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The Changing Face
of Conservation

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Welcome and Opening Remarks

Steve Williams
Wildlife Management Institute
Washington, DC

Welcome to the 72nd North American Wildlife and Natural Resources Conference. I thank you all for your attendance and participation in this conference, with special thanks to the cosponsors, whose support makes this annual event possible. And, I would like to extend a special welcome to the Secretary of the U.S. Department of the Interior, Dirk Kempthorne, and to Richard Louv, who join me on the dais. I would add a special thank you to the Trust for Public Land for enabling Richard's participation at this plenary session.

The North American Conference is your conference. Each year, it brings together federal, state and provincial resource agency administrators, researchers, educators, managers and conservation organization leaders to discuss the current and future status of natural resource conservation. It is intended to be the premier forum and opportunity for the professional business for conservation on this continent. We hope you find the conference productive, and please feel free to call on WMI staff for any needed assistance.

The theme of "Plotting the Course of Conservation" is particularly relevant in these times when we are faced with unprecedented demands on natural resources. Meeting those demands will require an understanding of our history and careful planning for the future. My remarks will touch on how we got to where we are today in conservation and on how we might plot a course for its future.

The history of conservation in North America is an extraordinary tale of individuals, organizations and governments overcoming incredible obstacles—political, cultural and economical—to develop the most effective fish and wildlife conservation effort in the world. It is a saga that tracks through periods of discovery, exploitation, protection, preservation, trial-and-error restoration, science-based management, and a shift of focus from game populations to habitats to biodiversity.

Although we have enjoyed a history of successes and a conservation model that is the envy of the world, our work is far from done. We have yet to address properly the majority of species that are not fished or hunted; we need to recruit and retain hunters and anglers at least at replacement rates. And, we must concertedly plan for the numerically, spatially and consumptively increasing human population and its associated impacts on fish and wildlife resources, values and opportunities.

Although states have developed action plans to manage all species of fish and wildlife, funding is inadequate to accomplish these plans. More time, dollars, energy and foresight need to be invested to meet the research and management needs of thousands of species before their habitats and populations reach the stage at which they are sustained not by the limits of their home ranges but by the forbearance of that most invasive of species, the human being. If we fail to apply conservation fairly and broadly and, by so doing, enable fish and wildlife to become at risk, a long line of plaintiffs, attorneys, judges, developers, biologists, businesses, property owners, politicians and regulators already have proven more than willing to put those species' long-term survival on the back burner in favor of other agendas. The time and expense required to work through the morass of agendas are indeed significant. In the end, the species suffer because dollars are diverted from on-the-ground projects to paper-shuffling exercises and legal fees. We can do better, and we can do it cheaper, if we are proactive.

We also need to be proactive to address a host of other looming, major issues. Let's take a look at where conservation is headed.

First, consider this early 1900s quote from Theodore Roosevelt. "Conservation," he said, "means development as much as it does protection." Consider, too, another Roosevelt quote: "The nation behaves well if it treats the national resources as assets which it must turn over to the next generation increased, and not impaired, in value." In those statements, some will see a contradiction. I don't.

What I do see is a nation that sometimes forgets the importance of the second quote. How we behave as a nation—in the United States, Canada, Mexico or other country—will dictate the course and pace of conservation.

The overriding issues facing conservation today are associated with the growth and sprawl of human population and the increase of its development-related impacts. Since I was born in the Year of Elvis, 1957, the U.S. population has increased by 50 percent. The U.S. Census Bureau estimates that human population growth in this country will continue to increase by 7 to 9 percent each decade for the foreseeable future. Couple this growth with the fact that 80 percent of the population already resides in urban areas, far removed from the beauty and complexity of nature. Is it any wonder that those of us who care about wild things and wild places have difficulty garnering political and financial support?

Development and the resultant habitat loss and fragmentation are occurring nationwide. Apple orchards farmed for generations near my rural home in Pennsylvania are being sold and stripped in favor of encroaching suburban developments of houses twice the size and with half the occupants of 25 years ago. Ranches in the West are being subdivided and subdivided again into ranchettes. An aging populace of humans is migrating to southern latitudes straining existing resources. Suburbia eats away at wildlife habitat outside virtually every major city in North America. This ongoing activity and human intrusion into wildlife habitat require energy and plenty of it. Global energy demands, as measured by British thermal units, are projected to increase by 70 percent in less than three decades, literally fueling new energy development, additional impacts to fish and wildlife habitat, strained agency budgets, and international loggerheads and distrust. Finally, increased demands for water, not just in the Southwest but throughout the country, will have dramatic impacts on fish and wildlife resources, agriculture, and human population distribution and the social problems attendant to congestion.

Where conservation is headed will depend in large part on how we approach energy issues. Oil and gas development in the West has had and may continue to have a major impact on sagebrush ecosystems. Current practices threaten traditional, critical mule deer, pronghorn and elk winter range, as well as sage-grouse populations. Roads and transmission-line corridors add to the disturbance. Efficient energy production will be increasingly imperative to meet the demands of a growing population, but it must be planned and carried out in a manner that is sensitive to multiple-use mandates and that proactively considers resource values that are the foundation of this continent's prosperity.

As we consider alternative means to generate energy, biofuels and wind energy have risen to the top of the list. Energy policy must consider the potential impacts of these sources on prairies, on agricultural landscapes and, in the case of biofuels, on water required to produce ethanol. Converting current crop production, pasture and Conservation Reserve Program (CRP) land to corn or switchgrass will have a substantial effect on the species that inhabit those areas. Farm Bill decisions will be driven by energy policy, pitting conservation against commodities and some commodities against others used for energy production.

Coupled with energy issues is the specter of climate change. Forget that no television meteorologist on the East Coast has done better than 50:50 on weather forecasts for any following 48-hour period, science convincingly shows that conservation must be ready to deal with predicted, long-term changes in temperature, precipitation, flooding and other climatological events that will affect fish and wildlife and their habitats. As we deal with climate-change policy, fish, wildlife and other natural resource interests must be at the table seeking funding to address the inevitable challenges of global warming.

Even as energy and climate change issues dominate congressional and media attention, Richard Louv's wonderful book, *Last Child in the Woods*, eloquently describes one of the greatest uncertainties of future conservation—an increasingly disassociated public. The decline in participation in outdoor activities by North America's youth threatens their personal development, character, health and, almost certainly, that of their future environment. The next generation needs to understand conservation to care about it, and it needs to care about conservation to embrace its principles and practices on personal, community, national and global levels. If conservation is to head anywhere, that has to happen.

All of the conservation issues we face must be considered in the context of available funding. The federal budget is dominated by domestic entitlement and defense spending. Conservation has always taken a back seat to other programs at the state and federal levels forcing agencies to look for innovative programs. Some of the 2008 federal budget requests are symptomatic of the current budget climate.

Selling $800 million worth of public land to finance rural schools, to reduce the deficit and to fund land acquisition projects has been proposed again this year. Deferring enrollment into CRP and the Conservation Security Program has been proposed to stretch conservation dollars into the future. The Healthy Lands Initiative, a $22 million investment in sagebrush country, attempts to deal with energy development. We hope this initiative includes efforts to avoid and minimize impacts as well as fund off-site mitigation projects. The U.S. Fish and Wildlife Service's budget to manage the National Wildlife Refuge System is forcing leadership to make difficult decisions about staffing and operational plans.

Finally, the private match requirement for the U.S. National Park Service's Centennial Initiative is indicative of conservation dollars stretched thin to accommodate other priorities in the federal budget. Given the difficulty of meeting the financial priorities of the nation, these counterconservation symptoms are likely to continue well into the future.

It is evident that human population growth, energy development, water and climate-change issues are driving the current path of conservation in North America. It also is evident that funding may not be available to address these issues satisfactorily. Given those realities, it is incumbent upon the conservation community—you and me—to take the initiative to plan, implement and bolster natural resource conservation in a comprehensive approach. International, national and regional models exist—the North American Waterfowl Management Plan, the National Fish Habitat Plan, and state wildlife-action plans, to name a few.

To be successful, we also must address issues in a coordinated approach. One of my great disappointments is the dearth of effective coordination between states, between federal agencies and between conservation organizations. Friends, you know as well as I that conservation is not a separate agenda. We need to recognize that disorganized competition for finite dollars is counterproductive. If, together, we can assess our strengths, weaknesses and programmatic gaps and if we can collaborate to assign priorities for funding, we may be able to take the chance and directional happenstance out of tomorrow's conservation efforts.

Enlightened leadership and science are the lynchpins of comprehensive and coordinated planning. The National Conservation Leadership Institute (NCLI) and Conservation Leaders for Tomorrow are examples of programs designed to ready and embolden the next generation of prime movers in the conservation community. We have a number of the 2006 NCLI fellows in the audience today. The cooperative fish and wildlife research units (coop units) of the U.S. Geological Service have defined a vision to improve the science used in decision making at the federal level. This vision is simple, yet effective—fill existing vacancies and provide a competitive funding mechanism to address the priority conservation issues of today and tomorrow. The coop units can and should lead the way for institutionalizing adaptive management at the federal and state level. By their very nature, energy development and climate change dictate such an approach.

Adequate investment in the long-term health of our natural resources is paramount. The existing sources of funding—license fees, excise taxes, tax dollars and conservation organization donations—will not, by themselves carry the day, nor should they be expected to anymore. Additional investments—such as linking subsidies and tax incentives to conservation efforts, expanding excise taxes to other products, providing tax incentives for land conservation, capturing the true costs of natural resource development, assigning energy revenue and royalties to conservation, and auctioning carbon credits—all these will assist in turning over our natural resources, as Roosevelt envisioned, "to the next generation increased and not impaired."

Let me conclude by stating that I sincerely believe there is hope to staunch the overdeveloping, overpaving, overgrazing, overindulging and undermining of North America. The hope is in this room. It is in the minds, vision, work ethic and hearts of all in this room who have chosen to dedicate themselves to the ecological priority and social responsibility of conservation to put an end to the protracted period of exploitation and who have come to be in position to make the hard choices and decisions that will ensure that where natural conservation is headed is not an entrenchment of wishful thinking but, instead, proaction to ensure the sustainability of those resources far beyond our time. The hope is in this room. It has always been in this room. Thank you.

Remarks of the Secretary U.S. Department of the Interior

Dirk Kempthorne
U.S. Department of the Interior
Washington, DC

Thank you, Steve. I thank you for inviting me to address the 72nd North American Wildlife and Natural Resources Conference. I say this with an emphasis on the phrase "Seventy-second."

