exit road leads to the southeast gate where all hunters and legal deer are checked out. Movement of deer is not affected by the hunting compartment system on Sandhill.

The Sandhill anterless deer hunt occurs one week prior to the general opening

Table 1. Sandhill hunting compartments compared by gross area, net huntable area and kilometers of access roads.

Compartment	Gross area (ha)	Net huntable area (ha)	Usable access roads (km)
NW	908.1	640.1	8.9
NE	744.1	564.0	6.9
SW	661.9	434.4	8.1
SE	859.9	691.5	12.5

of the Wisconsin gun deer hunting season. Hunters apply for a permit either individually or in groups of two or four. Successful applicants are selected at random and assigned a day, Saturday or Sunday, and a hunting compartment within the Sandhill area to which their hunting is restricted. Application procedures and a description of the hunt are described in the 1980 Wisconsin hunting regulations summary published by the Wisconsin Department of Natural Resources.

Because of the application process, check-in and check-out procedures, and confinement to assigned compartments, hunters may feel more restricted than under normal conditions. Since the hunt takes place a week prior to the general session it is seen as a "bonus" deer hunt by some participants.

In 1980, 395 single and 348 group applications representing 1,344 individuals were received. Four hundred and fifty-six permits based on a random drawing were issued for the 1980 hunt, 227 for Saturday, 15 November and 229 for Sunday, 16 November. Three hundred and forty-eight hunters participated in the two day hunt, 179 on Saturday (47 no shows) and 169 on Sunday (60 no shows).

Assignment of Hunters to Compartments

At the time of the drawing for permits, successful applicants were also assigned to a hunting compartment on Sandhill, each on a particular day. The northwest compartment was assigned as the high density area for Saturday, and the southeast compartment was the high density compartment Sunday to avoid any effects due to a unique characteristic of a compartment. One hundred hunters were assigned to each high density compartment while the number of hunters assigned to the low density compartment ranged from 35 to 50 depending on the number of hectares in the compartment. In the high density conditions, there were 8.5 to 8.9 ha (21 to 22 acres) per hunter, while in the low density assigned condition there were 17 to 19 ha (42 to 47 acres) per hunter.

Questionnaire Administration

Two one page questionnaires were used to collect data on the participating hunters. A pre-hunt questionaire was enclosed in the mailing in which successful applicants received their Sandhill permit. This questionnaire was used to determine hunters' expectations of the Sandhill deer hunt and was not used in this analysis. Each hunter was given a one-page field questionnaire when he entered his respective hunting compartment. The questionnaire was collected at the end of the day as individuals checked out. Completed field questionnaires were obtained from 346 hunters (99 percent) of those who participated in the hunt.

The purpose of the field questionnaire was to obtain hunter perceptions of satisfaction, quality, and crowding while accounting for deer seen, shots fired, deer bagged, and contacts with other hunters. The use of this questionnaire and its rationale is described in Shelby and Heberlein (in preparation). The hunter density (number of hectares per hunter) was the primary independent variable used in this analysis. The primary dependent variable was "overall satisfaction with your hunt today," which was obtained on a six point scale including: poor; fair, the day didn't work out very well; good, but a number of things could have been better; very good, but some things could have been better; excellent, only minor problems; and perfect.

Actual Hunter Densities in the Field Experiment

Not all the hunters who received a permit and were assigned a hunting compartment actually hunted at Sandhill. The actual density of hunters in the field thus differed somewhat from densities proposed in the study design. (Table 2).

Analysis

Sandhill hunters from both days were combined into either a high density or a low density category for purposes of analysis. There were 159 hunters in the high density condition ($\bar{x}$ = 11.2 ha per hunter) [27.7 acres per hunter] and 189 in the low density condition ($\bar{x}$ = 25 ha per hunter) [61.8 acres per hunter]. Data were analyzed using programs from the *Statistical Packages for the Social Sciences* (Nie et al. 1975) on a Univac 1110 computing system at the University of Wisconsin-Madison.

Results

Sixty-two percent of the hunters saw at least one legal deer within shooting range and 43 percent got at least one shot at a legal deer, with means of 1.52 deer seen and 0.98 shots taken per hunter. (Table 3) This is a much higher success rate than observed by Kennedy, and is probably comparable to the Michigan study reported by Cue (1978) and Langenau (Cue and Langenau 1979). The hours spent in the field ranged from less than 1 hour to 10 hours with a mean of 7.70, and 95 percent of the hunters reported at least one contact with a hunter from another group with a mean of 8.97 reported contacts (Table 3).

In the high density condition hunters saw more legal deer within shooting range, took more shots, were more likely to bag a deer, and reported more contacts with hunters from other parties. In the low density areas, hunters spent more time in the field probably because the lower success rate prolongs the hunt. The differences between the low and high density conditions all exceed four standard errors of the total sample.[2]

Overall, 65 percent of the hunters characterized the hunt as not at all crowded (the lowest 2 points on a 9-point scale). Table 4, however, shows that the perception of crowding varied between the high and low density conditions. Over 76 percent labeled the low density condition as not at all crowded, while less than 50 percent in the high density condition did the same. Of twenty recreational groups who have responded to this crowding item on previous surveys, Sandhill low density hunters are the second lowest, with only goose hunters at a low density managed hunt feeling less crowded. Sandhill high density compares with the general Wisconsin hunt where about 50 percent of the hunters report some crowding.

Hunters assigned to the high density condition were also more likely to report interference from other hunters, as shown in Table 5. Although the percentage of hunters reporting interference from other hunters is not high in an absolute sense,

[2]The significance of the difference does not reach the 0.05 level; however, the consistent direction and pattern of the findings makes it unlikely that we are simply capitalizing on chance. The findings represent substantial and non-trivial percentage differences. Adhering strictly to a 0.05 level, one would have to say increased density had no effect on the game related variables. We think this is unrealistic.

Table 2. Hunter density (ha/hunter) by compartment and day of hunt for 15–16 November 1980 at the Sandhill Wildlife Area.

		Saturday, 15 November			Sunday, 16 November		
Compartment	Total hectares	Assigned hunters	Actual hunters	Hectares/ hunter	Assigned hunters	Actual hunters	Hectares/ hunter
NW[a]	908.1	100	77	11.8	50	40	22.7
NE	744.1	40	35	21.3	40	24	31.0
SW	661.9	35	27	24.5	35	23	28.8
SE[b]	859.9	40	40	21.5	100	82	10.5

[a]High hunter density condition 15 November 1980
[b]High hunter density condition 16 November 1980

Table 3. Effect of hunter density on seeing, shooting, bagging and interpersonal contacts. Comparison of low density and high density areas.

	Mean and std. error total	Mean low density	Mean high density	p[b]
Success rate	0.21 ± 0.02	0.17	0.25	0.08
Legal deer[a] seen/hunter	1.52 ± 0.09	1.36	1.70	0.07
Shells used/hunter	0.98 ± 0.08	0.84	1.12	0.08
Hours hunted/trip	7.70 ± 0.13	8.01	7.29	0.01
Reported contacts with other hunters in the field	8.97 ± 0.39	7.24	10.95	0.00

[a]All antlerless deer and males with antlers less than 3 inches in length were legal.
[b]Based on a two-tailed test of differences between means.

Table 4. Effects of density on perceived crowding by hunters.

	Percentage of hunters agreeing		
Rating of perceived crowding	Low density	High density	Difference
Not at all crowded	76.6%	49.7%	+26.9%
Slightly crowded	10.6%	30.9%	−20.3%
Moderately crowded	11.7%	18.1%	− 6.4%
Extremely crowded	1.2%	1.3%	− 0.1%

$X_4^2 = 29.01, p < .001$

Table 5. Effects of density on reported interference from other hunters.

	Percentage of hunters agreeing:			
Reported interference items	Low density	High density	Difference	p
There were too many other hunters to enjoy being in the field.	9.7	24.2	−14.5	0.001
Other hunters occasionally kept me from hunting where I wanted to.	15.3	28.4	−13.1	0.001
The number of other hunters made stalking a deer impossible.	9.3	28.5	−19.2	0.001
There was too much competition from other hunters where I hunted.	8.6	19.4	−10.8	0.001
Where I hunted there was a chance of 2 or more hunters claiming the same deer.	7.4	20.2	−12.8	0.001

p = difference of proportion test for each item.

it is comparable to other studies (Kennedy 1974, Heberlein and Laybourne 1978). Of the five items used to measure interference, all five show a statistically significant difference in the proportion of hunters agreeing in every case.

The data in Tables 3–5 have shown that in the high density condition hunters see more legal deer, get more shooting, and are more successful in bagging a deer, but they report more contacts with hunters from other parties, feel more crowded in the field and report more interference from other hunters while in the field. We would expect the game related factors and increased interference to affect ratings of satisfaction with the hunt in opposite ways. The advantage of seeing, shooting, and bagging could partially be offset by unpleasant encounters with other hunters.

Hunters in the low density condition were more likely to rate the hunt as poor or fair, while hunters in the high density condition were more likely to rate the hunt as good or very good (Table 6). There were no differences in the percentage of hunters rating their hunt as excellent or perfect between the two conditions. In the low density condition, approximately equal numbers of hunters rated their hunts as poor or fair and good or very good, while in the high density condition the number of hunters reporting a good or very good hunt was over twice as high as those reporting a poor or fair hunt. In each density condition, about one-fourth of the hunters rated their hunt as excellent or perfect.

The zero order correlation between density and satisfaction is $r = 0.10$ ($p < 0.10$), indicating that increased hunter density increases overall hunter satisfaction. The tables presented thus far in the paper show density increases game related variables, but also increases interference. Intuitively these should have opposite effects on satisfaction. Using path analysis (Wright 1960, Duncan 1966, 1975, Heise 1975), it is possible to decompose a correlation in terms of a causal model and show the relative effects of each variable in standardized regression coefficients.

Only those causal paths that are significantly different than zero at the 0.10 level are displayed in Figure 1. There is no direct path from hunter density to satisfaction. This means that density has no effect on satisfaction except through game related and interference variables. There is nothing particular about hunter density itself that increases satisfaction, except through the mechanisms described in the path diagram.

An increased number of hunters did increase the number of deer seen. The effect was a very small, $B = 0.10$. Most of why one sees deer is still unexplained, ($U = 0.99$ the path coefficient from the unexplained factors $U = \sqrt{1 - R^2}$). Seeing deer, in turn, increased the number of shots taken, and the probability of bagging a deer illustrated by the positive path coefficients between seeing deer and these

Table 6. Effects of hunter density on satisfaction with the deer hunting experience. Comparison of low density and high density areas.

Rating	Low density	High density	Difference
Poor or fair	37.5%	22.1%	−15.4%
Good or very good	35.8%	54.5%	+18.7%
Excellent or perfect	26.7%	23.4%	− 3.3%

$X_4^2 = 13.3, p < 0.01$

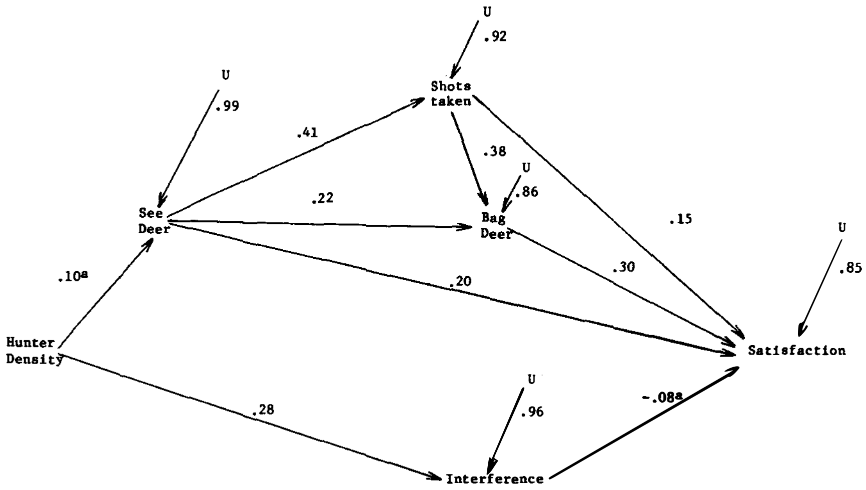


Figure 1. Path analysis of hunter density effects at the Sandhill Wildlife Area managed deer hunt, November 15 and 16, 1980. ($U = \sqrt{1-R^2}$)
[a]Path coefficient is significant at $p < 0.10$; all other coefficients are $p < 0.05$.

variables. Note that increased hunter density itself has no direct effect on shooting and bagging. The higher levels of these events in the high density conditions are due entirely to the increased deer sightings.

Seeing, shooting, and bagging all have direct effects on satisfaction, with bagging having the strongest direct effect. Variables can have both direct effects as well as indirect effects through other variables. Seeing deer alone increases satisfaction even if the hunter gets no shooting and fails to take a deer. This is illustrated by the direct path, $B = 0.20$. But seeing also increases the number of shots taken and the probability of bagging. The total effect of seeing then is 0.20 + (0.22)(0.30) + (0.41)(0.15) + (0.41)(0.38)(0.30) = 0.37. This is larger than the effect of bagging, so the path diagram shows that the total influence of seeing deer on satisfaction is greater than the total effect of bagging.

Internally to the game related variables it can be seen that seeing deer increases the number of shots taken ($B = 0.41$), and the number of shots taken has something to do with bagging a deer ($B = 0.38$). The direct effect of seeing deer on bagging implies that hunters somehow bag deer without shooting at them. This finding is, in part, an artifact of the inability of linear regressions to represent necessary conditions well (i.e, one cannot bag without seeing a deer) and in part due to hunters missing shots. Think of the U's as all the excuses hunters give for missing. A hunter who empties his gun, rapidly shooting five shots, does not have a higher probability of success than one who shoots one deliberate shot. Or put another way, missing is a prerequisite for a high value on the shooting variable, which reduces the relationship between shots taken and bagging.

Looking now to the human dimension of the path diagram, it can be seen that the hunter density has a much larger effect on interference than on seeing deer in standard units. A manager who increases hunter density increases the degree of interference by almost three times as much as deer sighting is increased. As expected, hunters who report more interference are less satisfied, but this influence is much smaller than the positive direct effects from the game related variables. About 30 percent of the effect of density on satisfaction goes through the human dimension, while 70 percent goes through the wildlife variables.[3]

Discussion

This experiment shows that increasing the number of hunters in an area affects the hunting experience and overall satisfaction of hunters. At 25 ha per hunter, the typical hunter sees seven other hunters and feels little interference. He is more likely to have a poor or fair hunt because he is less likely to see and subsequently shoot and bag deer. At twice the density (12 ha per hunter), hunters see eleven others and feel twice as much interference. Yet they are more satisfied because they see and consequently shoot and bag more deer. The high density compartments produced no greater percentage of excellent or perfect hunts, presumably because of the negative effects of interference. Thus, managers can reduce the number of poor or fair hunts by increasing hunter density to provide a satisfactory experience, but they cannot increase the probability of a truly outstanding hunt by doing so. Increased density changes the human dimensions of the experience by increasing contacts and interference from other hunters, which cannot be totally offset by seeing more game.

The interference-satisfaction relationship is not powerful or consistent. Perceived crowding and reported contacts in similar models on the Sandhill data yielded no significant negative effects on satisfaction. Cue and Langenau (1979) found no effect of a variable similar to interference on satisfaction. Our own prior work found that self-reported contacts sometimes decreased satisfaction and sometimes did not after seeing, shooting and bagging had been controlled (Heberlein and Laybourne 1978).

This raises some doubts about the adequacy of satisfaction alone as a mechanism for evaluating hunter densities. Elsewhere (Heberlein and Shelby 1977, Shelby and Heberlein, in preparation) we have been critical of a global satisfaction index for establishing recreational carrying capacity. Satisfaction alone does not reflect the social effects of increased density because it is too broad and general.