What an extraordinary thing that our nation's leaders in wildlife conservation—our best scientists, wildlife managers, educators and administrators—have been gathering every year since the Great Depression of the 1930s: back when so much of our wildlife and its habitat were being swallowed up by the Dust Bowl, back when visionaries like Ding Darling and Aldo Leopold called our country to a new conservation ethic, back when extraordinary new ideas rose up out of the dust—ideas such as the Civilian Conservation Corps, to put young people to work on projects across the land, and the Federal Aid in Wildlife Restoration Act, to fund state conservation and wildlife management efforts.

Every year since then, you have come together to discuss new research and new methods to help us conserve our land and its wildlife more expertly, more efficiently and more effectively. I applaud you on this 72nd meeting of this great conference.

This is my first opportunity to address you as Secretary of the Interior. Those who know me know that I believe in a walk-around management style. You can't manage properly what you haven't seen.

In the case of the U.S. Department of the Interior (Interior), that requires a lot of walking around. I discovered our mandate covers 12 time zones, from the Virgin Islands in the Caribbean to Palau on the Pacific Rim. The sun literally never sets on the Interior. I've logged thousands of miles in trains, planes and automobiles—even airboats and motorcycles. I've seen first-hand the enormous mandate of the Interior—that rivals just about any governmental department in its breadth and diversity—and its importance to the everyday lives of our citizens.

In each place I've visited, I've been reminded that we have a responsibility—even a sacred responsibility—to the people of this country to manage our wildlife and other natural resources intelligently and effectively, remembering always that our land must be accessible not only to us but to generations yet unborn. Many of you have been doing this for decades. I applaud your dedication and professionalism. In many ways, I still feel like a newcomer. The topic of this year's conference is "The Changing Face of Conservation." It is a topic I am eager to embrace. Indeed, I believe we are in a time when the face of conservation is changing perhaps as much as it did in the 1930s. In many ways, the stakes are just as high. We have arrived at the threshold of great opportunities. Yet, we also face great risks.

In the past two decades, we have seen an evolution in conservation that is allowing us to manage our wildlife and natural resources more effectively. On one hand, we are becoming more focused. We have gained a greater understanding of wildlife and its habitat so that we are able to concentrate our limited resources on areas where we can achieve the greatest good. On the other hand, we have become broader in our outlook, managing not just parts of the landscape but the landscape as a whole.

We have learned the value of using adaptive management to address complex resource management problems, to test and verify our management solutions. We are using adaptive management more and more to guide our actions, whether in adaptive harvest management of waterfowl or in dealing with other issues. I have just approved a new policy providing for better understanding and use of adaptive management by all of Interior's bureaus.

Finally, we have learned to tap more fully into the power of partnership, bringing together federal and state agencies, tribes, conservation groups, businesses and private landowners in the common cause of conservation. These are more focused conservation efforts with landscape-level management and with cooperation and partnership. This is the new era of conservation.

The new era of conservation begins on a local level with individuals who make a difference. In October, I visited the Crane Meadows National Wildlife Refuge (Crane Meadows Refuge) in Minnesota. I met a young man at the refuge named Ron Beam. Ron was a local boy who went off to college and came back home to become part of the team to establish the Crane Meadows Refuge. He was the catalyst for change. The farmers trusted him, and he helped to quiet their suspicions about the refuge. A local farmer named Elkin Faust, known as Bumpy, came to Ron and asked him how he could return a 30-acre (12.1 ha) pasture on his land, a space only 7 miles (11.3 km) from the new refuge, to the wetland it used to be. He was the original owner who got government funding to drain the wetland for pasture many years ago. Now that he was retiring, he wanted to give something back. Ron helped him through the Partners for Fish and Wildlife program. He designed a dike and drainage ditch and spillway. Now, the 70-year-old Bumpy walks to the wetland with his dog, sits in an old car seat under an oak tree and identifies the different species of migratory fowl that drop by to visit. On occasion, Bumpy hunts on his land but is sparing of what he considers a wonderful resource. Bumpy's story speaks to partnership and a passion for respecting people and nature. Individual's stories, like Bumpy's, are repeated across the country.

And, his story is repeated on larger scales in places like the Blackfoot Valley in Montana. The valley is a scenic area depicted in the movie, "A River Runs Through It." In the 1990s, residents of the valley became concerned over growing environmental issues, including degraded water quality, loss of wetlands, fragmentation of wildlife habitat and the development of vacation homes that threatened the valley's traditional rural way of life. In many places, this could have led to a deluge of government regulation and litigation. Instead, more than 500 local landowners, 27 state and federal agencies, and a number of nonprofit organizations created the Blackfoot Challenge. The partners in this endeavor voluntarily have contributed more than $5 million to restore and enhance more than 2,600 acres (1,052.2 ha) of wetlands, 38 miles (61.2 km) of streams and 2,300 acres (930.8 ha) of native grasslands. Private landowners voluntarily have set aside nearly 90,000 acres (36,421.7 ha) of their land permanently through conservation easements. Together, these partners took an honest look at the entire landscape—the landscape where they live and work and play and raise families, the landscape they share with all kinds of wildlife. Together they found ways to accommodate the change and development while protecting the natural environment and landscape they cherish. It is a model of the new era in conservation.

But, there are many more models. Last month, I visited an area managed by the U.S. Bureau of Land Management (BLM), south of Carlsbad, New Mexico. I had a good conversation with Joe Stell, who grazes cattle on the land. In that part of New Mexico, creosote and other invasive species have crowded out the native grasses. Historically, creosote comprised 10 to 15 percent of the landscape. Today, the figure is 75 percent. I asked what caused this to happen. I was surprised when the answer came back: "The Chisholm Trail."

The five million cattle driven from Texas to Kansas along the Chisholm Trail in the late 19th century decimated the native grasses and allowed creosote to take over. We often think of habitat destruction and degradation as a recent phenomenon. But, here was habitat destruction from more than a century ago that was still evident on the landscape. Today we're undertaking aerial spraying of the area to combat the creosote. Ranchers like Joe Stell, are joining in the effort. We are not only treating BLM land. We are treating state and private lands. It is a voluntary program. Lush native grasses are coming back. We will soon reintroduce native species, such as pronghorn, turkey and bighorn sheep to restored areas throughout New Mexico. Ranchers participating in this program agree not to increase the number of cattle on their allotments. At the same time, they understand that the cattle they do have will get fatter faster.

Our vision is to return the grasslands, woodlands and riparian areas to fully functioning ecosystems in New Mexico and in other western states. We are doing this in partnership with the Joe Stells of the world. This *is* a new era in conservation.

President George W. Bush made a major commitment in his budget to support the kind of landscape-level conservation we are doing in New Mexico. We are calling it the Healthy Lands Initiative. Under the initiative, we will invest $22 million to help restore nearly half a million acres (202,342.8 ha) of federal land in six targeted areas of the West. These areas have seen growing conflict among competing uses of the land, including wildlife habitat, recreational opportunities and energy production.

I am well aware of the friction among conservationists, recreationists and energy developers on public lands. Access has become a rallying cry among many groups. That cry is only equaled by the clamor for more energy and less dependence on foreign oil. Our goal must be to deliver that energy to the nation in an environmentally sensitive way. And, our goal must be to maintain centuries-old wildlife corridors for game to continue into the far distant future. It will take a holistic approach to do this—one that brings together all competitors for the land and that looks at the entire area, not at individual tracts.

The Green River Basin in Wyoming, for example, is one of these targeted areas in our Healthy Lands Initiative. As in other places in the West, the basin has world-class energy resources sitting under world-class wildlife resources. The area has enough natural gas to heat 4 million homes. It also has 100,000 deer, 100,000 pronghorn, 40,000 elk, 8,000 moose and 1,400 bighorn sheep. Under the Healthy Lands Initiative, we will use landscape-level conservation planning to develop the basin's energy resources while conserving the wildlife habitat and the recreational opportunities that have made the area so popular for hunters, anglers and other visitors. We will undertake restoration of riparian areas, plant sage grass, aspen and other native vegetation, restore water sources for wildlife, and form partnerships to complete other conservation projects.

Last fall, I visited Wyoming's Pinedale Anticline gas fields (Pinedale). I was impressed that energy producers there have been able to greatly reduce impact to wildlife by consolidating roads, pipelines and production facilities, by using directional drilling, by reducing truck traffic, and by developing temporary wooden pallets for well pads. With these efforts the footprint for development has been reduced dramatically from 8 to 10 acres (3.2 to 4.0 ha) down to half an acre (0.2 ha). Every acre of development reduced, leaves an acre of habitat.

In addition to the Healthy Lands Initiative, we recently took another important step to conserve western landscapes and wildlife habitat. The BLM and the U.S. Forest Service issued an update of "Onshore Oil and Gas Order Number 1" (Order). This was the first update in 20 years. It will improve the way we regulate energy leasing on federal lands, like Pinedale. It also addresses many of the issues that are of concern to sportsmen and sportswomen and to western landowners related to preserving the wildlife values of the West as we develop our domestic energy.

For example, the Order addresses the issue of split estates by requiring energy operators to make good faith efforts to reach agreements with private surface owners. Where a good faith effort fails and no surface agreement can be reached, the Order requires the operator to post a bond to protect against damages to the surface.

In addition, the Order encourages the use of best management practices to reduce surface impacts from oil and gas development. These include:

- drilling several wells from a single well pad
- establishing buffer zones to protect wildlife
- painting structures and machinery to match vegetation colors
- burying power lines and pipelines next to existing roads
- using technology to monitor well activity from remote locations to reduce the need for travel to each site.

When I was governor in 2001, for example, we recognized the importance of upland bird hunting both as a traditional recreational activity in

Idaho and as an economic engine to local communities. We wanted to ensure that populations remained healthy so that we could safeguard this great tradition.

I authorized the Pheasant and Quail Initiative, directing Idaho Fish and Game to examine our management practices and to determine how we could be proactive in conserving upland birds and their habitat. We took a number of steps to conserve and restore upland bird habitat across key parts of the state.

One of our biologists came up with something he called a "quail condo." He built a wire frame and planted fast-growing vines around its base. As the plants grew, the enclosure mimicked the thick brush and shrubs where quail like to roost. The idea worked. Landowners reported a bumper crop of California quail across Idaho's quail range last year. It is this type of creativity that we need to promote and support. As Secretary of the Interior, I will help you tap into this creativity. I will help you to build the partnerships and to find the funding needed to seize the opportunities that are all around us in this new era of conservation.

I mentioned earlier that we face risks as well as opportunities as we enter this new era. The risks are that our children will become disconnected from the nature and the traditions of hunting, fishing, bird-watching and other outdoor recreation.