Preferences for contacts are more specific and could be more useful for identifying appropriate hunter densities than global satisfaction, which is influenced by many other variables. Our prior survey of Wisconsin deer hunters showed that 57 percent preferred to see 5 or fewer other hunters and 82 percent preferred to see 10 or fewer. Thus even the low density condition at Sandhill produces more field contacts (7) than most hunters prefer, and the high density condition exceeds the preferences of 4 out of 5 hunters.

Providing the best possible hunting experience in terms of preferred contacts

[3]Note that all of the variables account for only 28 percent of the variance in hunter satisfaction. We have no test-retest reliability on this single item indicator, but a 0.80 reliability is not uncommon for such measures. This means that there is about 64 percent of the variance which might be reliable. The four variables in the model account for 27.7 percent of the total variance. The rest is due to the many aspects of a hunt such as fights with partners, getting lost, guns that jammed, or missed shots.

would take more than 25 ha (62 acres) per hunter, and it would also reduce the game related dimensions of the hunt. It is difficult to simultaneously optimize on both the game and human dimensions of a deer hunt. Increasing hunter density can provide at least satisfactory hunts for most hunters, along with increased contacts. Although the limits of this need to be explored, there is certainly some density level that would be completely unacceptable for nearly all hunters.

Given that hunters have differing preferences for contacts while hunting, managers should consider providing different opportunities for hunting experiences, low hunter density for those preferring few contacts and who are willing to trade off the game related elements for less interference; and higher hunter densities for those willing to accept some interference for increased seeing, shooting, and bagging. The consequences of these situations for seeing, shooting, bagging, contacts, and interference could be spelled out, and the hunters could choose the type of recreational experience they prefer.

References Cited

Cue, D. C. 1978. Firearm deer hunter densities and satisfaction: a preliminary report. Michigan Dep. of Natural Resources, Lansing. 19 pp.

Cue, D. C., and E. E. Langenau, Jr. 1979. Satisfaction and deer hunter density. Wildlife Division Report No. 2848. Michigan Dep. of Natural Resources, Lansing. 15 pp.

Decker, D. J., T. L. Brown, and R. J. Gutierrez. 1980. Further insights into the multiple satisfactions approach for hunter management. Wildlife Soc. Bull. 8(4):323–331.

Duncan, O. D. 1966. Path analysis: sociological examples. Amer. J. Sociol. 72:1–16.

Duncan, O. D. 1975. Introduction to structural equation models. Academic Press, New York. 180 pp.

Gilbert, A. H. 1977. Influence of hunter attitudes and characteristics on wildlife management. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 42:226–236.

Haug, J. C., R. T. Hess, T. Zimmermann, and L. Hannahs. 1977. Sandhill Wildlife Area Master Plan. Wisconsin Dep. of Natural Resources, Madison. 33 pp.

Heberlein, T. A., and B. Laybourne. 1978. The Wisconsin deer hunter: social characteristics, attitudes and preferences for proposed hunting season changes. Working paper #10. Center for Resource Policy Studies, School of Natural Resources, College of Agricultural and Life Sciences, University of Wisconsin, Madison. 96 pp.

Heberlein, T. A., and B. B. Shelby. 1977. Carrying capacity, values and the satisfaction model: a reply to Griest. J. Leisure Res. 9(2):142–148.

Heise, D. R. 1975. Causal analysis. John Wiley and Sons, New York. 301 pp.

Hendee, J. C. 1974. A multiple-satisfaction approach to game management. Wildl. Soc. Bull. 2:104–113.

Kennedy, J. J. 1974. Attitudes and behavior of deer hunters in a Maryland forest. J. Wildl. Manage. 38(1):1–8.

Kubisiak, J. F. 1979. Deer population and management following herd removal at the Sandhill Wildlife Area. Perf. Report, Study 212. Wisconsin Dep. of Natural Resources, Madison. Mimeo. 35 pp.

Miller, R., A. A. Prato, and R. A. Young. 1977. Congestion, success and the value of Colorado deer hunting experiences. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 42:129–136.

Nie, N. N., C. H. Hull, J. G. Jenkins, K. Steinbrenner, and D. H. Bent. 1975. Statistical package for the social sciences. Second edition. McGraw Hill, New York. XXIV + 675 pp.

Shelby, B. B., and T. A. Heberlein. In Preparation. Social carrying capacity in recreational settings. 420 pp.

Vaske, J. J., M. P. Donnelly, T. A. Heberlein, and B. Shelby. 1982. Differences in reported

satisfaction ratings by consumptive and nonconsumptive recreationists. J. Leisure Res. 14:195–206.
Wright, S. 1960. Path coefficients and path regressions: alternative or complementary concepts? Biometrics 16:189–202.

Nonconsumptive Wildlife-Associated Recreation in the U.S.: Identifying the Other Constituency

James R. Lyons[1]
Division of Program Plans
U.S. Fish and Wildlife Service
Washington, D.C.

Introduction

Sportsmen are the traditional clientele of wildlife management. As an organized force, sportsmen have long endorsed the principles of conservation upon which wildlife management is based. As a source of political and financial support, sportsmen continue to represent wildlife's most recognized constituency.

Public interest in wildlife and wildlife-related recreation encompasses more than traditional fishing and hunting activities. As recently documented, participation in nonconsumptive forms of wildlife-associated recreation is substantial. In 1975, 49 million Americans spent 1.6 billion days engaged in wildlife observation (U.S. Fish and Wildlife Service [USFWS] 1977). In 1980, approximately 29 million individuals took trips primarily to observe wildlife, while 56 million observed wildlife in residential settings.[2]

Though a sizeable portion of the public participates in nonconsumptive activities, relatively little is known about the characteristics of this segment of wildlife management's clientele. As characterized by More (1977), with regard to nonconsumptive activities we remain at the stage of counting participants and describing categories of users. In light of the high degree of public participation in nonconsumptive activities, our lack of knowledge seems appalling. It is, however, quite understandable when one considers both the current status of funding for wildlife programs and the nature of nonconsumptive recreation.

Though the interests of the wildlife profession have expanded to include both a broader mix of species (both game and nongame) and a diversity of roles (i.e., from promoting recreational use to protecting threatened and endangered species), management activities remain, for the most part, financially dependent on receipts from the sale of hunting and fishing licenses and Federal funds from taxes on sporting equipment. Recent initiatives have been taken at both the state and federal levels to establish alternative funding bases for nongame programs. However, traditional sources of funding continue to provide the dominant portion of support for wildlife management.

The nature of nonconsumptive wildlife-related recreation, in itself, has hindered efforts to gather needed data. First, because records similar to those provided by hunting and fishing licenses are not available for nonconsumptive activities, individual participants cannot be identified through a tally of license holders. Second, since a great deal of elaborate equipment is not needed to participate in most

[1]Currently Director of Resource Policy, Society of American Foresters 5400 Grosvenor Lane, Bethesda, Maryland.
[2]Figures reported from the 1975 and 1980 Surveys are not comparable due to differences in activity definitions, respondent characteristics and methodologies.

nonconsumptive activities, product sales cannot be used to measure participation. Third, the product of participation is difficult to define and less easily quantified than the product of a successful hunt or a day of fishing. Finally, individuals can engage in nonconsumptive activities in a multitude of settings, including nonresidential and residential sites in urban and rural environs. Characterizing participants based upon the site of their activity or the focus of their interest is usually difficult.

Though studies of selected participants in specific nonconsumptive activities have been conducted, these have tended to focus primarily upon people who actively pursue wildlife observation. Most have been based upon local samples relevant only to the area studied. Basic data pertaining to the characteristics and behaviors of nonconsumptive users, the activities in which they engage, and the types of wildlife and habitats that they use are lacking. In fact, an acceptable definition of nonconsumptive use is still wanting.

Why invest the time, effort, and money required to identify this non-traditional segment of wildlife management's constituency—the nonconsumptive user? The following reasons are proposed:

First, for the most part, responsibility for the management of fish and wildlife resources has been placed in the hands of public agencies. These agencies have a responsibility to seek to maximize public benefit in the conduct of their activities. In fact, this charge is explicitly stated as the mission of the U.S. Fish and Wildlife Service: ". . . to provide the Federal leadership to conserve, protect and enhance fish and wildlife and their habitats for the continuing benefit of people" (USFWS 1980).

Though it may be argued that wildlife programs have sought to maximize public benefit, management efforts have traditionally focussed upon only one segment of the public—the consumptive sportsmen. As recognized by Nelson (1976), ". . . our clients are no longer just fishermen and hunters—they're everybody— It is not our responsibility as stewards of fish and wildlife to scratch our heads and puzzle over this phenomenon. We must accept it and begin, perhaps, to think differently of our constituencies."

Second, by virtue of the estimated size of the population of nonconsumptive users, this clientele warrants additional attention. Forty-nine percent of the U.S. population 16 years of age and older participated in nonconsumptive wildlife-related recreation in 1980 (USFWS 1982). The extent of participation in these activities reflects not only a substantial demand for the products of wildlife management, but a potentially significant impact on the resource base. Concern for the effects of nonconsumptive activities has been expressed by other authors (Weeden 1979, Wilkes 1977). In fact, Wilkes has stated that ". . . the nonconsumers are shown to be the most serious consumers, simply by virtue of their numbers, by what they do, and where they do it."

Third, as increased demand is placed upon wildlife management agencies to meet the needs of an expanding clientele, new sources of funding must be sought. Nonconsumptive users, as a largely non-paying beneficiary of current wildlife management efforts, represent an untapped source of additional program support.

Fourth, lack of data pertaining to the nonconsumptive uses and users of wildlife has led to many misunderstandings regarding this wildlife-user segment. In fact, these misperceptions may be viewed as a myth, consisting of the following elements:

1. Nonconsumptive users are "for the birds"—i.e., nonconsumptive use is synonymous with birdwatching;
2. Nonconsumptive users are typified by the "little old lady in tennis shoes"—a stereotype of the average participant in nonconsumptive wildlife-related recreation;
3. Nongame and nonconsumptive use are synonymous terms, implying that the sole focus of nonconsumptive activities is nongame species of wildlife; and
4. Nonconsumptive users and consumptive sportsmen comprise two separate and distinct user groups. This dichotomy is further emphasized by the belief that nonconsumptive users, for the most part, are opponents of hunting—i.e., "It's Them versus Us."

Methods

In order to increase understanding of the characteristics and behaviors of nonconsumptive wildlife users, the 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation included, for the first time, a detailed segment on nonconsumptive wildlife use. Through a screening interview administered by telephone, nonconsumptive users were identified based upon the types of activities in which they engaged. Nonconsumptive activities were sorted into four distinct categories based upon two key criteria: (1) whether involvement with wildlife was the primary purpose of the activity or secondary to some other purpose and (2) whether the activity occurred in a residential setting (in the immediate vicinity of home) or more than one mile from home (non-residential). The following framework resulted:

	Non-Residential	Residential
Primary		
Secondary		

A total of 116,000 households participated in the screening phase.

Detailed data for nonconsumptive activities were gathered through indepth, face-to-face interviews with a subsample of those who were identified during the screening phase as participants in nonconsumptive activities. Approximately 6,600 individuals participated in these detailed interviews, generating information regarding participant behaviors, socio-economic characteristics, and expenditures.

The 1980 National Survey was conducted by the U.S. Bureau of the Census for the U.S. Fish and Wildlife Service. A 95-percent response rate was achieved for both the detailed and screening phases of the Survey.

Results[3]

Participation in nonconsumptive wildlife-associated recreation in 1980 was extensive. Ninety-three million Americans, 16 years of age or older, participated

[3]The results reported are initial findings from the 1980 National Survey. As such, they are subject to minor modification prior to publication of the final national report.

in at least one nonconsumptive activity in 1980. Participants in primary activities totalled 83 million or 49 percent of all adults 16 years of age or older. Non-residential participants included 29 million Americans (17 percent of the adult population) and participants in primary residential activities numbered 80 million (47 percent). Participants in secondary activities included 69 million non-residential users and 81 million residential participants. A total of 88 million Americans (52 percent of the adult population) participated in at least one secondary nonconsumptive activity in 1980.

The remaining results will be presented as they pertain to the elements of the myth of the nonconsumptive user:

1. *For the birds.* As anticipated in the design of the nonconsumptive questionnaire, Americans participated in a diversity of wildlife-related recreational activities, of which birdwatching was only one. Activities for which participation data were gathered included, for nonresidential settings, wildlife observation, photography, and feeding, and, for around the home, observation, photography, feeding of birds and other wildlife, maintaining plantings and natural areas for wildlife, and visiting public parks (see Table 1). The focus of these activities included not only birds, but also large mammals such as deer, small mammals such as chipmunks and squirrels, reptiles, amphibians, and fish.

2. *The "Little Old Lady in Tennis Shoes."* Data from the 1980 Survey indicated that participants in nonconsumptive activities came from a wide range of socioeconomic groups and age classes. As the data for one user group, non-residential wildlife observers, indicate, the majority of participants were male (52 percent), under 35 years of age (58 percent), and from households with incomes of between $10,000 and $30,000 (55 percent) (see Figure 1).

3. *Nongame—Nonconsumptive Use.* Both game and nongame species were the focus of nonconsumptive wildlife-related recreation in 1980. As illustrated in Figure 2, the use of game species of wildlife by nonconsumptive users was extensive. Game species most often observed, photographed, or fed on trips included waterfowl, deer, rabbits and hares, and upland game birds.

Table 1. A summary of participation data for primary nonconsumptive activities.

Activity	Number of participants (millions)	Percentage of population
Any primary activity	83.2	49
Any residential activity	79.7	47
Special interest observation	55.9	33
Photography	12.4	7
Fed birds	62.5	37
Fed other wildlife	20.8	12
Maintained natural areas	10.1	6
Maintained plantings	12.5	7
Visited public parks	13.5	8

Source: USFWS 1982

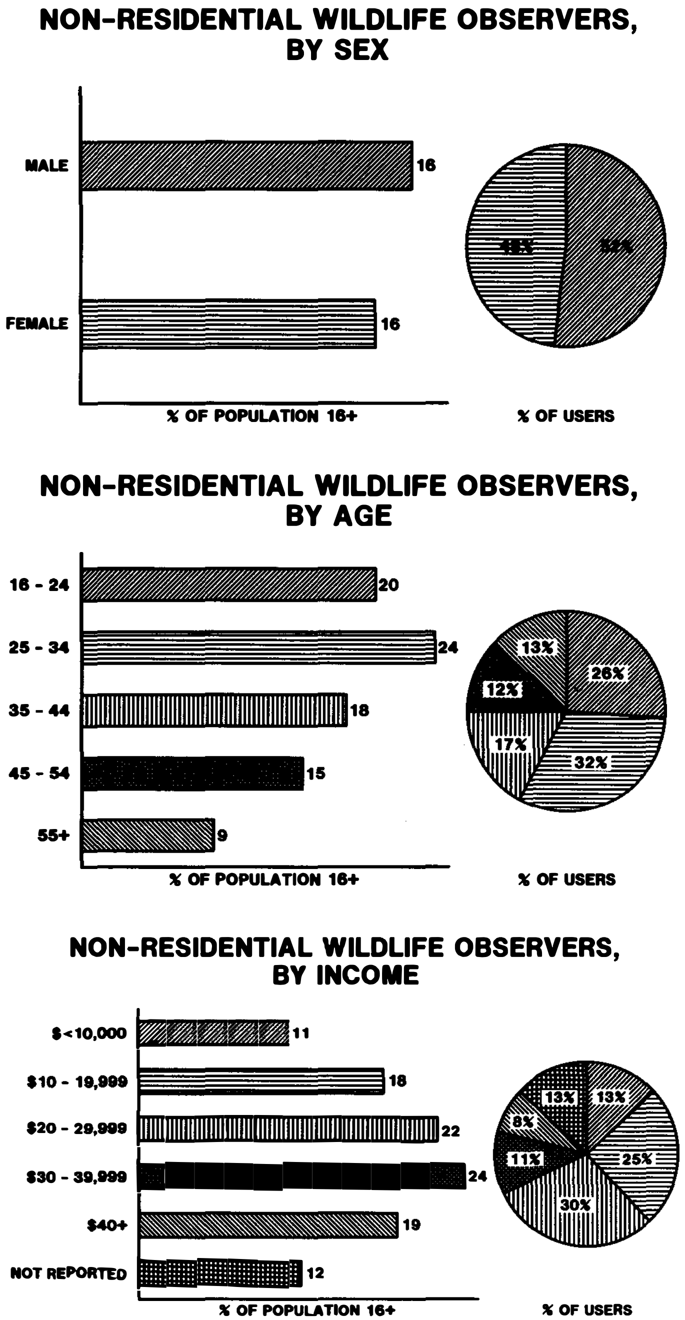


Figure 1. A summary of selected socio-economic characteristics of nonresidential wildlife observers.

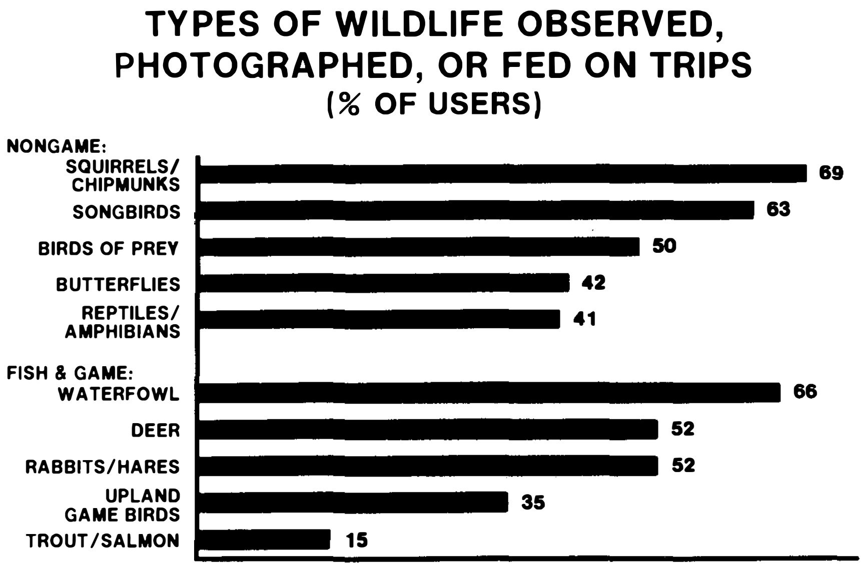


Figure 2. Relative use of wildlife by participants in nonconsumptive activities.

4. *"Them versus Us."* A large percentage of nonconsumptive users also participated in fishing and hunting. Thirty-six percent of those who participated in any primary activity were also sportmen. With reference to specific activities, 42 percent of those who observed wildlife on trips and 34 percent who fed birds around the home also fished and/or hunted.

A majority of sportmen also participated in nonconsumptive activities. Sixty-five percent of all sportsmen participated in at least one primary nonconsumptive activity in 1980; 26 percent took trips primarily to observe wildlife while 46 percent fed birds around the home.

Discussion

Sixteen years ago, John Gottschalk, as Director of the Bureau of Sport Fisheries and Wildlife, summarized the problems of fish and wildlife conservation at the time (Gottschalk 1966):

> The problems besetting wildlife conservation in 1966 are reasonably clear and have scarcely changed in fundamentals in recent decades. . . . We need habitats. . . . We need access. . . . We need know-how. . . . And we need public support. If I ever, in my professional career in this business of conservation administration, had any doubts about this [latter] facet of the modern conservation needs/solutions equation, it has been effectively dispelled in the brief time I have had to appreciate the growing obstacles of indifference, exploitiveness, and selfishness which combine to thwart so many of our altruistic efforts. Obviously, public support is what is required to get more healthy habitat, and access to it, and scientific know-how.
>
> Fish and wildlife will share the benefit when we have the facts to justify a larger role. To get the facts we need increased research—and I don't mean life history

> or population dynamic studies—as valuable as they are for management purposes. We need to know our *customer* better. We need to study the markets—beyond the usual consumptive public. Who is our public—and what do they really want—and what are they willing to pay? We need to know!

The same problems besetting wildlife management in 1966 continue to plague the profession today. In fact, as a result of the expanding interests and legal responsibilities of wildlife management during an era of constricted program budgets, these same problems are exacerbated.

Data generated by the 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation provide the opportunity to understand our "customer" better than ever before. Wildlife management's clientele is a diverse and substantial segment of the U.S. population. Active participants in wildlife-related recreation in 1980, sportsmen and nonconsumptive users combined, accounted for more than *one in every two* adult Americans. These individuals came from a wide range of age, education, and income groups and do not appear to reflect the special interests of a narrow segment of society.

As these data also reveal, participants in nonconsumptive activities, as previously hypothesized, represent a significant portion of wildlife's constituency—our "customers." Unfortunately, concern for the fact that nonconsumptive users are largely non-paying customers has led to an apprehensive if not adversarial relationship between nonconsumptive and consumptive users of wildlife. This attitude is typified by the following excerpt from a 1978 article in *Outdoor Life* regarding a U.S. Fish and Wildlife Service funded study of American attitudes toward wildlife and natural areas (Starnes 1978):

> . . . What if the big, three-year study . . . is actually the subtle opening gun in a long-range campaign to switch the emphasis on the use of our land and game away from hunting and into birdwatching, hiking, and other saintly, non-noisy enterprises? . . . For whose primary benefit are deer herds, the flocks, and our dwindling reserves of wild land really intended? These resources . . . have been preserved, bought and paid for largely by the hard dollar taxes and fees spent by gunners and fishermen. The Bambi set has shown some latter-day skills at fund raising . . . but I have yet to hear of them springing for one acre of wetland. I suspect their dough all goes for effete cocktail parties, where they sip vile chartreuse drinks and swap stories about what a bunch of roughnecks the rest of us are. . . ."

Preconceived notions regarding the characteristics and behaviors of nonconsumptive users, the foundations of the "myth of the nonconsumptive user," are dispelled by the findings of the nonconsumptive segment of the 1980 National Survey. In short, nonconsumptive users:

1. include, but are not limited to, birdwatchers. Individuals engaged in a diversity of nonconsumptive activities in 1980, which focussed on species of birds, mammals, reptiles, amphibians, fishes, and insects;
2. are neither predominantly female nor old. A range of socio-economic groups are represented in the ranks of the nonconsumptive users;
3. do not restrict their activities to the pursuit of nongame species. Both game and nongame species of wildlife were the focus of observation, photography, and feeding by nonconsumptive users; and
4. include both sportsmen and those who engage in purely "appreciative" activ-

ities. Nearly two-thirds of all those who fished or hunted in 1980, also participated in at least one active form of nonconsumptive recreation.

Perceived distinctions between the consumptive and nonconsumptive populations have also led to the belief that nonconsumptive users are opposed to sport hunting. Several recent studies shed additional light on the attitudes of nonconsumptive users toward hunting. In each, a sample of birdwatchers, one segment of the nonconsumptive population, was surveyed to determine their attitudes toward sport hunting. In a 1978 study by Shaw et al., 56 percent of those surveyed agreed with the statement, "Hunting is essential to prevent overpopulation of some types of wildlife." A study by Witter and Shaw (1979) revealed that 75 percent of the avid birdwatchers surveyed believed that "hunting should continue as a management tool." Finally, in a recent national survey by Kellert (pers. comm.), 66 percent of those who were categorized as avid birdwatchers, approved of hunting "for recreation and meat." As the findings of these studies indicate, concern for opposition to hunting among birdwatchers is largely unfounded.

A recent issue of *Field and Stream* contained an article by George Reiger (1982) entitled "Age of Unreason." The author, in evaluating the current status of the conservation movement in America, described a "polarization [which is] being pushed upon the sporting community by various factions." Though efforts may be made to exagerate the differences that exist among various segments of the wildlife community, perceived distinctions between consumptive and nonconsumptive users are not well founded.

Concern that nonconsumptive wildlife programs would provide competition for already scarce financial resources generated primarily by the sporting community is valid. Wildlife managers cannot continue to meet their expanded responsibilities without finding new sources of financial support. As the data presented indicate, both game and nongame species are the focus of nonconsumptive activities. In this sense, nonconsumptive users may be considered the non-paying beneficiaries of current wildlife management efforts. However, the lack of an appropriate vehicle for nonconsumptive users to provide financial support to current wildlife management programs has hindered the expansion of these programs to address existing demand for nonconsumptive wildlife-related recreation. This lack is likely to persist until appropriate sources of new program funding are identified.

Conclusion

Whether hunted with a rifle or camera or taken home in a creel, game bag, or on a roll of film, the majority of all adult Americans have an active interest in wildlife. The other constituency, nonconsumptive users, represents a potential and, thus far, untapped source of additional financial and political support for both game and nongame wildlife programs. Though often viewed as an adversary, the nonconsumptive segment of wildlife's constituency should be considered an ally if fish and wildlife resources are to benefit.

Literature Cited

Gottschalk, J. S. 1966. Potential effects of land and water conservation fund on wildlife. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 31:359–365.

More, T. A. 1979. The demand for nonconsumptive wildlife uses: A review of the literature. Tech. Rep. NE-52. USDA Forest Serv., Amherst, Mass.

Nelson, H. K. 1976. Viewpoints on hunting. Presented at the Mississippi Flyway Council Meeting, Duluth, Minnesota, August 1, 1976.
Reiger, G. 1982. Age of unreason. Field and Stream. February.
Shaw, W. W., D. J. Witter, D. A. King, and M. T. Richards. 1978. Nonconsumptive wildlife enthusiasts visiting southern Arizona: their beliefs about wildlife management programs and policies. Presented at the Arizona-New Mexico Wildlife Society—American Fisheries Society Annual Conference, Douglas, Arizona, February 3–4, 1978.
Starnes, R. 1978. Hunting's newest powderkeg. Outdoor Life. August.
U.S. Fish and Wildlife Service. 1982. Initial findings from the 1980 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. Presented at the 47th North Amer. Wildl. and Natur. Resour. Conf. Portland, Oregon, March 28, 1982.
______. 1980. Service Management Plan. U.S. Fish and Wildlife Serv., Division of Program Plans, Washington, D.C.
______. 1977. The 1975 National Survey of Hunting, Fishing, and Wildlife-Associated Recreation. U.S. Fish and Wildlife Serv. Washington, D.C.
Weeden, R. 1979. Nonconsumptive users: A myth. Ducks Unlimited 43 (Nov./Dec.):46–47.
Wilkes, B. 1977. The myth of the nonconsumptive user. Can. Field Natur. 91(4):343–349.
Witter, D. J., and W. W. Shaw. 1979. Beliefs of birders, hunters, and wildlife professionals about wildlife management. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 44:298–305.

Identifying and Relating Organized Publics to Wildlife Management Issues: A Planning Study[1]

Tommy L. Brown and Daniel J. Decker
Department of Natural Resources
Cornell University
Ithaca, New York

Wildlife managers, particularly at the state and federal levels, are faced with the sometimes awesome task of managing wildlife species for very diverse constituencies. These include many groups having primary wildlife interests ranging from consumptive to preservationist, and other groups for whom wildlife is not a primary focus. The spectrum includes organizations from both the public and private sectors.

When wildlife management issues arise, agencies must assess the likely reaction of affected publics to management alternatives. This is true for both biological and political reasons, and because agencies have a responsibility to the public. Given wildlife agencies' broad responsibilities today for nongame as well as game species, and given the multitude of organizations from the local to the national level that have some interest in wildlife, it is very difficult to determine all of the organizations that may have interest in a particular issue. This study represents an initial attempt at the state level in New York to identify and classify constituent organizations by their interest in the management of representative wildlife species groups, and to gain an understanding of how these organizations perceive and communicate with the state wildlife management agency. The general purpose of this study was to develop information that would enhance wildlife managers' understanding of organizations' values, concerns, and attitudes regarding wildlife.

Methods

The study method consisted of several phases. The first phase of the project involved a detailed literature review and several consultations with Bureau of Wildlife staff of the New York State Department of Environmental Conservation (DEC). Following this, mail questionnaires were sent to 99 DEC wildlife staff. These were used to compile a set of wildlife interest groups that the agency deals with and to ascertain the perceived degree of familiarity of staff with each. In addition to determining the names of organization leaders, the survey developed an index that reflected DEC staff's perceptions of the degree of influence each organization had on agency policy and staff opinions about the appropriateness of the amount of influence. Staff perceptions of the organizations' opinions of wildlife management in the state were also obtained. From a list of 211 organizations generated by staff, 40 key organizations were chosen for further study.

The next phase of study consisted of personal interviews of 48 DEC staff members who indicated they were most knowledgeable of the 40 key organizations. Typically, detailed perceptual information was obtained from four staff members

[1]Funded by New York Federal Aid in Fish and Wildlife Restoration Project W-146-R.

regarding each of the 40 organizations. The interviews obtained staff perceptions regarding the organizations' attitudes toward (1) the values of several wildlife species groups and (2) various wildlife management policies and practices.

The final phase of the study involved personal interviews with leaders of 38 of the 40 key wildlife organizations (two refusals were encountered). Leaders were asked to represent as clearly as possible their organization's perspective, rather than any personal perspective that might differ. Four primary types of information were obtained:

1. attitudes toward values of four wildlife species groups: songbirds, deer, rabbits, and hawks and owls;
2. attitudes and concerns about wildlife management;
3. evaluation of state wildlife management;
4. communications channels between the organization and the wildlife agency.

For each wildlife species group listed in (1) above, organization leaders provided detailed values information. In this study, an expanded version of the classification of wildlife values developed by King (1947) was used; the major value categories are recreational, aesthetic, educational, biological/ecological, social, and commercial.

Results

It should be noted that the primary purpose of this paper is to indicate the types and uses of information from a study such as this for a state or federal wildlife agency. The results section is organized accordingly; i.e., the process used in this study will be emphasized while the data obtained will be used sparingly to illustrate the types of output it can yield. For a detailed report of the New York study see Decker et al. (1981).

Identification and Perceived Familiarity of Wildlife Publics

The study procedure required the agency (i.e., the collective staff) to itemize the wildlife publics it deals with and to identify simultaneously the staff who are most familiar with each organization. This information alone is valuable for reference as issues arise. Furthermore, the process obtains a measure of the perceived degree of influence each organization exerts on the agency and the perceived appropriateness of this level of influence. This provides a mechanism for agency administrators to discover large perceptual differences in the appropriateness of each organization's level of influence and to determine whether corrective action is desirable in the more incongruous cases.

The initial listing of 211 organizations in New York illustrates the number of wildlife interest groups a state agency must deal with. (In addition to these groups, each of which was requested to be at least regional in scope, many county and local organizations interact with a state agency.) The list of 40 key New York organizations includes public agencies such as the State Office of Parks and Recreation and the Department of Agriculture and Markets, the Soil Conservation Service, and Cooperative Extension. Private wildlife-oriented organizations identified by agency staff include those focusing on both game species (e.g., Ducks Unlimited, National Wild Turkey Federation) and nongame species (e.g., National

Audubon, New York State Falconry Association), and organizations whose primary focus is not wildlife-oriented (e.g., American Humane Society, Grange).

Identification of Communications Channels

An analysis of communications channels typically used between the wildlife agency and an organization can determine whether each is using the most effective channel for specific purposes. Sometimes the media or other intermediaries such as lobbyists distort (whether intentionally or not) the programs, objectives, or policies of both the wildlife agency and the organization. Good direct lines of communication help guard against this problem. For most of the key wildlife organizations surveyed in New York, communication both with and from DEC was most frequently via direct personal contact. Printed media (reports, policy statements and other documents) were also frequently used.