We've already seen troubling trends. Most states, for example, are experiencing a decline in the number of hunting licenses issued. Richard Louv's fine book cleverly describes this as "nature deficit disorder."

A fundamental truth of human nature is that people take care of that which they love and cherish. Everyone in this room loves and cherishes wild places and wild creatures. You wouldn't be here otherwise. Most likely, you cherish these things because someone—a parent, a grandparent, a scout leader—took you hunting, fishing, hiking or camping when you were a youngster. We now have a generation growing up in North America that is more urbanized and more computerized. The closest many children get to nature is the screen saver fish swimming across their computer screens.

Ladies and gentlemen, we can do this. It can be accomplished. Look at the success we are already having. We are going to do great things together. God bless each and every one of you.

Remarks by Richard Louv

Richard Louv
San Diego, California

Somewhere in my garage is this bottle, and my garage is just a war zone. But, I have a 14-foot bass boat in there and fishing gear. I do not know where I got all this stuff. I think I support Bass Pro; my sons and I support Bass Pro Outdoor World single-handedly. But, somewhere there is this jar with about that much formaldehyde. It is a fruit jar, about that much formaldehyde left in it. And, there is a curled-up really pale, sickly-looking copperhead in that jar, and it is from when I was a kid. I do not remember where that came from. I knew it was from when I was a kid, but I do not remember the snake.

And the other day, my best friend in high school, in junior high, came and stayed with us for a few days, and he said: "I remember that snake." He says, "I remember seeing you down at the bottom of the hill. At junior high, you were at the bottom of the hill, and you were running up the hill, and your knees were bloody, your elbows were bloody, and you were waving this live copperhead in the air. And, you looked so happy." The idea that that might end for kids is intolerable to many of us, that experience. How can we let that end?

Now, my sons had the luck to have a father who liked to do that, and he was looking for new fishing partners. I knew my younger son definitely had the fishing gene because when he was three, I caught him fishing in the humidifier. But, they spent a lot of time outdoors, and they still do; they are now 19 and 24—25 actually. My older son lives in New York City and loves Central Park. My younger son is now at Evergreen State College not far from here. He found the only college in America where he could actually fly-fish for salmon from campus; he has got his priorities straight. But, the idea again that that might be the last bothers us.

A few weeks ago, I was asked to testify in Congress, to the U.S. House of Representatives Interior Appropriation Subcommittee. Cheryl Charles went with me, my colleague, and she sat behind me, you know, on the row of chairs. I had never done this before; she wanted to make sure I behaved myself. And, I told her later it would have been great if she had leaned forward, you know, like the attorneys do to make me feel really important and had whispered, "You are going to jail."

But, what was interesting, that was a little like what Secretary Kempthorne talked about, who has been so helpful to this issue was there were six congressmen. Actually, six congressmen showed up and we were supposed to talk about long-term trends that would affect the U.S. Department of the Interior. And afterwards, those six congressmen, all they wanted to talk about was what it was like when they were kids, when they went outside in the nature.

Now, there were congressmen there from the far left and the far right, and, in those moments, there were no Democrats in the room. In those moments, there were no Republicans in the room. There were just men telling about that special place in their childhood that they went to. And, that still exists in their hearts to which they still go to find strength.

When I was a boy earlier, when I was younger, I lived on the edge of Kansas City, in the suburban edge. I could walk out my basement door through the yard, through a hedge, into the cornfield (where there was my underground fort) and then into the woods, in the fields and in the streams that seemed to go on forever. I owned those woods; they were my woods. I had such a sense of ownership of them that I pulled out, I think, hundreds of survey stakes that I knew had something to do with the bulldozers that were taking out other woods and fields.

I was in Albuquerque, New Mexico a few months ago, and I told about that. And then afterwards in the Q-and-A session, a rancher stood up; the Quivira Coalition to whom I was speaking is a really interesting group. It is bringing together ranchers and conservationists, not that the two are necessarily separate at all, but bringing people together, really, to do land trusts, *et cetera*, in the West. A rancher stood up, and he was the real deal. His jeans had not been acid-washed. He had thick plastic-rimmed glasses on and a handlebar mustache, white handlebar mustache. He was in his 60s, sunburned.

He said, "You know that story you told about pulling out stakes?" And I said, "Yes." And he said, "I did that when I was a boy."

And then he began to cry in front of 500 people, half of whom were wearing cowboy hats. But, he continued to talk despite his deep embarrassment, to talk about his sense of grief that his might be one of the last generations to have that kind of sense of attachment, of ownership of land.

A little while later, a woman came out. I was signing books. A woman came out; she was a rancher in her 40s. And she said, "You know that story you told about pulling out stakes?" I said, "Yes." And she said, "I did that, too." And she said, "But I did it different. I did it from my horse when I was a little girl. And my horse got so used to me pulling out stakes that it started taking me over to the stakes. I reached over and pulled them out."

So, many of us have that experience. So, I'm going to ask. The Secretary of the Interior has left the house, left the room, so you can be honest. How many of you when you were kids pulled out survey stakes? There you go. Good, good. Truth in government, is that not great? You are hereby inducted into the Secret Society of Stake Pullers. You are stakeholders in that society. God, my sons hate puns. Do your kids hate puns? Mine hate puns.

We know that there is this separation between children and nature occurring. We do not know that because of fine longitudinal studies over the decades because nobody thought to ask the question. We always assumed that this relationship would be forever. What we do know, pretty much, is what kids are doing with their time—44 hours per week spent plugged into some kind of electronic medium, more and more hours spent doing homework, more and more hours in the backseat of the minivan on the way to the play date with a flip-down television screen where they are watching the National Geographic specials about nature instead of looking out the window.

Their lives are extremely structured, many of them. We know that they do not have much time for any kind of free play, let alone play in nature. We know that the attendance at national parks is going down. Now some of that may be because of increasing fees. It may be because of other factors. But, we do know that families and young children are decreasing their visitations. That does not bode well for the future of the national parks or for any other kind of park that is losing attendance.

Where will the political constituency come from for those parks if children are not going out and bonding with nature as Teddy Roosevelt did—Little Teddy, that was his nickname. You know, he had this habit of bringing home, as I did, reptiles and other animals. And, he brought home a huge snapping turtle one day and chained it to the cook's—you know they had a cook—to the cook's table in the kitchen and demanded that she make soup, and she threatened to quit.

Now, we need a lot more of that kind of behavior. But, where will—you know, if there are not any Teddys in the future—where will the support come for our parks, for our fish and game, for our fish and wildlife, for our fishing and hunting, and for all of the outdoor activities? Where will that support come from politically and culturally and socially?

There is a photograph that I saw recently in the back of a magazine. It was, you know, those magazines they have in your hotel room? You always wonder where they come from. This was on the back page, and it was this wonderful photograph, this black-and-white photograph of a beach. And behind, off in the distance, there are storm clouds, and surf is rolling in, and there is this little boy on the beach. He is about eight years old, and he is running along the beach. His arms are wide, and his eyes are fully alive. And, he is grinning at the camera. The story that accompanies that photograph talks about how this little boy was wiggly in class. He was disruptive and got kicked out of school because he could not sit still. And, his parents did not know what to do. But fortunately, his parents were very observant parents, and they had seen that nature did something for their boy. That it calmed them—calmed him, that it helped him focus. And so just based on that knowledge, for the next 10 years, they took this little boy all over the West to all kinds of parks and outdoor areas and wilderness, and the kid did all right. The photograph was taken in 1906, and the little boy was Ansel Adams.

Now, what if they had put little Ansel on Ritalin? What if they had put little Ansel on Ritalin and put him back in a cubicle that we call a classroom today? What if in that school they had canceled recess? What if they had canceled field trips? What if nature was no longer part of the classroom? What if they no longer allowed terrariums in the classroom because of regulations about salmonella?

That is the environment we are raising kids under today. I am convinced that the woods were my Ritalin, that I would have been placed on Ritalin. Now I am not pretending that nature is a panacea; there are children who need to be medicated. They need medication, some of them. But, there are ongoing studies at the University of Illinois, and this is part of the good news, this emerging body of knowledge. There are ongoing studies at the University of Illinois that show that kids with the symptoms of attention deficit disorder, that the symptoms get much better with just a little bit of contact with nature and that kids, in general, that their attention spans get longer with just a little bit of contact with nature.

The people who did those studies—and they are wonderful studies—ask: could it be that, perhaps, we should add nature therapy to the other two traditional therapies for attention deficit disorders, which are behavioral modification and Ritalin and other stimulants? I agree with them, but in my book, *Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder*, I ask another question: "Could it be that at least some of the huge increase in the number of kids being placed on these stimulants, on Ritalin, *et cetera*, could it be that at least some of the kids who have been prescribed antidepressants—even kids as young as kindergarten age, and we now know that that is not good for young children—could it be that at least some of the increase in teenage suicides, could it be that at least some of all of that might have something to do with the fact that we have taken nature away from kids and that we have placed them in cubicles and then expected them to behave differently?

A number of studies have emerged, mainly in the last decade, in the last dozen years. Now, there were pioneers out there who were doing work on this. But, for some reason the effect of nature on healthy child development was pretty much ignored until recently. Lots of studies now show stress reduction on kids and adults because of nature experience. Other studies look at obesity, not specifically on nature's effect on it. But, the greatest increase in child obesity in our history occurred during the same two decades as the greatest increase in organized sports for children in our history.

Something is missing from this debate—studies of cognitive skills and creativity showing how kids play in natural play areas versus on flat asphalt or turf play areas that we seem to prefer. The kids in the natural play areas are far more likely to invent their own games and are far more likely to play creatively. Interestingly, they are also far more likely to play cooperatively.

The leaders—they are the kids—who emerge in these two environments are interesting. On the flat playgrounds, asphalt and turf, it is the physically strongest kids who emerge as leaders. In the natural play areas, it is the smartest kids, which makes sense; they are inventing their own games. I think if we really care about bullying on the schoolyards, we would green all the schoolyards.

Other studies of cognitive functioning show that kids who go to schools with outdoor classrooms do much better across the board from social studies to standardized testing. Two years ago, the California Department of Education looked at three school districts that had some kind of immersion program still in nature, like a sixth grade camp. The kids in those environments did 27 percent better on science testing than the kids in the traditional classrooms.

There is a lot of evidence like this emerging that people need to know about, I think, as the U.S. public learns more about it and as parents learn more about it in particular. We can change things. Things will change. Already, we are seeing the emergence of what can loosely be called a movement. I hesitated to call it a movement for a while, but now it is official. *USA Today* had a story, a front-page story, on Thanksgiving Day about the children-in-nature movement that is emerging. And, *The Economist*—of all things, who knew—*The Economist* during the first week of February, had a story about the same thing, this emerging children-and-nature movement.

Across the country, and I have been moving across the country a lot lately, we see this phenomenon of regional movements, of regional campaigns emerging. This is an interesting kind of movement. It is not top-down; it is not something that somebody announced in Washington, DC, then handed out the rules. This is happening pretty much in a self-organized way. And, there is a special quality to it. It is bringing together people who do not usually get in the same room. It is kind of like that hearing in Washington that I attended. We are getting civic leagues together with fish and wildlife people. We are getting the nature centers, seeing them get together with the conservation organizations; even developers are now involved.

Not long after the book came out, I got an e-mail from the CEO and founder of the largest privately owned residential builder in the country. And, he said that he was profoundly disturbed by the book. Now, for somebody who pulled out a lot of stakes when he was a kid, that was kind of nice to hear. But, he went on to say that he was really committed to this issue now, and he wanted to do something about it. So, he invited me to an envisioning session in Phoenix. They had about 80 developers and real-estate folks in the room, and he asked me to give my sermon. I did.

Then, he did something remarkable. He asked them all to go into small groups and solve the problem. How are we going to connect kids to nature in the future? How are we going to build residential developments in the future to help do that? They went into their small groups. They got excited. There was happy noise in the room. They came back. They started reporting their solutions. Some of them were really interesting and practical, like "leave some land in the first place," a good place to start.

Other ideas were, once you have that natural area, have a nature trail through it leading to the local school and have kids along that nature trail acting kind of like its crossing guards except they would be nature guides, you know, with their cell phones. And then, once we get that, we can put in a little nature center, and that will deal with the parents' fear. And, we can put that there, and then we can market that as an amenity.

Now, it does not matter what the quality of these ideas were; they were really interesting ideas. It does not matter what the quality of those ideas were to me. What matters is the fact that they had them. These were developers. If developers can have those kinds of ideas and that kind of excitement, think what else can happen in many other rooms across the country.

This movement is emerging. I think it will be your ally. I think that you have a very, very difficult job. You deal with many competing interests; I understand that. But, there are a lot of people out there who really do care that hunting and fishing and birding and all of the other activities that many of us did as children, that they continue, that they not end. And, they will help you. And that will build a bigger pie, I hope, for funding.

Finally, I want to end by talking about something I have thought about a lot since the book came out. When you think about the reasons for this disengagement, the obvious causes include electronics, video games and lack of time on the parents' part. Now, all of those are understandable, but I do not think they are the real reason. I think the underbelly of this issue is fear. I think that parents are scared to death of stranger danger, and this is forcing the raising of a generation under virtual house arrest. There are not nearly as many kidnappers out there as my profession, as a news media, makes us believe. There are only about a hundred a year of the traditional classic stranger kidnappings. Now, one is too many, but a hundred crimes a year should not be changing our society, and it is.

And it is because of my profession. I like to think it is the electronic guys, not us print guys. But, all you have to do is watch CNN or Fox and you will see how they take a handful of terrible tragedies against children, some of them in our national parks, *et cetera*. They will take a handful of those, and they will repeat those over and over and over again; that is the very definition of conditioning. We are, I am, you are being conditioned by my profession to live in a state of fear.

This is changing even the way we have housing built in the United States. You know the covenants and restrictions on almost every new housing development now prohibit all kinds of day activity; they have criminalized, essentially, the activity that we enjoyed when we were kids. One woman came up to me recently and said that her community association had recently outlawed chalk drawing on the sidewalks, which leads to cocaine. And, this is crazy. I mean, just try to put up a basketball hoop in one of those neighborhoods, let alone let the kids build a tree house or a fort. I actually got kicked off of the little pond where I was fishing with my son—or they tried, but I would not leave—because it was against the community association rules to fish in that pond. We have really got to question that. We have to question how we are talking to young people and to ourselves about the future of the environment also.

Not long after the book came out, I was asked to speak at a high school. I did not want to do it. It was near where I lived. I had been on the road. I was tired, and then I started thinking why I wrote this book about kids. I started feeling guilty, so I went. I expected 20 kids, but there were 200. They have been given extra credit. And, I spoke for an hour, and you could have heard a pin drop. And, it is not because I'm a great speaker; I'm not. I'm an okay speaker. It was because of something else.

I talked about two things. I talked about the fact that their health is connected to their experience of nature—not an abstraction, their health. The second thing I talked about was the fact that, because of global warming, climate change and all of these environmental issues that we do face, because of them, everything in the next 40 years must change. Learning new kinds of agriculture is already beginning. Building new kinds of architecture and urban planning is already beginning with green urbanism and biophilic design, *et cetera*. Build new kinds of cities that bring nature into them; design it into those cities from the beginning so that it is not something we have to drive 40 miles to. As we redesign or redevelop cities, it is already beginning. Everything must change. Whole new careers will emerge that do not even have a name yet because everything must change.

As the kids left, I turned to the Biology teacher who had invited me and said, "What was that all about? Why were they so attentive? I did not expect that." And he said, "Simple, Rich. You said something hopeful about the future of the environment. They never hear that." They never hear that. My own son, I should have listened to my younger son. I should have listened to him more carefully. He had already begun to say things that were strange to hear from my son, the fisherman: "You know Dad, maybe it is okay they sliced off all those hills across the lake and put in a housing development because, you know, those are made out wood, too and that is nature, right?" And he kept saying things like it. I did not expect that from my son. I finally sat down with him and said, "What is going on? What are you thinking?" And he said, "Dad, every time I think about nature being destroyed, it is too painful to think about." It is too painful.

So, my own son was beginning to construct a worldview that would cause him less pain. He was beginning to disassociate from environmental issues, from nature itself. Now, as I said, he has come around; he is now at Evergreen College. But, we have to ask if we are disassociating future generations, for two reasons, from nature. One is we have physically taken them out of nature. We need to get them back in. And the second is, the way we are talking to them about the future. Yes, they get other messages about it, but the one that gets through to these kids over and over again is that when it comes to the environment, game's over. And then, we wonder why they do not want to suit up for the game.

Now in those moments, in that auditorium, I saw those eyes light up. I saw that fire that was dim go up. The framing of the future can change the way we create the future. These kids are ready to do that. Every generation, including ours, has wanted, when we were that age, to create a new civilization.

Session One.
Conservation and the Fuels Game

Renewable and Nonrenewable Energy Resources on the U.S. Landscape

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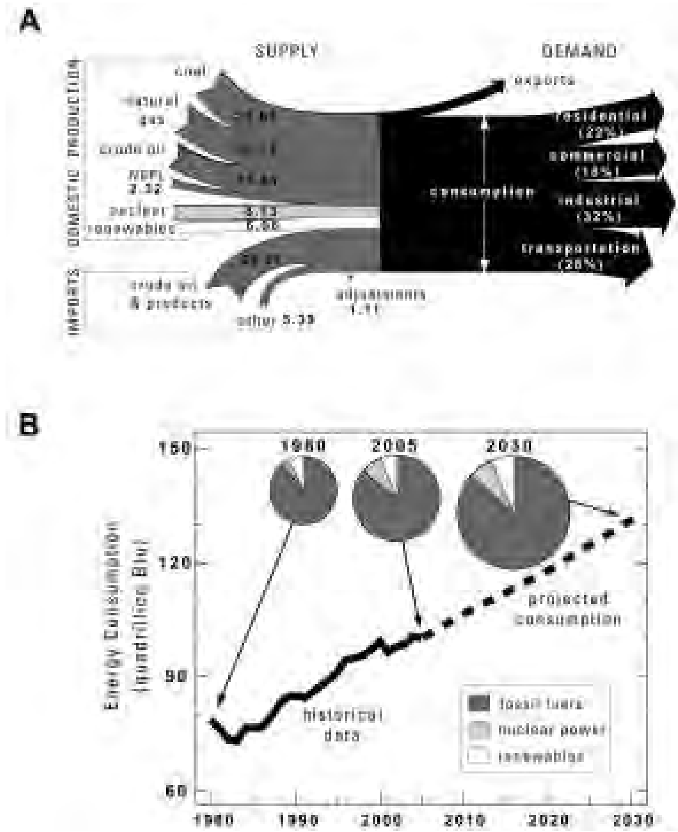
Introduction

Energy resources are an integral part of modern society and global economies. Because of this link between energy and society, considerable effort is expended to ensure that a sufficient supply of energy resources is economically available. This effort poses several challenges for resource management on the landscape both onshore and offshore, requiring a judicious balance between a growing need for energy resources and the needs and demands on other natural resources comprising the landscape that collectively are essential to maintain our quality of life and to preserve ecosystems and ecosystem services.

These challenges are particularly visible in the United States, the world's largest energy consumer (Energy Information Administration 2006a). In 2005, the United States consumed more than 7.5 billion barrels of oil (BBO), 21.9 trillion cubic feet of natural gas (TCFG) and 1.1 billion short tons (bst) of coal (Energy Information Administration 2006b). These fossil fuels currently comprise more than 80 percent of the total U.S. energy consumption (Figure 1a; Energy Information Administration 2006b). Given the long time frame (millions of years) needed for the natural transformation of precursor materials into fossil fuels, they are typically termed nonrenewable energy resources to reflect the fact that usable quantities of these resources do not form rapidly enough to be useful on human time scales. In contrast, renewable energy resources may be defined as those resources that can accumulate or replenish on much shorter time scales, such as geothermal, biomass, wind, solar and hydroelectric-power resources. In 2005, these renewable energy resources collectively accounted for approximately 6 percent of the U.S. energy mix (Energy Information Administration 2006b).

Projections indicate that energy consumption in the United States will grow approximately 30 percent by the year 2030 (Figure 1b, Energy Information

Figure 1. (a) Flow diagram depicting U.S. energy supply (energy resources) and demand (major energy consuming sectors) for 2005. All values, except percentages, are expressed in units of quadrillion British thermal units (BTUs). Modified from Energy Information Administration (2006b). NGPL refers to natural gas plant liquids. (b) Graph showing the historical trend in total U.S. energy consumption, and consumption projected to calendar year 2030. The pie diagrams, which correspond to the mix of the U.S. energy supply, have been scaled according to the total annual energy consumption for the year indicated (Energy Information Administration 2007).