Satisfaction of Organizations with Management

At least two aspects of satisfaction become interwoven when an organization's leader is asked to evaluate a wildlife agency. The first is largely current and issue oriented, often focusing on how well the agency's current management program for a given species group corresponds to the interests of the organization. The second aspect is broader, dealing more with the degree of confidence the organization has in the agency's ability to manage that species group. Both aspects of satisfaction were investigated in the New York study for seven species groups: deer, beavers, coyotes, rabbits, hawks and owls, red-winged blackbirds, and geese. In interpreting the satisfaction results, it is instructive to analyze the "No opinion" response as well as the ratings of organizations providing definitive responses for each species.

State agencies have traditionally devoted the majority of their efforts to managing game species, so it is not surprising that the vast majority of organizations were able to evaluate DEC's management of deer and geese (the evaluations were highly satisfactory). For other species, the ratings of both actual management and ability to manage were favorable on balance, but the "No opinion" responses ranged from 21 percent for satisfaction with management of rabbits and hawks and owls to 53 percent for perceived ability to manage red-winged blackbirds. This should not necessarily be viewed as a problem, since a number of the key organizations had species-specific interest. However, further analysis of those organizations providing "No opinion" answers regarding satisfaction with agency management of particular species is needed to more clearly discern if a problem exists.

Wildlife Values Typologies

It is undoubtedly an understatement to note that successful state and federal agencies in the 1980s must be politically astute. Both from the standpoint of better understanding the interests and concerns of wildlife-related organizations and in considering the political ramifications of doing so, wildlife agencies need to estimate in advance which organizations will be concerned about particular aspects of a proposed management option.

In attempting to provide DEC with such an estimate, a cluster analysis procedure was applied to the values data for each of the four species groups for which detailed information was obtained from key wildlife organizations. The procedure used (Barr et al. 1979: 157–161) performs a hierarchical cluster analysis, beginning with one cluster for each of the 38 organizations, placing the two organizations whose values toward a given species are most similar into one cluster (leaving 37 clusters), and continuing successively until only a specified number of clusters remain (five in this study). These clusters of organizations having similar values toward a given species group will be referred to as "wildlife attitude types" or simply "types." An illustration of the typology that can be developed using this procedure is shown in Table 1. Space limitations prohibit the listing of all organizations of each type; those listed were selected to illustrate the diversity of organiztions falling within each type.

An important general finding of this analysis is that, although the values portion of the survey asked of wildlife-related organizations was identical for each species group, the organizations whose values cluster together differ considerably from species to species. This finding indicates that the common practice of stereotyping organizations based solely on their attitudes toward deer or other game species may be erroneous. Some organizations holding generally opposing attitudes toward the values of one or more species groups may hold similar attitudes toward the values of others.

It should be emphasized that this technique for identifying wildlife value typologies is not proposed as a definitive tool to be used as a substitute for other research. If a new policy or program is being considered that obviously has a strong relationship to the interests of one or more wildlife-related organizations,

Table 1. Wildlife organization attitude types regarding values of hawks and owls.

Type	Summary description	Examples of organizations in type
I	Regard ecological values highly; pragmatic about potentially negative attributes; strong opposition to consumptive use.	NYS Federation of Bird Clubs NYS Veterinary Association Defenders of Wildlife Society of American Foresters Ducks Unlimited
II	Most concerned about negative values; little concern about extractive use.	Adirondack Furtakers Association NYS Falconers Association Grange
III	Ecological values important, but less important than social action or cause value.	NYS Trappers Association Regional Planning Boards Soil Conservation Service
IV	Nonextractive recreational use highly favored; extractive use highly disfavored.	Nature Conservancy NYS Farm Bureau Adirondack Park Agency
V	Highly positive attitudes toward a wide array of values; highly opposed to consumptive use.	Sierra Club Fund for Animals Great South Bay Audubon American Humane Society

the wildlife agency may wish to elicit specific reactions from the organizations' leaders, and perhaps from rank and file members. The typologies are most useful as a planning tool, permitting the agency to project the array of organizations most likely to support or express concern about a proposed program or policy.

Attitudes About Wildlife Management Programs and Practices

In addition to determining the broad values base from which an organization decides what level of support or opposition to give to a particular wildlife agency program or policy, the agency needs more specific information about key organizations' attitudes toward such management programs and practices as habitat acquisition, harvest regulations, and damage/nuisance control. Key organizations' attitudes toward 23 typical wildlife management practices were obtained relative to game/furbearer and nongame/nonfurbearer species. For each practice with which their organization was familiar, leaders were asked if they supported or opposed it, how strongly they felt about it, and whether they desired the level of activity to increase, remain the same, or decrease.

As was done with attitudes toward wildlife values, cluster analysis was used to describe two sets of five attitude types, one for game/furbearer management and one for nongame/nonfurbearer management, among key wildlife-related organizations (Table 2). The analysis for game/furbearer management attitudes produced a typology of organizations that ranged from a type having little interest in specific practices relating to game species to one showing a wide base of support. It also included a type having a wildlife resource orientation but expressing only secondary concern for human use. The analysis of attitudes toward nongame/nonfurbearer species-management produced a typology of organizations representing an equally broad range of attitudinal types.

Disparity Analysis of Agency Perceptions of Organizations

Information about the wildlife values and the attitudes toward management practices held by organizations was asked of both wildlife agency staff and leaders of key wildlife organizations, with those agency staff most knowledgeable of each organization indicating their perception of how the organization would respond. Analysis of these data allows the wildlife agency to ascertain how closely it has understood the values and attitudes of each wildlife-related organization.

In this study, a disparity ranking of the 38 key organizations was assembled for the actual versus agency-perceived values of each of the four representative species groups and for the actual versus agency-perceived attitudes toward management of game/furbearers and nongame/nonfurbearers. Although the correlation is far from perfect, wildlife agency staff had a better understanding of the attitudes and values of game-oriented than of nongame-oriented wildlife organizations. Similarly, for organizations whose interests span both game and nongame species, agency staff more frequently understood the organizations' values toward game species. We would hypothesize that this would be true of most state wildlife agencies.

Application of Attitudes and Values Information

The wealth of information produced by this study has several uses. First, we suggest its use in a planning context as a decision-making aid when a new or

Table 2. Wildlife organization attitude types regarding the management of game/furbearers and nongame/nonfurbearers.

Wildlife Referent	Summary description of type
Game/furbearer	I—Little concern for game/furbearer management activities.
	II—Limited concern in terms of number of policies and practices supported.
	III—Broad base of support for current wildlife management.
	IV—Primarily wildlife resource centered with secondary concern for "use" of wildlife.
	V—Focused concern in its high support for the management of user behavior.
Nongame/nonfurbearer	I—Broad support for nongame/nonfurbearer management, especially efforts to protect species and disseminate information about them.
	II—Unique in strongly supporting only one management activity for nongame/nonfurbearer species—law enforcement.
	III—Little concern for nongame/nonfurbearer species management.
	IV—Strongly supports protection and law enforcement aspects of management for nongame/nonfurbearer species; but differs by strongly supporting some indirect enhancement and nonconsumptive use enhancing activities.
	V—Strongly supports several protection related actions, but places moderate importance on information/education and little importance on research.

modified policy or planning goal is contemplated. The process for applying the information can be viewed as a series of steps (Figure 1). The first two steps require definition and analysis of the proposed wildlife policy or management goal in terms of the values of wildlife affected and the feasible alternative management practices to operationalize the policy or to reach the goal. The third step involves determining wildlife value types favoring, opposing, or neutral toward the proposal, thereby suggesting overall support or opposition. Next (step four), the wildlife attitude types supporting, opposing, or neutral toward various management alternatives to reach the goal are determined. These are then evaluated to estimate the most acceptable alternative.

This information is also useful as a reference document. When an agency staff member is asked to address a wildlife-related organization on a particular topic, or when the agency is addressing a concern expressed by an organization about a particular regulation or management practice, referring to these study results will provide a review of the broader orientation of the organization toward wildlife.

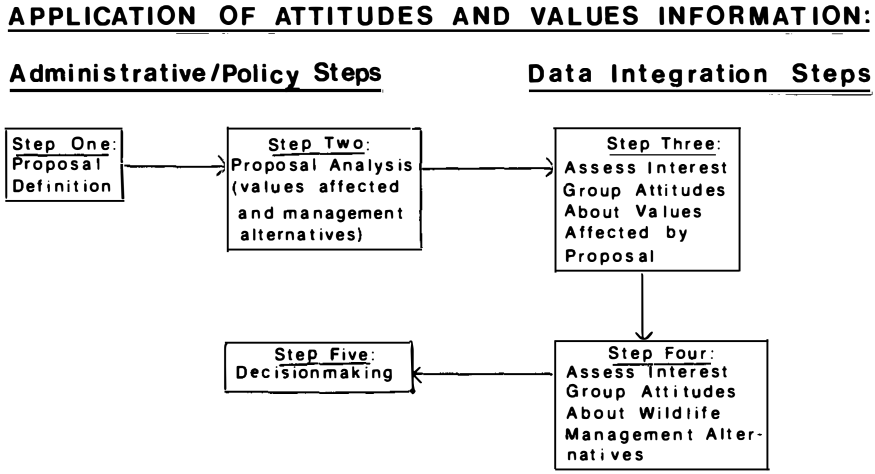


Figure 1. A process for applying wildlife-related organizations' attitudes and values information to agency decision making.

References Cited

Barr, A. J., H. H. Goodnight, J. P. Sall, W. H. Blair, and D. M. Chilko. 1979. SAS user guide. SAS Institute, Inc., Raleigh, N.C. Pp. 157–161.

Decker, D. J., T. L. Brown, and D. L. Hustin. 1981. Design and preliminary studies for identifying attitudes and values toward species and their management. P-R Project W-146-R-7; Job VIII-1. Dept. of Natur. Resour., N.Y. State Coll. of Agric. and Life Sci., Cornell Univ., Ithaca, N.Y. 238 pp.

King. R. T. 1947. The future of wildlife in forest land use. Trans. N. Amer. Wildl. Conf. 12:454–467.

Hunter-Landowner Relationship: A Management and Educational Perspective

Robert M. Jackson
University of Wisconsin, La Crosse

Raymond K. Anderson
University of Wisconsin, Stevens Point

The problems associated with landowner-recreationist relationships continue in spite of a long line of studies and suggestions for programs and solutions that date back at least to the early 1900s. The following was published in *Outdoor Magazine* in 1901:

> In the well-settled agricultural areas, there is war between the farmer and the sportsman. Both parties agree that to insure against the extinction of wildlife, protection is needed, but the laws satisfy neither party. Ask the farmer and he tells you that the game laws are made in the interest of sportsmen from the cities. Ask the same question of the city man, and he declares that farmer legislators with farmer constituents, make the laws with a view of cutting the city man out as much as possible.

In 1929, all landowners of Williamstown Township, Ingham County, Michigan, collectively posted the entire Township in an attempt to control the farm trespass by hunters. A fixed number of trespass permits were issued to each landowner, based on the size of their landholdings; these permits could be given away, sold, or used themselves. The second of "seven basic actions" proposed by Leopold (1931) to improve the wildlife-landowner situation at that time was: "Recognize the landholder as the custodian of public game on all other (than public) land, protect him from the irresponsible shooter, and compensate him for putting his land in productive condition."

A review of the professional literature, popular sportsman magazines, and the contemporary offerings of workshops and conferences by state and provincial agencies indicate that related issues and concerns still face every region of North America. As Decker and Brown (1979) point out, hunting requires a great deal of land per recreationist. The availability and quality of private land, habitat, and access are the keys to continued hunting activity. In addition, the current and future status of the wildlife resource per se is frequently ignored or relegated to low priority in sociological studies of hunter-landowner relationships. Wildlife is an obvious essential component of the relationship between landowner and hunter; there are no landowner-hunter problems where wildlife does not exist.

Trainer (1982) reminded participants at a recent Wisconsin conference on landowner relations that, "Approximately 85 percent of Wisconsin's land is in private ownership, and 80 percent of the wildlife harvested in Wisconsin is from private land." Nationwide, approximately 75 percent of all hunting occurs on private lands. Hendee and Potter (1971), Decker et al. (1979), and Henry and Grau (1981) all extensively reviewed the literature on hunter-landowner relations; among the recommendations for continuing research were these topics: (1) the supply of hunting land and the terms and conditions under which it will be available or withdrawn; (2) surveys of landowner attitudes and policies that monitor changes in both access and habitat; (3) continued efforts to both develop and test programs of access and habitat management that will be acceptable to both landowners and hunters; and (4) the development and evaluation of educational programs that enhance positive attitudes and behaviors in both young and adult hunters and other recreational users. Decker et al. (1979) note that these studies and programs should also be related to "specific locations" often with known and unique management or access problems.

In the light of the above needs are recommendations, the specific objectives of our studies were to determine: (1) the diverse attitudes, policies, and behaviors of hunters, landowners, and professionals as they related to hunter-landowner relationships; (2) the nature and extent of the problem and directions of change as monitored through observation and follow-up studies; (3) the ways in which regional and local factors associated with the resource, the land, economies, and hunter attitudes and behavior affect each other; and (4) to develop educational and management strategies and programs that would offer new approaches to the problem.

Methods

The research on landowner-hunter relationships being reported is one of a series of studies concerning hunting and hunter behaviors being conducted by the investigators. The landowner subjects were 218 individuals who lived in five different Wisconsin deer management units (numbers for the Units were 54, 47, 41, 39, and 37 respectively). These units were selected after extensive consultation with personnel from both the law enforcement and wildlife management bureaus of the Wisconsin Department of Natural Resources (WDNR). Type of terrain, hunting pressure, size of deer herd, hunting regulations, distance from major population centers, and ratio of private to public land were major variables that were considered in selecting management units for the study.

Within each management unit,a single township was selected as being representative of the many counties typically found in each unit or region. This selection was typically based on the written appraisal of district wildlife specialists and conservation officers. Thus, they recommended "Washington Township in Unit 59 (La Crosse County) as being characteristic of the river block of counties with their unglaciated hills, high reproductive rate, and a unique split season; a deer of either sex is legal opening weekend, but only bucks can be hunted during the remainder of the nine-day season. Deer populations estimated at 15–25 per square mile of deer range; annual kill about 6.0." We chose Arena Township in Unit 70 (Iowa County) based on the following: "It is only 30 miles from a major metropolitan center and has very heavy hunting pressure; only three landowners in five actively farm their own land with absentee owners including hobby farmers, and rental or corporate interests occupying the rest. The township has a dense deer population and is representative of most of the deer range north of the boundary known as the Military Ridge." Each of the other three units had unique and important profiles which recommended their selection.

As in other phases of this project, a pilot study was conducted during the preceding hunting season. As a result of this testing process, refinements were made in both the instruments to be used and the methodology to be followed. In particular, the pilot study confirmed our belief that hunter behavior could be observed and logged with landowner cooperation.

The actual subjects were selected randomly from *each* of the township's 36 sections. Current plat maps were used, which gave the names and locations of all landowners. Random procedures were then used to select the names of two owners with land in each section. The 72 names were ordered by first and second choice; the latter would also serve as a pool from which replacement subjects could be drawn in those instances where landowners could not be contacted or refused to cooperate. Research teams were asked to complete between 36 and 55 interviews. Differences in population among units within that range were considered unimportant because the major analysis planned to focus on unit differences rather than group averages. Prior to the study, newspaper and local meetings were held to inform residents of the area about the intent and nature of the study. Landowners were notified that they could expect university students to telephone them with a request for an interview. Well-known, local figures were informed about the study and encouraged to communicate their endorsement to residents of the township. Less than 10 percent of the landowners contacted refused the interview. Replacements, where necessary, were always sought first from the same section of the township, then from the remainder of the randomly drawn pool of subjects.

The timeline for the interviews stipulated that all of the interviews be conducted between October 1 and the Sunday preceding the deer season, traditionally the second weekend in November. Student research teams were selected and trained in interview techniques; role playing was used to familiarize them with the four-page questionnaire and the other data collection procedures. Each student was required to complete one trial interview with a landowner prior to the actual survey. In particular, each landowner participating in this study was to be motivated to maintain a daily log of hunting behaviors as they were observed over each day of the deer-gun hunting season. Each family received a copy of a model of a *completed log sheet* to serve as an example along with a table of nine blank questionnaires, one to be filled out for each day of the season. The landowners were told that they were not expected to see all hunters and hunter behaviors. Subjects were asked to indicate for each day what percentage of that day they were actually in a position to make observations (an absentee landowner, of course, might not ever be able to observe hunter behavior). The game and property violations logged in this study were thus a *minimal estimate* of the extent of trespass, violation, and positive hunter behavior. The research team, in addition, contacted each family by phone on the third or fourth day of the season to ask how the observation was going and to tactfully remind the landowner to complete the log over the entire season. Research assistants then picked up the logs after the season and asked one final oral question, "As a result of your experiences with deer hunters this year, will your policy towards posting be different next year?" Landowners were also informed that this was a longitudinal study and that they would be contacted again by mail or by phone in three years.

The follow-up study was again conducted between October 1 and the Sunday preceding the deer-gun season exactly three years later. *Seventy-seven percent* of the original cooperators responded to the mailed survey or a follow-up telephone call. They were asked to declare their land use policy for the up-coming deer-gun season. Less than 5 percent of the original sample refused to cooperate. The other subjects could not be reached or no longer owned the property. No more than two refusals were encountered in any of the five townships.

Other data about hunter behaviors and hunter-landowner relationships were collected from hunters themselves. Students from three state university campuses conducted 486 field interviews from these five townships during the nine-day Wisconsin deer season (these were distributed by day of the week and by hunter success ratios based on data from previous seasons). In addition, a sample of approximately one hunter in four ($N = 118$) was randomly selected from this group for a post-season home interview. Specially trained professionals used a 12-page questionnaire that included demographic items, self-rating scales, and open-ended questions in probing their attitudes, values, and hunting practices.

The final data collection efforts in this study were designed to evaluate the perceptions and internal frame of reference of landowners, hunters, and two professional groups concerned about the present and future of hunting. To assess the relative importance of hunter-landowner relationships and other hunting related problems, a Likert-type scale was developed which asked the respondent to rate the importance of 11 different problems on a five-point scale. The landowner subjects came from these five deer management units. The deer-gun hunters ($N = 409$) who responded to the scale were attending pre-season evening deer clinics conducted in the two weeks prior to the season at sites scattered throughout the state. Finally, 51 of the 55 state wildlife managers (93 percent) and 120 of 168 field conservation officers (71 percent) completed and returned rating forms mailed to them by the investigators.

Results

It is not uncommon in Wisconsin and other North American locales for writers and speakers to claim that the hunter-landowner relationship is the "number one problem facing hunters." Landowners in this study (Table 1) concurred with that evaluation by giving "failure to seek permission from landowners" their highest rating ($\bar{X}$ = 3.81). Wisconsin's resource managers also agreed with that top rating ($\bar{X}$ = 4.35). While the conservation officers rated poaching as the most important problem ($\bar{X}$ = 4.34), they rated "failure to seek permission", second ($\bar{X}$ = 3.70). In contrast, the sample of deer-gun hunters rated this problem as sixth, although it had a relatively high mean rating ($\bar{X}$ = 3.92). The data suggested that the perceptions and internal reference of the hunter group and landowners are more remarkable for their differences than for their similarities (rank order correlation of −0.20). The differences in rank order placement for 7 of the 11 items are four places or greater (indiscriminate shooting, 2 and 9; hunting accidents, 3 and 10; failure to get permission, 6 and 1; failure to make adequate efforts in retrieval, 7 and 11; taking more than one deer a season, 9 and 3; hunting in large parties, 10 and 5; and group bag, 11 and 4). These same differences can be found in comparing hunter ratings with those of wardens (r_s = +0.19). There is evidence in our data, however, that hunters and managers are much more congruent in their perceptions (r_s = +0.75), as are wardens with landowners (r_s = +0.72).

Landowner observations of hunters (family logs) indicated some of the reasons for the top rating this group gave to "failure to ask permission." While only 124 of the landowners maintained a complete log of hunter behaviors, 78 of these (63

Table 1. Rank order and mean-ratings of deer-gun hunting problems as evaluated by hunters, landowners, conservation officers, and wildlife managers.

Deer-gun hunting problems	Gun hunters	Wildlife managers	Wardens	Land-owners
Poaching (out of season; nights, etc.)	1 (4.17)	2 (3.93)	1 (4.34)	2 (3.67)
Indiscriminate shooting	2 (4.10)	4 (3.44)	9 (3.06)	9 (2.74)
Hunting accidents, unsafe gun handling	3 (4.06)	6 (3.35)	4 (3.65)	10 (2.45)
Shooting illegal deer and letting them lay	4 (4.06)	3 (3.65)	6 (3.56)	6 (2.88)
Usage of alcohol while or around hunting	5 (4.05)	5 (3.40)	7 (3.32)	8 (2.79)
Failure to seek permission from landowners	6 (3.96)	1 (4.35)	2 (3.70)	1 (3.81)
Failure in skill (or effort) to make adequate retrieval of wounded deer	7 (3.92)	10 (3.09)	11 (2.72)	11 (2.42)
Lack of practice and poor marksmanship	8 (3.82)	8 (3.33)	10 (2.95)	7 (2.87)
Taking more than one deer a season (using tags of non-hunters; children, etc.)	9 (3.47)	7 (3.33)	5 (3.64)	3 (3.27)
Hunting in large parties (10 or more)	10 (3.00)	9 (3.19)	8 (3.17)	5 (3.02)
Group bag (hunting for party)	11 (2.88)	11 (3.00)	3 (3.68)	4 (3.05)

percent) observed trespassing on their land at some time during the nine-day deer-gun season. The opening day reports of hunters who did not ask permission to hunt in the five units ranged from 42.3 to 85.7 percent. In addition to these experiences with deer-gun hunters, 46.8 percent of the landowners reported seeing a game law violation at some time during the season. On the opening day of the season, for example, 63.6 percent of the landowners in one of the units reported seeing a game law violation.

Landowners were also asked to observe positive behaviors on the part of the deer-gun hunters. In four of the five units, over half of the observers saw evidence of good sportsmanship and respect among hunters toward property or toward the wildlife resource on the hunted land. In the home interview, the subjects were asked if they ever had gone out and asked hunters to leave. While only 14.8 percent had done this in La Crosse County, the percentages ranged from 56.1 to 74.4 for the other four units. In contrast, the percentages of landowners *prosecuting* for a trespass violation ranged from 3.8 (La Crosse) to 13.5 for Waushara County.

In an effort to determine some of the factors that may lead one landowner to permit *open* hunting and another to *post* the land (hunting with permission, hunting for family and friends only, or no hunting), inferential analysis was made of the 40 items included on the home interview questionnaire. Table 2 presents those items that are germane to this question and for which the level of significance was at the 0.05 level or less. Among those items that we could class as economic, landowners who did *not* post: (1) rated the income productivity of their land as greater, (2) saw it less suitable to support game, (3) estimated a lower economic loss to deer damage, and (4) were less likely to advocate landowner compensation for deer killed on their land.

In responding to question classes as reflecting *attitudes towards hunters,* landowners who did not post: (1) rated hunter ethics and behavior as more positive, (2) were more likely to believe that game belonged to all and that hunting opportunity should be shared, (3) were less likely to hunt themselves, (4) were less likely to see road hunting as a problem, (5) were less likely to have ever asked hunters to leave their land, and (6) were less likely to advocate landowner preference for any sex deer permits.

In questions or rating scales dealing with land-use *policies,* those who did not post were less likely to have cooperative agreements with other landowners concerning deer hunting and less likely to have different policies for land use where the use was for fishing or other forms of hunting. Landowners who hunted themselves were also more likely to manage their land for the production of game, although the differences were not quite significant.

In the follow-up studies of the same individual landowners, the exact same questions were asked during the same time frame. During that three year period, the Wisconsin deer herd, favored by two mild winters, had risen to near record numbers. Unit comparisons, as shown in Table 3, suggest possible trends, although the differences between the total group of subjects over the three-year period do not show significant differences. The percentage of landowners forbidding any hunting or trespassing increased in four of the five townships, decreasing only in that county that had a particularly high percentage of no hunting signs three years earlier. Overall, the percentage rose from 12.1 to 15.9. Similarly, the percentage of landowners not posting in any way decreased in four of the five townships. The

Table 2. Factors for which significant differences exist between landowners who post and those who do not post their land.

Factors/attributes	X^2 or F value	df[a]	P value
Economic			
See land as more suitable to produce income	4.47	1,209	0.05
See land as less suitable to support game	4.82	1,211	0.05
Estimates less economic loss from deer damage to crops and trees	13.55	1,156	0.001
Less likely to report deer damage to crops and trees	8.14	1	0.01
Less likely to advocate landowner compensation for deer killed on land	6.04	1	0.05
Attitudes toward hunters			
Rates hunter ethics more positively	8.64	1,204	0.01
Believes game belongs to all and hunting opportunity should be shared	131.10	8	0.001
Less likely to hunt themselves	10.08	1	0.01
Less likely to advocate landowner preference for party permits	12.66	1	0.001
Less likely to see road hunting as apparent problem	7.68	1	0.01
Less likely to have asked hunters to leave land	36.96	1	0.001
Policy toward posting			
Less likely to vary land use policy for fishing and deer hunting	17.67	1	0.001
Less likely to have cooperative agreement with neighbors concerning deer hunting	12.61	1	0.001

[a]If only one value is listed for df the test was a Chi-Square test of independence. If two values are listed for df, the test was a One-Way ANOVA which compares mean ratings.

overall percentage not posting decreased from 39.5 to 33.5 in 1981. The differences for "posting with permission" were less than 1 percent overall; the percentage increased from 29.8 to 32.4 for "posting except for family and friends."

Data collection on the same management units, but from different sources, permits us to assess the complexity and interrelatedness of the many factors affecting landowner-hunter relationships. Each unit offers a unique mixture of history, physical conditions, and human attitudes, values, and behaviors. A profile collected from landowners, hunters, wardens, and wildlife managers for *one of the units* follows:

Profile of a Deer Management Unit (59)

Landowner logs and interviews

–Highest percentage (68) of unposted land
–Lowest percentage (15) of those asking hunters to leave land
–Highest self-rating of economic productivity of land
–Middle unit ranking for number who hunt themselves
–Highest rank for those who hunt other's land

Table 3. Changes in landowner policies towards the use of land by deer-gun hunters over a three-year period.

Adjusted frequencies:	Unit 37		Unit 59		Unit 65		Unit 67		Unit 70		Totals	
	1978	1981	1978	1981	1978	1981	1978	1981	1978	1981	1978	1981
1—Not posting	46.2	36.6	67.9	60.9	43.7	30.0	10.8	6.5	21.3	26.3	39.5	33.5
2—Posting with permission	15.4	6.7	17.0	24.4	17.9	13.3	21.6	25.8	21.3	18.4	18.6	18.2
3—Posting—allowing friends and family	33.3	30.0	9.4	4.9	33.3	46.7	56.8	51.6	25.5	36.9	29.8	32.4
4—Posting—no hunting or trespassing	5.1	26.7	5.7	9.8	5.1	10.0	10.8	16.1	31.9	18.4	12.1	15.9
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(X^2 = 2.13, p.n.5 with 3 df)

–Tied for highest in rating the ethics of hunters
–Sixty-eight percent not report neighbors for violating

Hunter interview
–Largest percentage (89) traveled 25 miles (40 km) or less to hunt
–Highest percentage (17) of single hunters
–Highest percentage (35) of those hunting in large groups
–Highest percentage (50) reporting personal knowledge of poaching
–Highest percentage (86) of trespassing on opening day
–Highest percentage (42) for having personal knowledge of violations during season

Wardens and wildlife managers assessments
–Hunting parties are not typically familiar or traditional; often created spontaneously each day
–Steady decline in hunter behaviors and attitudes over the past years
–Hunters do not know habitat and deer behaviors, but do know how to organize drives effectively
–Typical motivation is meat rather than trophy deer
–Alcohol usage not a problem

Each unit, of course, has its own salient behavior profile, which we have developed and shared with professionals and sportsmen as a stimulus and aid to problem solving.

Discussion

The data presented in this paper do confirm the existence and persistence of hunter-landowner relationship problems. Landowners were and are disturbed when trespassing occurs. As one landowner stated to us, "First and foremost, I absolutely want to know when someone is on my land!" There are important implications for the future of hunting when, as in this study, two of three landowners experience trespass and almost one-half see a game law violation during a nine-day deer-gun season. These experiences are crucial in explaining landowner policies and behaviors.

Economic factors, according to the data, also shape policies related to hunting access. Those who do *not* post, see their land as more economically productive and are apparently not motivated to permit hunting because of deer damage. In contrast, those who do post, were more ready to take every economic advantage available from either deer damage or hunter kills. The interviews did suggest that the property owner will be more tolerant if the trespasser is his neighbor; part of this as voiced by some of our subjects, is simply fear of retaliation.

The irrationality of the vandalism and destruction reported in the logs is hard to explain. To cite a few instances, cooperators in the study described: the shooting of livestock or pets; the knocking down of gates and driving over seeded fields; the cutting and stealing of Christmas trees; and armies of hunters driving small woodlots. These stories apparently spread quickly across townships and counties and become part of the local lore. One farmer reported losing a cow that attempted to digest an aluminum arrow. The rapid rise in posting against bowhunting in this local area as determined in the follow-up study indicated that other landowners soon accepted this occurrence as an almost universal phenomenon. However, this particular problem was *never* mentioned in the other units studied, even in response to specific questions.

This research also suggests that hunters themselves fail to see the seriousness of trespass and vandalism. The disparity between hunter ranking of problems and those of wardens, manager, and landowners suggests real failures to communicate and some insensitivity on the part of hunters, but deer hunters *do* seem to realize that they need private land to hunt. Hunter-subjects were asked by the researchers to rate the relative importance of 16 factors in selecting their hunting areas. Having permission to hunt was rated as the most important in two of the five units, while a third unit rated it second. "Returning to traditional areas," the highest rated selection factor in another unit, apparently relates to access to hunt because there is no public land in that particular management area. A few years ago, wildlife managers in Wisconsin suggested new rules that would redistribute hunters within the state. The proposal created an emotional, sometimes violent reaction among hunters. Part of that over-reaction has been attributed to the threat that these changes would create to long established and carefully maintained access compacts between hunters and private landowners. Evidently, many hunters realize the importance of permission to their hunting plans, but fail to see the problem from the view of the landowner himself. As the state's coordinator of hunter education stated, "Hunters still don't know what the landowner really wants, and landowners don't know what the hunter really wants." With better than one-half of the landowners contacted in this study participating as hunters themselves, the biggest need seems to be in educating hunters about landowner expectations.

Landowners and the management of private land need far more attention from sportsmen and state agencies if they are to provide needed habitat and better access to recreational users. The hunter must become actively involved in perpetuation of conditions whereby the wildlife resource can prosper. One-half century ago, Leopold (1933) recommended that the landowner be given control of the number of hunters to fix responsibility for abuses and to regulate harvest. At the same time, it was asserted in *The American Game Policy* (1930) that " . . . first of all, the private landowner must be given some incentive, more powerful and more universal than altruism, for controlling hunting and game environment on his land." Economic return for a product of the land is recognized as being the most universal incentive today. Both hunters and agencies must be willing to provide any of a number of economic incentives that will encourage the landowner to do that which is necessary to foster wildlife populations and promote hunting on private land. Only the landowner can put practices on his land that are beneficial to wildlife.

There are two important limitations facing any state agency hoping to solve these problems. First, landowners, recreationists, and agency personnel themselves have observed to us that any program identified solely with a state agency may already have been given the "kiss of death." Rejection occurs automatically with many because of this association.