Administration 2007). It is important to note that these projections account for current factors and trends that may influence future energy demands and are based largely on policies and regulations currently in effect (Energy Information Administration 2007). Thus, any future changes to policies or regulations, such as those mandating increased efficiency or conservation measures, have the potential to significantly affect these projections (Energy Information Administration 2007). Based on current projections, fossil fuels are expected to continue to constitute a major portion (more than 80 percent) of the U.S. energy mix over this time period (Figure 1b). However, given the anticipated growth in the total U.S. energy consumption over that time frame, utilization of both nonrenewable and renewable energy resources will experience significant growth and expansion across the U.S. landscape in order to meet domestic demand. The amount of imported energy resources, especially crude oil and liquefied natural gas (LNG), also likely will increase to satisfy overall demand. The United States presently imports 13.5 million barrels (MMBO) of crude oil and refined products per day, or approximately 60 percent of its daily consumption of this resource (Energy Information Administration 2006b). The two largest sources of these imports are Canada and Mexico, with 2.2 and 1.6 MMBO per day, respectively (Energy Information Administration 2006b). Thus, in addition to the U.S. landscape, energy demands in the United States may have repercussions on both energy-resource development and transportation infrastructure, such as pipelines and LNG terminals, that are felt throughout the North American landscape.

Given the anticipated growth in U.S. demand for energy resources in the coming decades, it is essential to have scientific information available to identify locations of potentially viable energy-resource accumulations and to evaluate the possible effects, or the footprint, of energy-resource extraction and utilization on other resources. Changes in technology have dramatically reduced the footprint typically associated with energy-resource development activities. For example, the advents of horizontal drilling, multiple completions and of fracturing techniques have dramatically reduced the size of the pad needed for oil and gas drilling while increasing the number of targets and amount of formation accessible from a single drilling pad. Given the scale of the U.S. energy demand, the cumulative effect of these local footprints may result in landscape transformations that are felt at the national scale. Examples that underscore the scale of U.S. energy demand include the number of oil and gas wells drilled (Figure 2a) and the infrastructure necessary to bring these energy resources to market (Figure 2b). Each energy resource, renewable and nonrenewable alike, has some footprint that can be observed on the landscape, and the effects associated with these footprints must be carefully considered and balanced in order to devise the best overall plan for responsible management of all resources.

The objectives of this paper are to provide an overview of the current understanding regarding the distribution of several energy resources—including both currently utilized and potential sources—across the United States to highlight salient research developments regarding these resources and to illustrate how interdisciplinary science can be brought to bear on the complex, interrelated resource issues facing our national landscape.

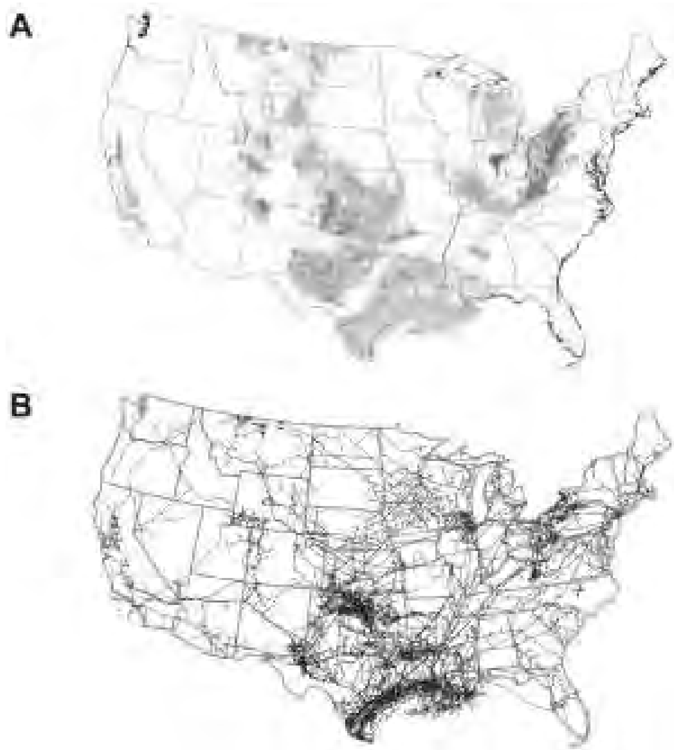


Figure 2. (a) The distribution of oil and gas wells across the conterminous United States (Mast et al. (1998). (b) The intrastate and interstate natural-gas pipeline infrastructure in the lower United States Energy Information Administration 2006c).

Nonrenewable Energy Resources

Petroleum Resources

Petroleum resources (oil, gas and natural-gas liquids) constitute the largest component of the U.S. energy mix, accounting for over 60 percent of U.S. energy consumption (Energy Information Administration 2006b). Given the importance of petroleum resources to the U.S. energy mix, the U.S. Geological Survey (USGS) conducts a considerable amount of research into the processes affecting the origin, generation, accumulation and quality of petroleum resources to provide insight into how petroleum-resource accumulations formed (e.g., Peters et al. 2006). Under the USGS National Oil and Gas Assessment (NOGA) project, these findings are integrated with research on oil and gas production and development activities to produce probability-based estimates of undiscovered, technically recoverable resources (UTRR). It is important to note the distinction between reserves and UTRR. Reserves are discovered, well-constrained petroleum accumulations that are commercially viable under present economic conditions. In contrast, UTRR constitute petroleum accumulations that have not yet been found but, if discovered, could be obtained with available technology. UTRR estimates are not predictions of petroleum resources that will actually be discovered or produced. To do so would require full knowledge of future petroleum economics, geopolitics on both national and international scales, the advent of new exploration and development technologies, and the extent of exploration effort that will be conducted in the area being assessed. Given the many geologic variables required for petroleum resource assessments, USGS resource estimates are represented as probability distributions rather than as single (point) values. However, the mean estimate from the probability distributions can be cited as a basis for comparison among assessments from individual geologic provinces.

The USGS assesses UTRR for the onshore United States, the offshore, state-controlled waters, and international areas. The Minerals Management Service (MMS), a sister agency within the U.S. Department of Interior, conducts analogous assessments of the federal Outer Continental Shelf (OCS). Taken together, the information from both agencies can be used to provide a snapshot of the distribution of UTRR across the onshore and offshore U.S. landscape (Figure 3). The mean estimates from respective probability distributions are illustrated in this figure, which highlights the heterogeneous distribution of undiscovered resources across the United States. As of the 2006 NOGA update, the mean USGS estimates of the national UTRR liquids resource base (crude oil plus natural-gas liquids) and natural-gas resource base are 58.03 BBO and 627 TCFG, respectively.

The USGS estimates of undiscovered oil and gas resources form the basis for the Energy Policy and Conservation Act (EPCA) inventory. This act, enacted in November 2000, directed the Secretary of the Interior, in consultation with the secretaries of the departments of Agriculture and Energy, to conduct a phased inventory of oil and natural-gas resources beneath onshore federal land that would identify the USGS estimates of underlying oil and gas resources and the extent and nature of any restrictions or impediments to the development of the resources.

The EPCA Phase II Inventory (U.S. Department of the Interior et al. 2006) examined 11 geologic provinces, including the 5 examined in the Phase I Inventory. The areas with USGS petroleum-resource estimates that were included

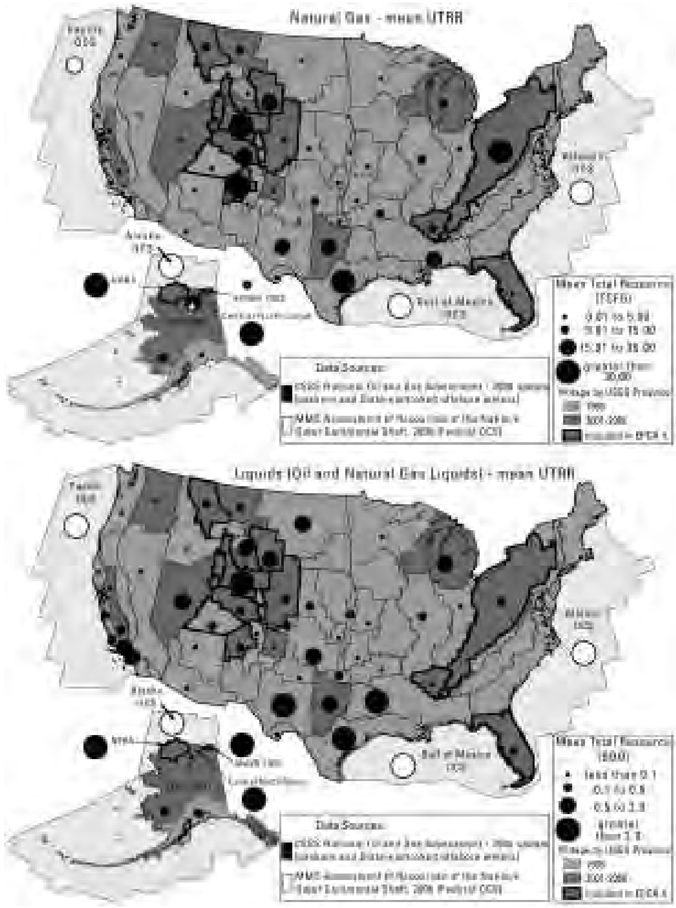


Figure 3. Mean estimates for the conterminous United States and Alaska of undiscovered, technically recoverable natural gas and liquids (crude oil plus natural-gas liquids) resources, expressed in units of trillion cubic feet of gas (TCFG) and billion barrels of oil (BBO), respectively. ANS refers to the Alaska North Slope; ANWR refers to the Arctic National Wildlife Refuge; CBM refers to coal bed methane; NPRA refers to National Petroleum Reserve in Alaska; OCS refers to outer continental shelf (Minerals Management Service 2006, U.S. Geological Survey 2006a).

in the Phase II inventory are highlighted in Figure 3. These areas were selected for the inventory because, as a group, they comprise most of the onshore, federal oil and gas resources. In addition, the federal lands within these areas, especially in the West, are increasingly important for recreation, livestock grazing, open space, wildlife habitat, cultural resources and mineral resources as well as for oil, gas and other energy production. The inventory will be expanded to include all federal onshore land and resources.

This inventory is available to assist in the development of management plans. The inventory enables public-land managers, such as the U.S. Department of the Interior's Bureau of Land Management (BLM) and the U.S. Department of Agriculture's Forest Service, to identify areas of high or low oil or gas potential and to devise appropriate land-management strategies, such as mitigating stipulations and conditions of approval. These strategies can be incorporated into adaptive management processes in order to balance the responsible development of energy resources with the protection of other natural resources in the area.

Coal Resources

Coal remains one of the major energy resources of the United States. The U.S. electric-power generation sector, the largest consumer of coal resources in the United States, uses coal as a fuel source for more than half the electric power that is generated. The spatial extent of the major U.S. coal fields covers a large portion of the U.S. landscape (Figure 4). However, the majority of coal extraction is relegated to a relatively small number of states. A large portion of the nation's recoverable reserves occurs in western states, particularly Wyoming (Energy Information Administration 2006d).

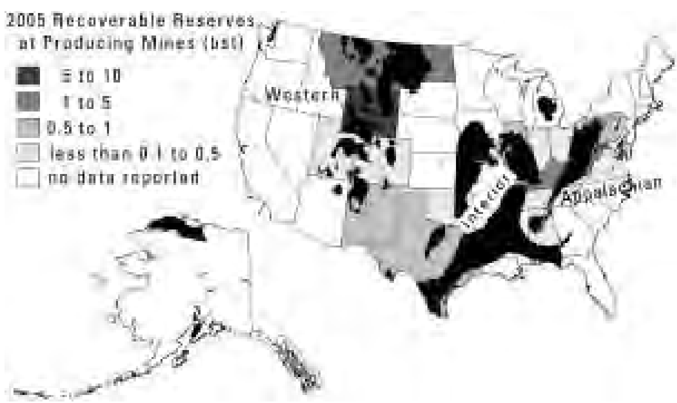


Figure 4. Locations of major U.S. coal fields; states are coded according to the amount of recoverable coal reserves, in bst, at producing coal mines as of 2005 (see Tully (1996). Recoverable coal reserves data from Environmental Information Administration (2006d).

Domestic coal production has witnessed a dramatic geographic shift in little more than a decade. In 1994, the three Energy Information Administration (EIA) coal-producing regions—Appalachian, Interior and Western—produced approximately 43, 17 and 40 percent, respectively, of the U.S. coal resources mined that year (Energy Information Administration 1994). In 2005, the Appalachian, Interior and Western regions accounted for 35, 13 and 52 percent, respectively, of U.S. coal production (Energy Information Administration 2006d). As the focus of coal production continues to shift gradually to the western states, more comprehensive assessment information will be needed to help planners anticipate the environmental consequences of increased coal activity in areas where a higher percentage of the coal resources occur under federal land.

The USGS has conducted digital resource assessments of the major coal-bearing basins in the United States. These assessments are the first of their kind and provide information on total in-ground coal resources and an associated, geographic information system coverage to facilitate analyses by a number of parameters, including surface-land and coal ownership. The studies were a cooperative effort between the USGS and a number of state geological surveys. With this new approach to coal assessment came a refinement of our understanding of coal occurrence, the mineability and usability of coal, new stratigraphic correlations and geologic and resource information across state boundaries.

Although there has been a significant amount of coal research done in the past, many challenges still exist, especially in light of the growing demand for coal resources, the increasing pressure for coal utilization to shrink its footprint on the U.S. landscape and the expanding uses of coal, such as the conversion of coal to liquid fuels. The growing demand for coal highlights a critical research need: this country has a substantial amount of in-ground coal resources, but only a fraction of those resources are technically and economically recoverable under current conditions. Thus, an inventory of this subset of coal resources, termed the coal-reserve base, is essential for the development of sound national-energy plans and resource-management plans on the U.S. landscape. The USGS has recently revised its coal-assessment methodology in order to determine the U.S. coal-reserve base and has started to systematically evaluate the Powder River Basin, the largest, producing, coal basin in the United States (Luppens et al. 2006). The USGS also conducts ongoing studies to characterize the quality and composition of coal to provide information that is critically needed by natural resource managers who must contend with the nation's ever-increasing need for energy while protecting the environment and human health.

Other Nonrenewable Energy Resources

Uranium. Uranium is used as fuel in nuclear reactors to generate electric power;

approximately 20 percent of the electric power generated in the United States is derived from this fuel (Energy Information Administration 2006b). The growing interest in uranium and nuclear energy, as evidenced by its mention in the Energy Policy Act of 2005 (public law 109-58), stems in part from an effort to diversify the U.S. energy mix and, thereby, to lessen the dependence on imported energy resources, particularly petroleum. In recent years, U.S. utilities have looked more favorably toward nuclear-produced electricity because of its greater efficiency and its relatively lower generating and fuel costs (Finch 2003). Despite the expanse of well-defined, approximate and inferred areas for uranium provinces in the United States (Figure 5), the relatively low price of uranium oxide over the past two decades has caused most uranium mines in the United States to delay opening, to be placed on standby or to close altogether (Finch 2003). In December 2001, only three uranium mines were in operation in the United States, two in Wyoming and one in Nebraska (Finch 2003). In 2004, Canada was the world's largest supplier of uranium and a significant source of uranium imports to the United States (Gurmendi 2004). However, recent price increases have sparked a surge in domestic uranium production (Energy Information Administration 2006b). Federal and state land-management and environmental agencies need reliable data on uranium-mine locations, uranium mine waste volumes and radioactivity, mine-reclamation completions, and areas of elevated, naturally occurring radionuclides. This information is needed to address legacy issues from previous uranium-mining activities and to plan for new activities coinciding with recent production increases. Although uranium-mill tailings have been the subject of extensive study and cleanup at mill sites across the United States (Finch 1997), uranium-mine waste remains at a number of sites throughout the western United States and constitutes a significant health hazard from gamma exposure and inhalation of windblown dust. Many areas of some western states continue to have exposed unreclaimed, uranium-mine waste at former mining sites. The leaching of radionuclides and other elements by precipitation and the erosion of waste piles by wind and runoff are primary mechanisms by which adjacent soil, water and ecosystems are impacted by uranium-mine-waste piles. Waste piles have not been sufficiently studied to determine whether such processes pose hazards beyond the immediate vicinity of the piles. The USGS is conducting studies to address these knowledge gaps.

Oil shale. Oil-shale resources may contribute to the U.S. energy mix in the future. Oil shale is a rock that, upon heating, yields substantial amounts of oil

Figure 5. Map showing the approximate extent of uranium provinces, including areas with well-defined, approximate and inferred resources (Finch 1996), and select unconventional fossil fuels, including major U.S. oil-shale deposits and potential gas-hydrate-stability zones within the OCS and onshore Alaska North Slope permafrost areas.

and combustible gas. An oil-shale deposit having economic potential for recovery of these energy resources is generally one that is at or near enough to the surface to be developed by open-pit or conventional underground mining or by in-situ methods. The footprint of oil-shale resource utilization on the landscape, such as the water and energy needed for oil-shale processing, may vary widely, depending on the technology used to extract and produce the resource. Although oil shale in the recent world market is not competitive with petroleum, natural gas or coal, it is used in several countries that have expended considerable investment in oil-shale resources because of the lack of other available fossil fuel resources (Dyni 2006).

Numerous oil-shale deposits occur in the United States. The two most extensive deposits are in the Green River Formation in Colorado, Utah and Wyoming, and in the Devonian-Mississippian black shales in the eastern United States (Figure 5). Other deposits occur in Nevada, Montana, Alaska, Kansas and elsewhere but are either too small or too low grade or have not yet been well enough explored to be considered as resources (Dyni 2006). The Energy Policy Act of 2005 authorized the USGS to conduct a new national assessment of these resources. The USGS has ongoing research efforts studying the oil generation potential of oil shale, modern analytical techniques to quantify this potential and conducting an oil-shale resource assessment with a focus on the

Green River Formation's oil-shale deposits of Colorado, Utah and Wyoming.

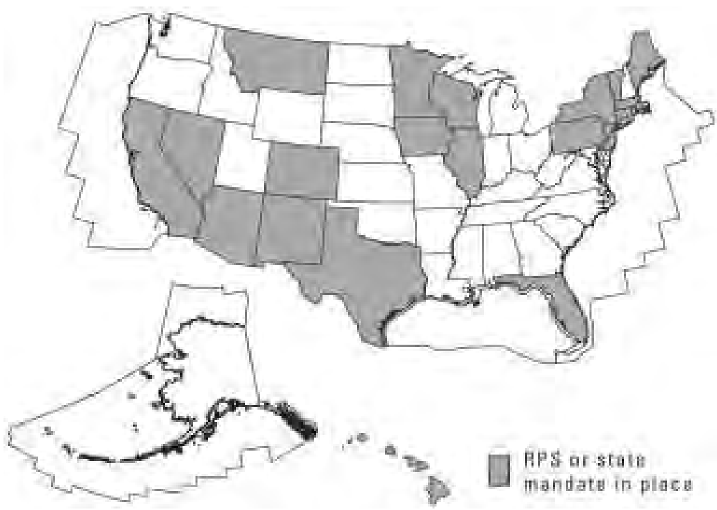
Gas hydrates. Gas hydrates, which are accumulations of methane (natural gas) trapped in ice-like structures with water, are an energy resource that appears poised to contribute to the U.S. energy mix in the future. Gas hydrates are known to occur in large quantities in areas underlying large portions of the world's marine continental shelves and Arctic continental permafrost. The approximate U.S. areas for potential gas hydrate resources are shown in Figure 5. Gas hydrates are important to study not only for their potential role in the U.S. energy mix but also because gas hydrates may pose a significant hazard to sea-floor-sediment stability and, thereby, may influence the potential for collapse and landslides. They also are important because gas-hydrate reservoirs may have a strong influence on the environment and climate, given that methane is a greenhouse gas.

Despite the tremendous energy-resource potential of gas hydrates, the precise magnitude and producibility of gas hydrates at a given site remain very much in question. Future contributions from gas hydrates to global energy supplies depend on issues pertaining to the availability, producibility and cost of extracting methane from the hydrate phase. One recent international consortium composed of research, industry and academic institutions—the Mallik Research Consortium, which also included the Geological Survey of Canada and the USGS as scientific coleads—drilled three test wells in the Mackenzie Delta of Canada in 2002 to study gas hydrates. This work demonstrated that gas hydrates are a producible energy source (Dallimore and Collett 2005), but further research must be undertaken to translate these results into estimates of recoverable gas-hydrate resources. To that end, the USGS, in partnership with BLM, maintains ongoing efforts in the Alaska North Slope to estimate recoverable, gas-hydrate resources. The USGS has also participated in a collaborative research study with the U.S. Department of Energy (DOE) and British Petroleum Exploration Alaska to test the occurrence and producibility of seismically predicted, gas-hydrate accumulations in this area. This work also builds on cooperative efforts between MMS and USGS as MMS develops a methodology to assess the in-place and recoverable resources of gas hydrates in the OCS of the United States.

Renewable Energy Resources

Historically, renewable energy resources have constituted a relatively small portion of the U.S. energy mix, accounting for roughly 6 to 9 percent of total U.S. energy consumption over the last 20 years (Environmental Information Administration 2007). Recently, however, renewable-energy resources have garnered significant attention as policymakers respond to concerns over the growing reliance on imported energy resources and are the possible ramifications of carbon dioxide (a greenhouse gas) emissions from energy-resource use on global climate and the environment. To address these issues, many states have adopted (or currently are considering) renewables-portfolio standards that stipulate, by a target date, that a certain percentage of the state's electric power must be derived from renewable-energy resources (Figure 6, Energy Information Administration 2006e).