The second problem relates to the individual differences among management units and locales as explored in this paper. Each area has its own history, characteristics, and problems as such may well demand an *individualized solution*

. . . one that comes directly from those who live and hunt in that area. This would suggest that the key role for the state agency is to (1) create general awareness among landowners and hunters in particular; (2) locate and motivate the movers and catalysts who can create programs and communication at the local level (sportsmen's clubs, wardens, farm organizations, etc.), and finally, (3) identify and communicate a variety of workable models that have been tested elsewhere in the state or in other states.

One such situation apparently developed spontaneously in one of our study units because of the research activities. Reports from residents in this locale suggested that some landowners were having second thoughts about their intent to post as a consequence of the home interview process. Some of these landowners did change their mind before the season and gave hunters another chance. This happened even though this locale had experienced irresponsible hunting behavior the preceding season, and sentiment for posting in the township had been running strong. The deer-gun season went well in this unit, and many residents reported in the post-season interview that hunting behaviors had been better than in many previous years. Even more important, a few leaders of local farm organizations and area sportsmen's clubs decided to meet together shortly after the season to discuss hunter-landowner problems. They talked at length about expectations and policies acceptable to both groups and began to lay a foundation for the next hunting season. In a second unit studied by the researchers, hunters and sportsmen's clubs were motivated and led by a county game warden to create a broad landowner-hunter program including leases and easements for access, a conservation education program that has drawn national attention, and in the purchase by sportsmen of marshland that created a major public hunting and recreational unit within the county.

These two illustrations (models) reflect the uniqueness of each region, the initiative and extensive involvement of local sportsmen, and the stimulus of key local leadership. In each, a *compact* developed between landowners and recreationists. We see these local and regional *compacts* as the key to the future of both access and habitat development. (Compact also describes the relationship which the individual hunter establishes to gain permission to hunt.) Educators and managers need to find the tools to bring the parties together, the stimuli that facilitate open communication, and a variety of models that offer workable solutions.

Literature Cited

American Game Policy. 1930. Proc. Amer. Game Conf. 17:281–309

Hendee, J. C., and D. R. Potter. 1971. Human behavior and wildlife management: needed research. Trans. N. Amer. Wildl. and Natur. Resour. Conf. 36:383–396.

Decker, D. J., C. P. Dawson, T. L. Brown. 1979. Expanding hunter's access to private lands: potentials, problems and research needed. Paper presented at the 35th Northeast Fish and Game Conference.

Decker, D. J., and T. L. Brown. 1979. Hunting in New York: participation, demand and land access. New York Fish and Game J. 26(2):101–131.

Henry, T. A., and G. A. Grau. 1981. Survey of rural landowner attitudes toward wildlife management. Unpublished. Ohio Department of Natural Resources, Division of Wildlife, Columbus.

Leopold, A. 1931. Report on a game survey of the North Central States. Sporting Arms and Ammunition Manufacturers' Institute, Madison, Wisconsin. 299 pp.
———. 1933. Game management. Charles Scribner's Sons, New York. 481 pp.
Trainer, D. O. 1982. Keynote address. Proc.: Deer Hunting and the Landowner Conference. College of Natural Resources, University of Wisconsin-Stevens Point. 20 Feb., 1982.

Recreation Opportunity Spectrum With Implications For Wildlife-Oriented Recreation

Perry J. Brown
School of Forestry
Oregon State University
Corvallis

Resource planning has undergone transitions over the years from a site to area to regional orientation and from a single function to integrated resource management orientation. Wildlife and recretation resource planning have been part of this evolution, which has been stimulated somewhat by recent land management planning-oriented legislation such as the National Forest Management Act and the Federal Land Policy and Management Act.

During the last couple of years, a system for recreation planning within the context of integrated resource planning has emerged. It is called Recreation Opportunity Spectrum (ROS) planning and arose as an old idea was made operational through new knowledge from recreation behavior research and through the necessity for designing a system that was integrative with other resource planning systems (e.g., Driver and Brown 1978, Clark and Stankey 1979, Brown 1979, Stankey and Brown 1981).

The idea for a recreation opportunity spectrum has been around for a long time. The notion (though not necessarily the label) occurs in the writings of Marshall (1937), J. V. K. Wagar (1951), Burch (1964), Lucas (1964), and J. A. Wagar (1966) among others. The behavioral research that has led to making the idea operational for planning is more recent. For example, in research leading to ROS concepts, Potter et al. (1973) have studied hunters, Driver and Knopf (1976) have studied fishermen, Schreyer and Nielsen (1978) have studied river runners, and Brown and Haas (1980) have studied wilderness backpackers. Based upon the ideas of these and several other authors, the ROS has been made operational for planning. It has been adopted by both the USDA Forest Service and USDI Bureau of Land Management (BLM) and thus is being applied on about 30 percent of the land area of the U.S. (Buist and Hoots 1982).

What is this planning system, how does it work, and how is it related to other resource outputs such as timber and wildlife?

Recreation Opportunity Spectrum Planning

Underlying Recreation Opportunity Spectrum Planning is the idea that quality recreation experiences are best assured by providing a diverse set of recreation opportunities (Clark and Stankey 1979). This idea is no different from suggesting that consumers are well served by producers supplying a variety of goods with which consumers can satisfy their desires. Specifically, in recreation it means that we might supply different opportunities for people to engage in specific recreation activities in specific recreation environments (or settings) to realize desired recreation experiences (Driver and Brown 1978). Further, the assumption suggests that these different opportunities can be arrayed along a spectrum of opportunities that are defined using activity, setting, and experience dimensions.

To plan and manage for an array of recreation opportunities, the Forest Service and BLM have divided the spectrum into six major zones, ranging from modern-urban to primitive opportunities. To enable the identification of land arreas that can support these opportunities, standards that specify appropriate conditions for each zone have been articulated. For resource management, which primarily deals with manipulation of environmental settings, standards for the physical, social, and managerial attributes of the setting are particularly important (e.g., USDA Forest Service 1981).

This basic approach to identifying recreation opportunities guides all stages of ROS planning. The major activities in the process are:

1. Conducting a demand analysis for Recreation Opportunities (ROs) defined along the ROS.
2. Conducting a supply analysis, which consists of (a) estimating the capability of the planning area to provide for different ROs and (b) identifying which ROs are currently provided on the planning area.
3. Determining where and how different ROs should be provided in integration with other planning area outputs (e.g., wildlife).
4. Allocating and managing lands and waters consistent with RO decisions in activity three.

This planning system is not logically different from many other planning systems. It deals with the integration of supply and demand information to arrive at resource allocations and specifies a consistent set of guidelines for management. Its contributions are that it: (1) requires supply and demand analyses to focus on the same products, recreation opportunities; (2) enables delineation on maps of areas providing different opportunities; (3) provides guidelines for management so that actions can be judged for consistency with opportunities to be provided; and (4) recognizes the multidimensional nature of recreation opportunities. The system, while being refined based on what we are learning during its application, has gone through testing in many different environments and has proven applicable under a wide range of conditions. It appears to be suitable for forest, grassland, and desert landscapes and fits all topographic and land ownership conditions.

Since the purposes of planning are to define goals and select means of attaining goals, a major activity of ROS planning must be analysis on the demand side of the planning equation. There are many techniques available for this analysis (King and Davis 1980), but the key to any of them is defining recreation products in ROS terms. Therefore, rather than continuing to define the products of recreation management as activities (e.g., hunting, swimming, etc.), we need to define them as recreation opportunities, fully recognizing their activity, setting, and experience components. This enables the integration of demand information with supply information that is similarly articulated.

The supply analysis portions of the process are the most developed and enable the integration of ROS planning with other resource planning activities (Brown 1979). Identification of three characteristics of supply are of primary concern: type of opportunity, amount of opportunity, and quality of opportunity.

To identify type of opportunity, standards have been developed that specify acceptable conditions for an area's remoteness from sights and sounds of man, man caused modifications of the resource, size of area, human use and social situation, and managerial inputs. The output of this phase of supply analysis is delineation on maps of areas that supply different types of opportunity along the spectrum. In essence, we identify areas having different recreational habitats as defined by physical, social, and managerial dimensions.

Once type of opportunity (ROS area) is identified, we have an area for which we can estimate amount of opportunity and evaluate the quality of opportunity. In estimating amount, we develop information based upon landscape features, such as vegetation, soils, topography, and water type and location, that enable characterization of capability areas within the ROS areas. Information on facility capacity is brought into the calculus, and estimates are made of the amount of recreation that can be supplied by capability area within ROS areas. Individual capability area amounts are then aggregated to determine ROS area amounts. For specific activities such as hunting, additional information, such as species and population information, would be input to arrive at amount.

Evaluating the quality of the recreation opportunity requires some additional information. Area attributes, such as diversity of landscapes and diversity of recreation opportunities, are important. Examining these kinds of attributes enables determination of the quality of opportunity within a type so that two areas of the same type can be compared.

The information in Table 1 is illustrative of the kind of tabular information produced during ROS supply analysis. This same information can be placed on maps so that one can see the spatial distribution of recreation opportunities and their characteristics.

In this particular instance, we have a 4,000-hectare (9,884-acre) area that contains three ROS zones: 800 hectares (1,977 acres) of rural opportunity, 1,600 hectares (3,954 acres) of roaded natural opportunity, and 1,600 hectares of semi-primitive non-motorized opportunity. Approximately 7,400 persons can be served at one time in the total area, and the quality of opportunity varies from moderate, in the rural and roaded natural zones, to high, in the semi-primitive non-motorized zone.

This brings us to the major focus of ROS planning, integration of recreation with other functional areas of resource management. In bringing recreation demand and supply information together to make land allocations, we need to consider how recreation affects other resource outputs and how management for other outputs affects recreation. This is possible in the ROS system because the land areas providing different recreation opportunities are delineated based upon specific standards for relevant conditions, as noted previously. Because these standards indicate acceptable conditions, the effect of any change in management, for any

Table 1. Recreation opportunity type, amount, and quality of a 4,000 hectare tract of land.

ROS class	Area (hectares)	Amount (paot)	Quality
Rural	800	4,000	Moderate
Roaded natural	1,600	3,200	Moderate
Semi-primitive non-motorized	1,600	160	High
Total	4,000	7,360	

output, on these conditions can be compared to the standards. We can evaluate the effects of recreation, wildlife, timber, or any other kind of management. Alternatively, we can determine what effect maintaining specific conditions for recreation will have on other resource outputs that might require changing the conditions.

For example, we might consider a proposal to harvest timber in the area identified in Table 1 that presently provides semi-primitive non-motorized forms of recreation. Harvesting the timber will require both building a road and manipulating the forest. Two criteria used in specifying the type of recreation opportunity are remoteness from the sights and sounds of man and human caused modifications of the resource, both of which would be affected by the harvesting activity. Therefore, if the road and harvesting sufficiently change the area's character, the recreation opportunity provided will be changed. In our example from Table 1, one harvesting proposal has the effect of reducing the semi-primitive non-motorized opportunity from 1,600 hectares (3,954 acres) to 1,200 hectares (2,965 acres), with a simultaneous increase in roaded natural opportunity of 400 hectares (988 acres). Due to the nature of the change, persons-at-one-time capacity for the entire area increased by about 800 persons. Also, the quality of the remaining semi-primitive opportunity declines to moderate while the quality of the roaded natural opportunity becomes high.

Such trade-offs as these are important to consider in resource planning, and the ROS planning system makes them possible. Although it is not possible to provide common units of measurement for tradeoffs of this sort (e.g., a timber allocation would be measured in terms of money and volume of fiber; recreation would be measured in hectares in ROS classes and number of people served), even non-common unit trade-offs give decision makers a much better notion of the kinds of gains and losses associated with alternative allocation decisions.

After appropriate land allocations are determined, it is necessary to manage the resource to insure desired production. The ROS planning system aids this activity because of the standards that are used to define recreation opportunities. These standards become parameters for management objectives that are articulated in ROS terms. As such, they provide guidance for recreation and other resource management and project planning because acceptable management actions and setting conditions are prescribed by the standards used to define recreation opportunity classes and to delineate each planned recreation opportunity. Once an ROS allocation is selected, management action and project plans are a natural outcome of allocation decisions.

ROS and Wildlife-Oriented Recreation

The ROS planning system gives us another tool for considering wildlife oriented recreation such as hunting, fishing, and birding. It enables specification of the kinds of recreation opportunities in which recreational use of wildlife takes place and provides a means for characterizing demands for recreational use of wildlife.

What it suggests on the demand side of the planning equation is a characterization of the activity, setting, and experience demands of wildlife users. On the supply side it suggests a characterization of what we can provide in the way of activity, setting, and experience opportunities.

To illustrate these points, we can refer to research undertaken in the Steens Mountain area of southeastern Oregon. This research focused on the relationship between deer hunter preferences for settings and experiences and the recreation opportunities provided at Steens Mountain.

The Steens Mountain Recreation Area is managed by the USDI Bureau of Land Management and covers approximately 960 square kilometers (370 square miles) of a very sparsely populated landscape. The nearest community (of 4,000 persons) is about 95 kilometers (59 miles) away. The mountain itself is a fault block characterized by slowly rising terrain on its western slope and an abrupt escarpment on its eastern slope. Its western slope is cut by several large U-shaped valleys that are remnants of former glaciation. The mountain rises about 1,500 meters (4,900 feet) above the surrounding desert.

With its spectacular scenery, good fishing in streams and lakes, and abundant game and nongame wildlife, Steens Mountain has become a popular recreation area. Major recreational activities are fishing, hiking, camping, off-road vehicle use, and hunting.

Most of the hunting use of Steens Mountain occurs away from its loop access road in zones delineated as providing semi-primitive motorized opportunity. A few hunters hunt along the main loop road and in areas where motorized vehicles are excluded. For most Steens Mountain hunters the experience can be described as one where the environment is essentially natural, where the sights and sounds of man are not pressing users, where there is some opportunity for solitude, but where there are other hunters around, and where the presence of management is infrequent.

In reviewing the specific experience preferences of these hunters, we find that harvesting an animal is important for many of them, though certainly not for all. Additionally, experiencing nostalgia of previous hunts, exercise, learning and relating to nature, being with people in one's hunting group, and being a well-equipped hunter are powerful motivators for many hunters. Among 24 different experiences, only three, escaping family, meeting/observing new people, and risk taking were not important positive experiences desired from deer hunting at Steens Mountain (Lee 1982).

This kind of information about the places where people hunt and some of their desires for hunting experiences tells us many things we might consider as we manage resources and manipulate the supply of recreation opportunities. In the case of Steens Mountain, for instance, we need to be concerned about providing opportunities away from main roads and in essentially natural environments. We also need to be concerned with not eliminating opportunities for people to gain exercise, learn about and commune with nature, and have interaction within their group. On the other hand, we might avoid providing opportunities for people to meet other hunters and to experience environmentally oriented risks. In general, we might conclude that the desired hunting experiences at Steens Mountain fit into the semi-primitive motorized and non-motorized categories based upon the standards that define acceptable conditions for these two classes of opportunity. Also, we can use this information to specify even more definitely the character of the opportunities desired and define appropriate subclasses within the six general classes of recreation opportunity.

Knowing that these hunting opportunities are desired, the manager can see if he can provide them on his area. Using ROS standards, he can identify the type, amount, and quality of opportunities provided at Steens Mountain and make recommendations to add more of the desired opportunities if necessary. Using the general framework for ROS planning, managers could look within these general opportunities to delineate more specific or sub-opportunities. This would require their specifying appropriate standards for the additional criteria used in subdividing the general classes of opportunity. With these additional standards, subclasses could be mapped and amount and quality of opportunity estimated.

Information about ROS zones in the Steens Mountain area could be used to direct hunters to areas providing desired opportunities. As has been mentioned elsewhere (Brown and Haas 1980), information about recreation opportunities can help users match their preferences with what is actually provided. Finally, because some wildlife management activities in the Steens Mountain area might require manipulating habitat or affecting populations, wildlife management might affect the type, amount, or quality of recreation opportunities. These effects can be judged because recreation opportunities have been determined for the area based on standards specifying specific requirements for each recreation opportunity.