Figure 6. Distribution of states with renewables-portfolio standards (RPS) or state mandates as of 2005 (Energy Information Administration 2006e).



Geothermal

Geothermal energy is an underutilized renewable-energy resource (Duffield and Sass 2003). Commercial, electric-power-generating geothermal facilities are presently operating in four states—California, Nevada, Utah and Hawaii—and are contributing approximately four-tenths of 1 percent to the total domestic energy consumption (Energy Information Administration 2006e). The last USGS national geothermal resource assessment was published in 1979. Advances in the field of geothermal energy and technology indicate that much of that information—as well as the geologic geothermal resource models in the earlier assessment—is outdated. In fiscal year 2006, in support of the Energy Policy Act of 2005 (public law 109-58), the USGS began a 3-year project to produce a new, national assessment of geothermal resources capable of producing electric power, with a focus on the western United States, including Alaska and Hawaii. The effort, conducted in partnership with the DOE, BLM, national laboratories, universities, state agencies and a consortium from the geothermal industry, will highlight geothermal energy resources located on public land. The USGS assessment will include a detailed estimate of electrical power generation potential and an evaluation of the major technological challenges and environmental effects of increased geothermal resource development.

Wind

Electric-power generation from wind energy has grown tremendously in recent years. From modest beginnings in 1983, when wind energy was harnessed for less than 0.05 billion kilowatt-hours of electric power, the use of this energy resource had grown to more than 14 billion kilowatt-hours by 2005 (Environmental Information Administration 2006b). In 2003, California and Texas generated the largest amount of electric power from wind energy; overall, 23 states reported net electric power generation from wind energy (Figure 7, Energy Information Administration 2006e). Current projections indicate that the contribution of wind energy to the U.S. energy mix may more than triple in the coming decades (Energy Information Administration 2007).

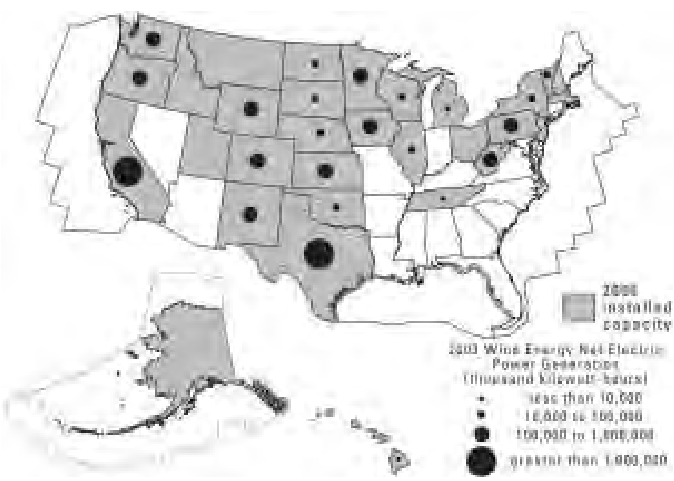


Figure 7. Distribution of states with net wind energy electric power generated during 2003 and states with currently (2006) installed generating capacity (Environmental Information Administration 2006e).

Despite the tremendous potential of this renewable energy resource, the rapid proliferation of wind turbines and communication towers across much of the United States and offshore poses challenges to natural-resource managers because areas with high concentrations of wind energy may coincide with migration routes for many bird species. There is a growing body of knowledge on how such changes to the landscape may impact birds (Usgaard et al. 1997, Osborn et al. 1998, Leddy et al. 1999, Osborn et al. 2000, Johnson et al. 2002), yet a consensus regarding the extent of these effects has not been reached. To help reduce the risk of bird and bat mortality from wind turbines, the U.S. Fish and Wildlife Service (FWS) has issued a set of voluntary guidelines to assist industry in the siting of new wind facilities (U.S. Fish and Wildlife Service 2003) as well as interim guidelines (U.S. Fish and Wildlife Service 2004). Research conducted to date is of limited scope with several factors currently unresolved. Radar-based studies are an exciting new tool that holds promise for deciphering habitat use and large-scale migratory patterns of birds and bats. Although the full application of this technology is not clear, the USGS and FWS are collaborating on research to utilize years of existing weather radar data to enhance our understanding of these movements (Figure 8, Ruth et al. 2005). Additional scientific studies addressing these topics are needed as a basis for future decisions with respect to these natural biological and energy resources.

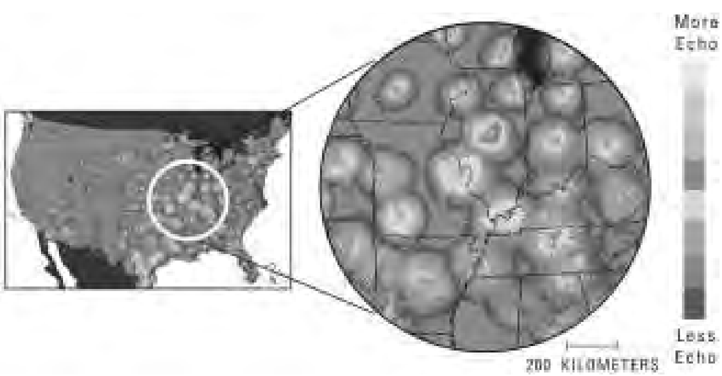


Figure 8. Radar captures a snapshot of bird migration across the United States on April 28, 2004, at 23:02 CDT. Individual radars detect birds out to a certain range shown as circular patterns of echoes. The pattern for the central United States (enlarged at right) indicates that birds are migrating as a relatively continuous layer. No substantial, large-scale structure appears in this layer; birds are migrating everywhere (Ruth et al. 2005).

Biomass

Energy production from biomass includes utilization of materials, such as crop residues and woody biomass, municipal solid waste, manufacturing waste, and landfill gas. Biomass has received considerable attention recently through prominent discussions of increasing ethanol production from corn for use as a gasoline additive or as a biofuel alternative to gasoline. As the number of alternative-fuel vehicles has more than doubled over the previous decade, demand for ethanol has grown dramatically; as a result, the quantity of ethanol consumed as a gasoline additive has increased two and a half times between 1995 and 2005 (Energy Information Administration 2006b). Growing concerns regarding the mitigation of greenhouse-gas emissions, such as carbon dioxide, also have augmented interest in biomass. Biomass is a relatively carbon-neutral energy resource; atmospheric carbon dioxide is taken up during biomass growth and then is released back to atmosphere during combustion.

The increased attention to biomass and biofuels is prompting the need to better understand the process of converting biomass into usable forms of energy as well as to better understand the landscape effects of increased biomass utilization. The vast majority of current ethanol production utilizes the starches found in corn, but the National Renewables Energy Laboratory (NREL) and other venues continue to explore ways of efficiently converting cellulose (instead of starches) from crop residues and woody biomass into ethanol. The possible change in agricultural practices to accommodate the expansion of crops grown for energy resources may pose challenges to other resources on the landscape, including water resources. Woody biomass utilization may provide additional benefits to forest ecosystem health and to communities within at-risk regions with identified forest-fire potential (National Renewables Energy Laboratory and U.S. Bureau of Land Management 2003), but these benefits need to be considered in concert with natural fire cycles and associated ecological benefits. The USGS is capable of providing the interdisciplinary science to address these emerging agricultural and natural resource issues (U.S. Geological Survey 2005, 2007).

Hydroelectric Power

Hydroelectric power has been a mainstay of renewable-energy resources in the United States, providing between 3 and 4 percent of the total domestic energy consumption for the majority of the past several decades. According to

Federal Energy Regulatory Commission's licensing information, California has both the most hydroelectric dams and the highest production capacity among the states; Washington ranks second in capacity. The projected contribution of hydroelectric power to the U.S. energy mix is forecast to decrease slightly over the next 25 years to less than 2.5 percent of overall energy consumption (Energy Information Administration 2007). In fact, a number of dams have been removed from the U.S. landscape in recent years owing largely to aging facilities and rising pressure over environmental concerns, such as the disruption to aquatic ecosystems by dams. The U.S. Bureau of Reclamation (BOR), a sister agency to the USGS, is engaged in managing, developing and protecting water and related resources for the general public in an environmentally and economically sound manner. The USGS has conducted numerous studies, often in collaboration with the BOR, to provide scientific and monitoring information needed to ascertain the health of aquatic ecosystems, including the status of fish populations (U.S. Geological Survey 2006b) and research on dam-induced changes to sediment transport processes (Wright et al. 2005). From the perspective of river management, the ecological implications associated with such changes are not well understood and are the focus of ongoing integrated science studies (Wright et al. 2005).

Natural Resources on the Landscape—Present and Future Challenges

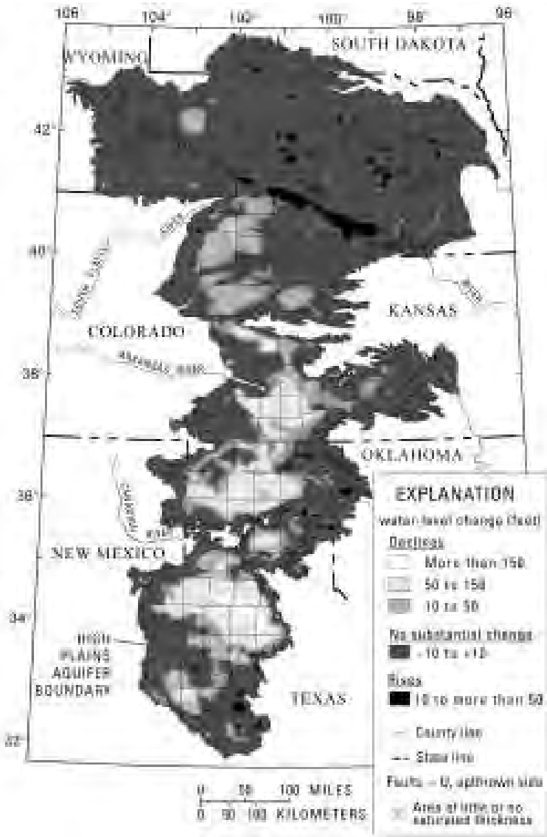
The anticipated growth in U.S. energy demand over the next couple of decades poses a national challenge to responsibly increase supplies of all energy resources currently in the U.S. energy mix, to better understand the resources that have the potential to be added to the energy mix in the future and to better understand the effects of energy-resource utilization on other natural resources within the landscape. Energy-resource development and utilization can stress other natural resources, and the nature and extent of stress may vary according to the energy resource. For example, USGS studies have examined the response of natural systems and species to energy-resource development, including the cerulean warbler (*Dendroica cerulea*) to coal mining activities (Weakland and Wood 2005, Wood et al. 2006), mule deer (*Odocoileus hemionus*) to natural-gas development (Sawyer et al. 2006) and elk (*Cervus elaphus*) to the presence of wind facilities (Walter et al. 2006). In some instances, this footprint on the landscape can persist long after energy-resource production and utilization activities in an area have ceased. Hence, the increasing demand for energy resources may prompt the need to consider potential development scenarios and adaptive-management strategies prior to resource utilization. Studies collecting biological data in areas with high-energy, resource-development potential, such as the Alaska North Slope (Phillips and Powell 2006, Phillips et al. 2006), provide baseline data needed for these efforts.