This illustration from Steens Mountain is confined to deer hunting. But information about species preferences, preferences for other recreation activities, preferences for specific attributes of the setting in which hunting takes place, and location of activity also could be useful to managers dealing with wildlife-oriented recreation. The ROS planning framework enables the use of these kinds of information about user desires and behaviors in determining the types of opportunity to provide and in providing guidance for management.

Conclusion

The ROS planning system is a product of managers and researchers working together to develop a better tool for land management planning. The primary research input to it came from studies of users of recreation sites and areas. The ROS planning system has been shown to be applicable to a wide variety of situations and environments. It is still under development as we learn more about natural resources and human behavior, and its basic framework is being extended into related areas such as wilderness and wildlife management. For wildlife management and wildlife-oriented recreation, it enables identification of the kinds of recreation opportunities in which the specific activities fit, it enables determination of the effects of management activities on recreation and of recreation on other resource outputs, and it aids in helping match people and their preferences to the opportunities that actually can be offered.

References Cited

Brown, P. J. 1979. The opportunity spectrum: techniques and implications for resource planning and coordination. Pages 82–87 *in* Dispersed recreation and natural resource management. College of Natural Resources, Utah State University, Logan. 91 pp.

______, and G. E. Haas. 1980. Wilderness recreation experiences: the Rawah case. J. Leisure Res. 12(3):229–241.

Buist, L. J. and T. A. Hoots. 1982. Recreation opportunity spectrum approach to resource planning. J. Forestry 80(2):84–86.

Burch, W. R., Jr. 1964. Two concepts for guiding recreation management decisions. J. Forestry 62(10):707–712.

Clark, R. N. and G. H. Stankey. 1979. The recreation opportunity spectrum: a framework for planning, management, and research. USDA Forest Service General Technical Report PNW-98. USDA Forest Serv., Portland, Ore. 32 pp.

Driver, B. L., and P. J. Brown. 1978. The opportunity spectrum concept and behavioral information in outdoor recreation resource supply inventories: a rationale. Pages 24–31 *in* Integrated Inventories of Renewable Natural Resources. USDA Forest Service General Technical Report RM-55. USDA Forest Serv., Fort Collins, Colo. 482 pp.

Driver, B. L., and R. Knopf. 1976. Temporary escape: one product of sport fisheries management. Fisheries 1(2):21–29.

King, D. A., and L. S. Davis. 1980. Recreation benefit estimation: a discussion summary. J. Forestry 78(1):27–28.

Lee, M. 1982. Characteristics and preferences of deer hunters on Steens Mountain, Oregon, 1980. Office Report, Resource Recreation Management, Oregon State University, Corvallis. 28 pp.

Lucas, R. C. 1964. Wilderness perception and use: the example of the Boundary Waters Canoe Area. Natur. Resour. J. 3(3):394–411.

Marshall, R. 1937. The universe of the wilderness is vanishing. Nature Magazine (April 1937):235–240.

Potter, D., J. C. Hendee, and R. N. Clark. 1973. Hunting satisfaction: game, guns, or nature? Pages 62–71 *in* J. C. Hendee and C. Schoenfeld, eds. Human dimensions in wildlife programs. Wildlife Management Institute, Washington, D.C. 193 pp.

Schreyer, R. C., and M. L. Nielsen. 1978. Westwater and Desolation Canyons: white water river recreation study. Institute for Outdoor Recreation and Tourism, Utah State University, Logan. 196 pp.

Stankey, G. H., and P. J. Brown. 1981. A technique for recreation planning and management in tomorrow's forest. Pages 63–73 *in* Proceedings, Division 6, XVII International Union of Forest Research Organizations World Congress, Kyoto, Japan. 504 pp.

USDA Forest Service. 1981. Recreation input to land and resource management planning. FSH 1909.12, Land and resource management planning handbook for national forests, ch. 500. USDA Forest Serv., Washington, D.C. 45 pp.

Wagar, J. A. 1966. Quality in outdoor recreation. Trends in Parks and Recreation 3(3):9–12.

Wagar, J. V. K. 1951. Some major principles in recreation land use planning. J. Forestry 49(6):431–435.

Registered Attendance

ALABAMA
Patrick W. Brown, James R. Davis

ALASKA
Louis Bandirola, Ed Bangs, Michael A. Barton, Alan J. Bennett, Laurel Bennett, Robert D. Burkett, Gregory F. Cook, Dirk V. Derksen, David J. Dunaway, Lloyd Fanter, David R. Gibbons, Thomas A. Hanley, W. Dale Heigh, Ben L. Hilliker, Mimi Hogan, John R. Howe, Ancel M. Johnson, Barbara Johnson, Ronald D. Kelso, Junior Kerns, Edward B. Kiker, Susan Littlefield, E. Richard Logan, Sue Matthews, John W. Matthews, Donald E. McKnight, Pete Mickelson, Donald C. Mitchell, Ray S. Mule, Allan V. Naydol, Margaret R. Petersen, Robert W. Phillips, Tom Pogson, Robert S. Roys, John Schoen, Keith M. Schreiner, Ronald O. Skoog, Daniel Timm, Mark Voight

ARIZONA
Sally Antrobus, Bud Bristow, Cole Crocker-Bedford, Frank Ferguson, Jr., Norma Ferguson, Paul R. Krausman, Evelyn M. Pratt, Jerome J. Pratt, Rick F. Seegmiller, Norman S. Smith, Harry R. Woodward

ARKANSAS
Carlton N. Owen, John C. Sunderland, James S. Walter, Billy E. White, Steve N. Wilson

CALIFORNIA
Dennis Ades, Judge Anderson, Mariann Armijo, John Beam, Joan R. Beattie, Steve Berwick, Doug Brewer, William Burger, W. Dean Carrier, Dave Chesemore, Blair Csuti, Laurie Daniel, Sharon Daugherty, Doug DeMasto, Paul J. DuBowy, Robert Ewing, Robert C. Fields, Lee Fitzhugh, Jeffrey B. Froke, Charles Fullerton, Glenn Gephart, David S. Gilmer, Peter Gogan, Richard T. Golightly, Jr., Hatch Graham, Win Green, Lisa Guminski, R. J. Gutierrez, William Hamersky, Joe Harn, John G. Hewston, Bruce Hulberg, Christopher Jacobson, Sandra L. Jacobson, Fred L. Jones, Gloria Jones, Robert J. Keiffer, John G. Kie, Kheryn Klubnikin, Gary Kramer, Jeffrey Laake, Patricia Lance, William F. Laudenslayer, Jr., Stephen A. Laymon, A. Starker Leopold, Barbara D. Marcotte, Sandra K. Martin, Ken Mayer, Michael McCloskey, Homer McCollum, Mary McCollum, Dale R. McCullough, Marta McWhorter, Karen J. Miller, Michael R. Miller, Tom Mings, Julie L. Moore, Tim Chip Moran, Barry R. Noon, Joel P. O'Kula, Martin G. Raphael, Dennis G. Raveling, Richard G. Reid, Russ Roach, Mike Ross, Timothy Sagraves, Hal Salwasser, Nancy H. Sandburg, Richard Sapon-White, Sarah Sapon-White, James Sedinger, Jon Shelgren, David A. Sinclear, David Solis, Larry Strong, George Studinski, William E. Talley, Richard D. Teague, Steven C. Thompson, Joe Thornton, Edward F. Toth, Hartmut Walter, Richart E. Warner, Bruce E. Watkins, Deborah J. Watkins, Maxine Whale, Kay Wilder

COLORADO
James A. Bailey, Delwin E. Benson, Clait E. Braun, David E. Chalk, Bob Comer, Robert S. Cook, Mrs. Robert S. Cook, Allen Cooperrider, Eugene Decker, Adrian Farmer, M. Susanna Goad, Jack R. Grieb, Retha Grieb, Dale Hein, Hans Hess, Thomas W. Hoekstra, Robert E. Keiss, Barbara Knopf, Fritz L. Knopf, Jim Lipscomb, Stephen P. Mealey, Harvey W. Miller, Stephen A. Miller, John W. Monarch, Arnold Olsen, Pauline D. Plaza, Marty Sabraw, Fred B. Samson, Mel Schamberger, Thomas G. Scott, William K. Seitz, Judy L. Sheppard, Evadene B. Swanson, Gustav A. Swanson, Elroy Taylor, John R. Torres, Mrs. John R. Torres, Bob Turner, Richard Weeks, Doriz Zemlicka

CONNECTICUT
John M. Anderson, Harry L. Hampton, Stephen R. Kellert, E. S. McCawley, Jr.

DELAWARE
Lloyd Alexander, William C. Wagner II

DISTRICT OF COLUMBIA
David Almand, G. Ray Arnett, Jack H. Berryman, Joseph K. Bratton, William Doug Brown, John D. Buffington, R. L. Carlton, Louis S. Clapper, John Crawford, Jeff Curtis, Edward L. Davis, Robert Davison, Henry J. Gerke III, John W. Grandy, Victoria C. Guerrero, Keith Hay, Wes Hayden, Ray M. Housley, Robert F. Hutton, Helen F. Jahn, Laurence R. Jahn, Robert A. Jantzen, Dale A. Jones, Lois Jones, C. Eugene Knoder, Ronald E. Lambertson, Richard E. McCabe, James M. Meehan, Doug Miller, Bob Nelson, Midge Nelson, James M. Norine, Dave Olsen, Charles K. Phenicie, Lillian Phenicie, Daniel A. Poole, Dorothy C. Poole, Martha Pope, Norville S. Prosser, Gilbert C. Radonski, William K. Reilly, Lee Resler, Rexford A. Resler, John P. Rogers, Cathy Sabol, Kenneth J. Sabol, Steve Shimberg, Dan Sokoloski, Bettina Sparrowe, Rollin Sparrowe, Dottie Taylor, Carl H. Thomas, Richard S. Thorsella, David L. Trauger, Rolf Wallenstrom, Charles K. Walters, W. Alan Wentz, Jackie Wescott, Lonnie L. Williamson, Gale L. Wolters, Barbara Wyman, John Yago, Charlie Ziegler

FLORIDA
J. Don Ashley, Pam Ashley, Robert M. Brantly, Allan L. Egbert, Larry D. Harris, Ronald F. Labisky, Richard L. Lattimer, Donald R. Progulske, Jr., Joan Scott

GEORGIA
Jeffrey J. Jackson, Jerry P. McIlwain, Victor F. Nettles, James W. Pulliam, Jr., Susan P. Rust

HAWAII
Ronald L. Walker

IDAHO
Ernest D. Ables, Mike W. Anderson, Shirley Badame, Charles Blair, Signe Sather Blair, Jenny Carson, Jerry M. Conley, Rex C. Crawford, Paul D. Dalke, Duane H. Fisher, Jr., Robert M. Gertsch, Diana Gilbert, Frederick F. Gilbert, Donna M. Gleisner, Dean Graham, Jeff Green, Richard Greer, Valerie Guardia-Harper, George G. Harrington, Paul Harrington, Greg Hayward, Terry Hershey, Helen Horn, Thomas C. Horn, Maurice Hornocker, Richard P. Howard, Howard G. Hudak, Jerry Hupp, Kenneth E. Hungerford, Danielle Jerry, Winifred B. Kessler, Ralph D. Kizer, Michael N. Kochert, Lisa Langelier, Peggy Lawless, Michael H. Luque, John Marshall, Samuel N. Mattise, Kathleen Milne, Richard L. Moore, William H. Mullins, Wally Murphy, Lew Nelson, Louis J. Nelson, Kenneth D. Norrie, Tim Patton, Ross Peck, James Peek, D. John Pierce, William Platts, Scott Pruitt, Robert Ralphs, Michael D. Samuel, Alan Sands, Michael D. Scott, Ruth Shea, Dean F. Stauffer, Karen Steenhof, John Y. Takekawa, Susan L. Tank, Cynthia L. Teipner, Rob Wielgus, Susan M. Wise, John R. Woodworth, Alice Wywialowski

ILLINOIS
George V. Burger, Jeannine W. Burger, Mike Conlin, Matthew B. Connolly, Jr., Suzanne S. Dixon, Wesley M. Dixon, Jr., Warren Garst, G. Tanner Girard, James E. Houk, David Kenney, W. D. Klimstra, Kenneth V. McCreary, Thixton Miller, Sarah F. Perkins, Edward M. Puls, Glen C. Sanderson, William L. Searle, James M. Shepard, Dennis Thornburg, David Wesley, Dale E. Whitesell

INDIANA
Bob Kern, Laura Kern, C. M. Kirkpatrick, Harmon P. Weeks, Jr.

IOWA
Bob Barratt, Richard A. Bishop, Robert B. Dahlgren, Allen L. Farris, Kathie Farris, Baxter Freese, James L. Hansen, Larry J. Wilson

KANSAS
George C. Halazon, Bill Hanzlick, Anice M. Robel, Robert J. Robel

KENTUCKY
Bill Graves, Bill McComb, Ward Rudersdorf

LOUISIANA
Joseph A. Dugoni, Allan B. Ensminger, Marilyn Ensminger, James G. Gosselink, Mrs. James G. Gosselink, Joe L. Herring, Jacob Lehman, Julia McSherry, Phillip J. Zwank

MAINE
Hew Crawford, Malcolm W. Coulter, Emma M. Mendall, Howard L. Mendall, Jim Sherburne

MARYLAND
Henry W. DeBruin, E. Hugh Galbreath, Harry E. Hodgdon, Malcolm E. King, William B. Krohn, Daniel L. Leedy, James R. Lyons, Edward Soutiere, Patricia Soutiere, Carl R. Sullivan

MASSACHUSETTS
Stuary Avery, Richard Borden, Richard Cronin, Howard N. Larsen, Joseph S. Larson

MICHIGAN
Richard Block, Marian S. Dressler, Richard L. Dressler, Charles Guenther, Don Hoyt, Sr., Edward J. Mikula, Glenda Robinson, William Robinson, Craig M. Roebuck, Ronald T. Rollet, Raymond D. Schofield, Howard A. Tanner, Louis J. Verme

MINNESOTA
Forrest Carpenter, Juanita Carpenter, Dan Frenzel, Roger Holmes, Robert L. Jessen, Gene M. Nelson, Harvey K. Nelson, Mary A. J. Pietz, Reuel H. Pietz, Bill Stevens, Milton W. Weller

MISSISSIPPI
Dale H. Arner, Billy Joe Cross, Jean Hunt O'Neil, K. T. Ridlehuber, Ross "Skip" Shelton, Lon Strong

MISSOURI
Ken Babcock, Thomas S. Baskett, John T. Brady, Allen Brohn, Emily Brohn, Amy Callison, Charles H. Callison, Edward A. Cleveland, Bill T. Crawford, George P. Dellinger, Carl DiSalvo, Leigh H. Fredrickson, James P. Fry, Larry R. Gale, Edwin H. Glaser, Sherman Kelly, Roger L. Kirkman, Dean A. Murphy, Charles A. Purkett, Jr., James M. Sweeney, Richard H. Thom

MONTANA
Gene Allen, Joe Ball, Don Childress, Paul J. Conry, W. Daniel Edge, Kevin B. Elliott, Rhonda Elliott, Robert L. Eng, James W. Flynn, Rod Flynn, Sidney Frissell, Tom Ganser, Ernest Garcia, Charles J. Griffith, Spencer S. Hegstad, Lorin L. Hicks, Lynn R. Irby, Donald A. Jenni, Susan Kraft, Rose Leach, Richard J. Mackie, Michael J. Madel, Ronald G. Marcoux, C. Les Marcum, Jina Mariani, Bart W. O'Gara, Sally Olson, Mary E. Pengelly, W. Leslie Pengelly, Michael Rath, Katherine Sylvester, Vernon E. Sylvester, John P. Weigand, Darrel Weybright, Karen Wilson, Leonard S. Young

NEBRASKA
William J. Bailey, Jr., Steven E. Bassett, Bruce Cowgill, Harold K. Edwards, Keith W. Harmon, Ken Johnson, Larry Klimek, Robert D. Marcotte, Terry Medjo, Karl Menzel, Tina Proctor, Robert M. Timm

NEVADA
Greg Beasley, Stephen H. Bouffard, Paul Dankowski, Phillip B. Davis, Bernice Fischer, Virlis L. Fischer, Jeff C. Harris, Donald Klebenow, Mike Lawrence, Ross Leonard, Frederick C. Pullman, Robin Pullman, Diana E. Sjoberg, Jon C. Sjoberg, Victoria L. Wade, Jim Yoakum

NEW HAMPSHIRE
Bill Mautz, Sue Mautz

NEW JERSEY
Sheila Link

NEW MEXICO
Roger Bumsted, David Coss, Robert A. Garrott, Ladd S. Gordon, V. Lee Grover, Harold F. Olson, Jean Olson, Sanford D. Schemnitz, Mike Spear, Beatrice Van Horne, Elizabeth White, Gary C. White, Bill Zeedyk

NEW YORK
Andrew F. Behrend, Donald F. Behrend, Tommy Brown, Clare Conley, M. Rupert Cutler, William R. Hilts, Jay McAninch, Russsell W. Peterson, Gordon C. Robertson, Ed Zern

NORTH CAROLINA
C. A. Alexander, W. Vernon Bevill, Phillip D. Doerr, Richard A. Lancia, James R. Linville, Thomas D. Peterson, Gary J. San Julian, Randy P. Strait

NORTH DAKOTA
Richard D. Crawford, Sarah Wharton, Karen Kreil, Randy Kreil, Gary L. Krapu, Charles H. Schroeder, Susan Gay Simpson

OHIO
Theodore A. Bookhout, Steven H. Cole, James H. Glass, Robert D. Hoffman, Tony J. Peterle

OKLAHOMA
Steve Lewis, Byron B. Moser, L. B. "Beau" Selman, Linda Shalaway, Scott Shalaway, Gene Stout, Glenn Titus, Oleta Titus

OREGON
Brooke Abbruzzese, Bill Anderson, Joyce Aney, Warren W. Aney, William C. Aney, Robert Anthony, Neil B. Armantrout, George Arnold, Rudy Arnold, Ronald B. Auler, Jack L. Baker, Cindy L. Barkhurst, Steele Barnett, Phyllis Baum, Robert C. Baum, Orrin Beckwith, John E. Benneth, Craig Bienz, Fred Bills, Lawrence Blus, Katie Boula, Elizabeth Boyd, John Boyer, Karen Boyer, Marianne Bromley, Anne Brower, David R. Brower, Rebecca A. W. Brown, Charles Bruce, Terry Bryan, Todd D. Buchholz, Richard A. Buckberg, Evelyn Bull, C. J. Campbell, June Campbell, Kim M. Campopiano, Rod Canutt, Richard Carmichael, Bill Castillo, Galen Chandler, Ron Chapin, Shelly Chapin, David B. Charlton, Henry P. Chrostowski, Michael D. Clady, Lloyd M. Collett, Patricia Collins, Joseph Cone, Don Corn, John E. Cornely, Char Corkran, Dave Corkran, Mary Cottrell, Jeffrey Craig, Steve Cross, David S. de Calesta, Michael Denis, Walter Devaurs, John R. Donaldson, Arlene T. Doyle, John K. Dueker, Dan L. Eastman, Daniel K. Edwards, George J. Eicher, Wayne Elmore, Claire Farrell, Mike Fellows, Truman J. Fergin, Brian T. Ferry, James Fessler, Keith W. Fletcher, John Forsman, William A. Freeland, Richard W. Frenzel, Helen Fulton, Robert Fulton, Ron Garner, George Gates, Roy Gault, Jack Gentile, Doreen Gillespie, Jessica L. Gonzales, Frank F. Graves, Gregory A. Green, Perry L. Greene, Joe Greenley, Jim Greer, Dorothea B. Groves, Frank W. Groves, Dennis Gutknecht, Thomas Haensly, Jim Hainline, Harvey H. Halvorsen, Jan Harmon, James F. Harper, Robert W. Harris, Jim Harvey, Gordon Haugen, John P. Hayes, Julie Henderson, Loree A. Henningar, William G. Henry, Mark Hodgkins, Kirk M. Horn, Scott Horngren, Mike Houck, Janet Howard, Roy Hugie, Nathan S. Jim, Sr., Buford Johnson, Jr., Kathy Johnson, N. D. Johnson, Wilbur Johnson, Sr., Marvin R. Kaschke, George Keister, David M. Kelly, Linda Kerley, Andy Kerr, Jack Kincheloe, Ted Kistner, David E. Kerley, Donna LaBar, Michael R. Leonard, Deborah L. Lewis, Brian Lightcap, Joseph B. Lint, Wayne D. Logan, W. M. Longhurst, Dean P. Longrie, Dave Luman, Ira D. Luman, Mary K. Lumsden, Herb Lundy, Lynn A. Maguire, R. William Mannan, Bruce Marcot, Lowell D. (Dean) Marriage, Curt Marshall, Betty Marshall, David B. Marshall, Paul F. Maslen, Caren Mathis, Gordon Matzke, Michael McAllister, Katherine L. McArthur, Linda C. McEwan, Patrick McIntire, Clarence McKinley, Robert W. McVicar, Karen E. Meier, Kim Mellen, E. Charles Meslow, Elaine Meslow, Neal Mettler, S. Mark Meyers, Rod Miller, Bernice Mitchell, Bill Monroe, Roger W. Monthey, Jerry N. Moon, Michael Morrison, Tom Morse, Pat Morse, William B. Morse, Alan Munhall, Rod Munro, Leon W. Murphy, Richard Myshak, Justin Naderman, Robert H. Naney, Rich Nawa, William A. Neitro, Paul Nelson, C. Dale Nelson, Teresa Nichols, Cecilia Noyes, James Noyes, Matthew J. Obradovich, William F. Oelklaus, Janet L. Ohmann, Reinard Okeson, Ralph Opp, Bill Ostrand, Bill Otani, Randal O'Toole, Geoffrey J. Pampush, Paul C. Paquet, Ed Park, Lue Park, Linda Parker, Michael J. Parton, Fred Paveglio, John Pay, F. Paul Peloquin, J. Mark Perkins, Nancy Peterson, Lew Pitt, Jr., Reuben C. Plantico, John C. Platt, Charles S. Polityka, Althea Pratt-Broome, Joan Price, Karen Prudhomme, Ralph Thomas Rogers, Alice Rohweder, Ron Rohweder, Jerry Roppe, Dean Rose, Rollie Rousseau, Ron Sandrey, William Sanville, Phillip W. Schneider, Roger Schnoes, John

E. Schwartz, Clyde A. Scott, Pamela E. Seiser, Lynn Sharp, Guy Sheeter, Suzanne Shoemaker, Beth Siddens, Gene Silousky, Chief A. Simtustus, Sr., Jeff M. Sirmon, Delbert G. Skeesick, Alvin J. Smith, Douglas A. Smithey, Richard A. Stahl, Ellie Standeven, Peter A. Stine, Jack L. Stiverson, Ed Styskel, Sherman Swanson, Fred Taylor, Mark S. Taylor, Neil R. TenEyck, Charles L. Thomas, Jack Ward Thomas, Margaret Thomas, Don Thompson, Dale E. Toweill, Dee Toweill, Al Trigg, Marion Tryon, Richard A. Tubb, Walt Van Dyke, Robert E. Vincent, Grant Waheneka, Nelson Wal Lu La Tum, Joe Warner, Wedge Watkins, Lee O. Webb, Siri Nimaz Wickramaratne, Rosanna Williams, Mitchell J. Willis, Robert E. Willis, Marcia Hammerquist Wilson, Gary Witmer, Dennis W. Woolington

PENNSYLVANIA
Glenn L. Bowers, Robert E. Fasnacht, Dale L. Haney, Ed Kuni, Harvey A. Roberts, Sherwood S. Stutz

RHODE ISLAND
Thomas P. Husband

SOUTH CAROLINA
G. P. Friday, Patricia Friday, Dennis Gunter, David C. Guynn, Jr., Elizabeth R. Kennedy, Fred W. Kinard, Jr., James A. Timmerman, Jr.

SOUTH DAKOTA
Les Flake

TENNESSEE
Ron Fox, Chester A. McConnell, Gary T. Myers, Michael F. O'Malley, Thomas H. Ripley

TEXAS
Sue Babb, Guy Baldassarre, Lytle H. Blankenship, Eric G. Bolen, Peter C. Cantle, Ted L. Clark, Charles A. Deyoung, Joyce Deyoung, R. J. "Bob" Erickson, Wain Evans, Fred S. Guthery, Marianna Heins, Greg Hiser, Clark R. Hull, Bill Kiel, Jean Kiel, Anne Ellen King, Wallace Klussmann, William Lehmann, Freddie Morrill, William I. Morrill, Judy Meuth Noyes, Susan Obenberger, Jim Perryman, Ted M. Sawyer, Kim Scribner, Milo J. Shult, Nova Silvy, R. Douglas Slack, Edward R. Smith, Wendell Swank, Tim T. Taylor, James G. Teer, Bruce C. Thompson, Thomas C. Urban, Murray T. Walton, Bill Wenstrom, Ernie P. Wiggers, Carolyn Zagata, Michael D. Zagata

UTAH
Bruce Ackerman, David R. Anderson, Deborah Blank, Evelyn Bulkley, Ross V. Bulkley, Kathy Christensen, Robert C. Christensen, A. Gaylon Cook, Robert L. Crabtree, Douglas F. Day, Keith E. Evans, Norman V. Hancock, Charles Harris, George S. Innis, Kurt Johnson, Bernice Kadlec, John A. Kadlec, Frederick G. Lindzey, Carl D. Marti, Nicki McCabe, Thomas R. McCabe, John W. Mumma, Jack Payne, Bud Phelps, Carlene Phelps, Kerry Paul Reese, Margaret Sigler, William F. Sigler, Loren M. Smith, Homer D. Stapley, Maryllyn Urness, Philip J. Urness, Kenneth R. Wilson, David S. Winn, Gar Workman, Clair Wyatt

VERMONT
David E. Capen, Edward F. Kehoe

VIRGINIA
Keith A. Argow, Hugh C. Black, Hugh Black, Jr., Bill Burbridge, Galen J. Buterbaugh, Mary Josephine Cross, R. H. Cross, Jr., James R. Fielding, Bernard Griswold, C. R. Gutermuth, Michael Hay, Eugene Hester, Barbara Helder, Margaret Leveridge, Walter J. Leveridge, Gene Ludlow, John Mattoon, James E. Miller, Charles Most, Marcus C. Nelson, William Harold Nesbitt, Jean H. Petoskey, Merrill L. Petoskey, Chester F. Phelps, Donald Seibert, Lloyd W. Swift, Rose W. Swift, Jerry Touval, Michael R. Vaughn, Edwin Verburg, Paul A. Vohs, Andrew J. Weber

WASHINGTON
Harriet Allen, Kathleen Armstrong, Keith B. Aubry, D. R. Barrick, Maureen A. Beckstead, Kim Bevis, Brian L. Biswell, Gale Blomstrom, Monette R. Boswell, Jim Bottorff, George L. Brady, Larry W. Brewer, Dave Brittell, E. Reade Brown, Kenneth R. Brunner, Brad Carlquist, John Casson, Robert G. Carson, Douglas G. Chapman, Mrs. Douglas G. Chapman, John R. Clark, Diane Converse, Carl N. Crouse, Eric Cummins, John Danielson, Robert L. Delong, James E. Doyle, John A. Dragavon, Lester E. Eberhardt, L. Lee Eberhardt, Paula M. Ehlers, Robert D. Everitt, Paul C. Fielder, Charles W. Fowler, Laura Frichtl, Ron Friesz, Jim Habermehl, Richard Haines, Jeffrey E. Hanson, Harry D. Hartwell, Neal A. Hedges, Joan Hett, Willis Hobart, Jeff Holm, David Townsend Hoopes, Mark Huff, Liese Hunter, Helen Edith Johnson, Murray L. Johnson, Randy R. Kelley, Karl W. Kenyon, Sandy Knight, Kenneth G. Knouf, K. Lea Knutson, Jim Kosciuk, Wendy Kosciuk, Edna Kridler, Eugene Kridler, Joe La Tourrette, Cynthia A. Lee, Kathy Leid, Larry Lennox, Lorie L. Leschner, Jim Likes, Ivan Lines, Leacy M. Lloyd, Frank R. Lockard, Jerry Lounsberry, Dennis Lowry, Sarah Madsen, Michael Mason, David A. Manuwal, Scott C. Matulich, John L. McKern, Evelyn Merrill, Lonnie E. Mettler, Pat Miller, Ruth Milner, Cheryl A. Moody, Bruce B. Moorhead, Robert H. Mottram, Cynthia Nelson, William H. Nelson, Jim O'Donnell, Thomas E. Owens, Christine Paige, Katherine L. Parker, Michael F. Passmore, Augustine H. Paz, Chuck Pery, Bob Pollard, Alice M. Purcell, Kenneth J. Raedeke, Ray Rasker, John Ratti, Robert L. Rausch, Virginia R. Rausch, Klaus O. Richter, Meribeth M. Riffey, Larry W. Roberts, Betty Rodrick, William Ruediger, Len Ruggiero, Diana Russell, Nick Sanyal, Jim Schafer, Jeffrey E. Schmaltz, Kim Severson, Joseph J. Shomon, Vera Shomon, John R. Skalsyl, Roberta Sherry, Judith Starr-Brewer, Greg Starypan,

Terri Steel, Gretchen Steele, Steve Sweeney, Richard D. Taber, Jim Tabor, Denise Taylor, Robert S. Taylor, Mike Craig Tyler, Gretchen Van Lom, Susan Whittlesey, Brian Wood, Don Zeigler, Tara Zimmerman

WEST VIRGINIA
Robert Putz, James M. Ruckel

WISCONSIN
Scott R. Craven, Steve DeStefano, Robert T. Dumke, Thomas A. Heberlein, James R. Huntoon, Robert Jackson, Marie S. McCabe, Robert A. McCabe, Scott M. Melvin, Robert E. Radtke, Robert L. Ruff, Don Rusch, Clay Schoenfeld, Megan Smith, Stephen C. Smith, William Vander Zouwen, Lorraine D. Vogt, William M. Vogt

WYOMING
Stanley Anderson, Bruce Baker, Patrick J. Baumann, Vicky L. Baumann, Scott Benson, Tim Byer, Clifford J. Clark, Jean F. Cochrane, Don Dexter, Kenneth L. Diem, Dan Fulton, Kevin J. Gutzwiller, Bernard Holz, Phoebe L. Holzinger, Douglas B. Inkley, Larry L. Irwin, Pat Long, Tricia MacLaren, Tom Mangelsen, George Menkens, Curt Meyer, Robin Sell

CANADA
Morley Barrett, Bruce D. J. Batt, Elizabeth A. Batt, Richard K. Baydack, Bob Bromley, Joyce Brynaert, Kenneth A. Brynaert, Fred Bunnell, Lloyd H. Eckel, Richard M. Ellis, Beth Ereaux, Rob Evans, Doug A. Foster, Alton Harestad, Thomas J. Henley, William B. Hughson, Doug Janz, Richard H. Kerbes, Gordon R. Kerr, John P. Kelsall, D. M. Lavigne, Albert T. Lees, Ian McTaggart-Cowan, Douglas K. Pollock, Morley E. Riske, Karen L. Sadoway, Michael A. Schroeder, Dennis Sherratt, Gordon H. Staines, Marjorie Staines, Tory Stevens, Linda Stordeur, Bert Tetreault, Bruce Turner, Jane Waterman, Daniel Welsh, Stephen P. Wetmore

FRANCE
Bertrand Des Clers, Mrs. Bertrand Des Clers

GUAM
Robert D. Anderson

Index