These present and future challenges to natural resource management encompass the national landscape but will be particularly visible in the western states, where the preponderance of federal land exists. Some of the inherent characteristics of the West add complexity to the task of managing natural resources on the landscape. The western states, including the arid Southwest, are experiencing the most rapid population growth in the United States, spurring increased demand for natural resources. For example, the increasing need for water resources has been met in some of the major aquifer systems, such as the High Plains Aquifer (Figure 9), with significant declines in water levels.

As it has with other natural resources on the U.S. landscape, USGS science has played a key role in improving the understanding of water resources. The focus of USGS water science has evolved—from a focus on development and construction to consequences and environmental awareness to sustainability—as society's values have changed (Anderson and Woosely 2005). The emphasis on sustainability reflects the present efforts of water managers and other natural resource managers to sustain water supplies beyond the present generation. These issues are part of the larger, ongoing Water 2025 effort that aims to more effectively mange water resources on the landscape (U.S. Department of the Interior 2005). Sustainability, as presently interpreted, extends beyond water availability for human use to include water availability for ecosystem functions as well as for individual species (Anderson and Woosely 2005). This interpretation will continue to present a significant challenge to translate science into measurable water-management strategies that can be balanced in concert with other natural resources on the landscape.

Interdisciplinary science offers a multifaceted research base to augment the understanding of these interactions among natural resources on the landscape. Without such a holistic approach, the utility of one natural resource can be compromised at the expense of another. As one example, deposits of potential, aggregate, mineral resources—necessary to support infrastructure for the expanding population in the Colorado Front Range—have been rendered

Figure 9. Water-level changes in the High Plains Aquifer, predevelopment to 2005 (McGuire 2007).



inaccessible in some areas owing to collocation of infrastructure from existing oil and gas activities (Figure 10).

The issue of produced water disposal on the landscape is another example underscoring the utility of interdisciplinary research. Produced water is water that is brought (pumped) to the land surface during the extraction of oil and gas (including coalbed methane) resources. Studies have documented instances where surface disposal of produced waters adversely affected the landscape (see Otton 2006). Collaborative efforts between the USGS and BLM to study coalbed-methane resources (Stricker et al. 2006) and associated produced waters (Rice et al. 2000) are providing information that can be used to mitigate the effects of produced-water disposal and to investigate potential benefits of produced waters. Ongoing USGS research will provide additional insight into

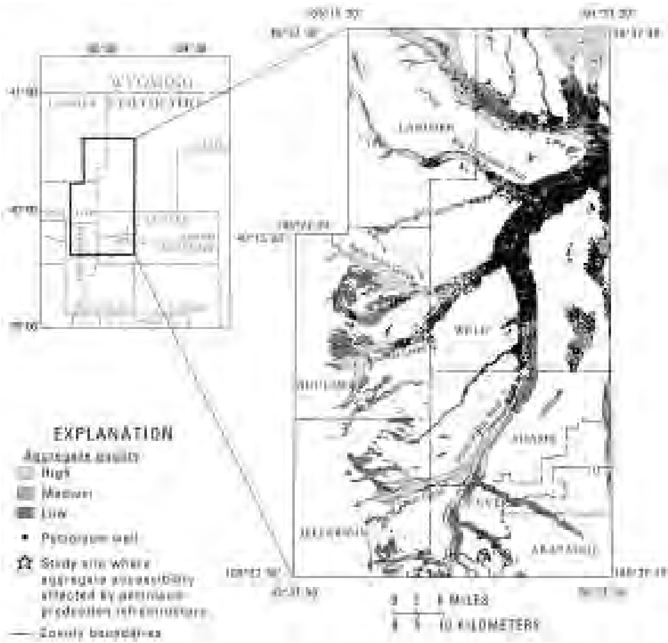


Figure 10. Distribution of high-, medium- and low-quality aggregate (from Schochow et al. 1974) and study sites (black stars) where petroleum production infrastructure in the Front Range of Colorado has compromised aggregate resource accessibility (Fishman et al. 2005).

the effects of coalbed-methane production on fish assemblages and sage-grouse (*Centrocercus urophasianus*) behavior. The integrated results from these efforts can provide information leading to successful development and implementation of best-management practices for produced water.

Multiple challenges have arisen, particularly in the western states, because of the development of the U.S. landscape and because of the increases in national demand for natural resources. Hence, a grand challenge to natural-resource managers is not solely the responsible development of energy resources in the West to meet national needs but also the responsible development of the West in response to population growth and to ensuing regional pressures on all natural resources. To address these challenges, the U.S. Department of the Interior is collaborating with federal and state partners in a new initiative to apply a more holistic approach to resource management on the western landscape. This effort, the Wyoming Landscape Conservation Initiative, is aimed at providing the science needed to address these complex, interrelated issues facing the U.S. landscape (U.S. Bureau of Land Management 2007). Given the large volume of gas resources estimated to exist within the study area, the science thrusts of this initiative will facilitate the responsible and effective management of the natural habitat on this landscape in the context of anticipated energy-resource development. This interdisciplinary venture is essential to providing information needed by land managers to make informed decisions and to facilitate the effective and responsible management of all natural resources on the U.S. landscape.

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Energy Development and Fish and Wildlife Resources: Trade-offs

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I offer my thanks to the Wildlife Management Institute, the conference steering committee and the Association of Fish and Wildlife Agencies' Energy-Wildlife Policy Committee for the opportunity to speak this morning and to hang out for a few days with some of my favorite people.

Many of you may wonder why an unemployed fisherman from Cody, Wyoming was asked to talk to an esteemed group like this. Certainly there are lots of you who know more about wildlife, there are a few of you who know a great deal about the technology and economics of energy development, and then there are also experts on the legal and procedural aspects of leasing, permitting, mitigation, reclamation, National Environmental Protection Agency (NEPA), Endangered Species Act and so on.

What I will offer is my perspective as a biologist and an administrator with the Wyoming Game and Fish Department during several oil and gas booms, a coal boom, uranium boom, massive wind-energy development, and even a few new power plants and hydropower rebuilds. After finishing my career with the Wyoming Game and Fish Department, I had the opportunity to work for all the states during my 4 years with the Association of Fish and Wildlife Agencies in Washington, DC. This gave me exposure to an array of wildlife-energy issues from wind energy and bird migrations on the East Coast to mountaintop strip mining in Appalachia to natural gas and coal-bed methane impacts on sage-grouse and water in the West to proposals for energy development on the Arctic National Wildlife Refuge. I learned just a little about a whole lot of energy-wildlife issues. More importantly, I was able to meet, work with and, in many cases, get to personally know folks from the energy industry, federal regulatory agencies, and the conservation and environmental community who are players in the energy-wildlife arena.

Given this background on the evolution of my perspective on the trade-offs between energy development and fish and wildlife resources, I would like to offer a few observations on why we don't do better in balancing these trade-offs and on how we might do better in the future. If you came to hear about the technical aspects of how to drill a better well, how to reclaim a site for sage-grouse or the comparative habitat loss between fossil fuels and wind energy, you will be disappointed. The good news is that the experts on these subjects are probably at this conference, so maybe you can find time to visit.

There can be no doubt that there are trade-offs in wildlife and wildlife habitat whenever we have any type of energy development. On a small scale, wildlife habitat is lost and wildlife is displaced from the sites directly disturbed for well pads, roads, storage tanks, etc. Wildlife populations can be impacted over a far greater area depending on timing, intensity of development, noise, human presence and other factors. My one, major contention today is that our loss of wildlife habitat due to energy development, or our ability to avoid losses and even to enhance wildlife habitat when we look at the large scale, is going to be far less dependent on our technical ability to drill better wells, to erect more bird-friendly wind turbines or to develop better science about seasonal occupancy or road densities critical to certain species than it is on our ability to develop better ways to work together.

Why Can't We Just Get Along?

At the highest level in the energy-wildlife game, nearly all of us share a common goal: cheap, reliable energy and a healthy environment—including abundant wildlife. If we want to achieve both of these outcomes, it seems advantageous that all the players work together. Unfortunately, as we step down from our overarching goals (motherhood and apple pie), our organizational or personal values and agendas seem to get in the way of productively working together. There are a few hopeful signs, but there is still huge room for improvement. Given this fast-moving train we call domestic energy development, if we want to better balance energy development with wildlife habitat, we need to learn to work together, and we better do it soon.

Why don't we work well together? There are three reasons I think are most fundamental to our continued difficulty in addressing energy and wildlife trade-offs in a more balanced fashion.

It Is Hard to Have a Good Game When Everyone Is Playing on a Different Field with Their Own Set of Rules

We don't have traditional channels of communication and long-established personal and working relationships between the energy industry, the environmental and conservation community, and government. In many situations we don't even have adequate communication and relationships between conservation and environmental groups or between state and federal agencies. We have lots of issues to address—things that are complex, but they aren't rocket science—like leasing, permitting, reclamation, on-site and off-site mitigation, and so on. All of these can be improved. But, between the major players, we don't know who to talk to, or where, when and how to communicate. So, we fail to build the necessary relationships, to clearly define the real issues and to make the needed improvements in each of these processes. Meanwhile domestic energy development rolls forward with a fair amount of waste for everyone, way too much animosity, and too much time and money put into paperwork and litigation rather than on-the-ground resources.

Where Am I Off to? I Don't Know. Where Am I Heading? I Ain't Certain

All of us have been through planning exercises, *ad-nauseum*, where we were asked to come up with a common vision of success before we designed a plan to get there. We can probably agree on the common vision of cheap, reliable energy and a healthy environment. But, as we step down to the actual permitting, mitigation and reclamation for a specific location, then mix in organizational goals, our common objectives get real fuzzy. To those in the energy industry, it might be a vision of abundant, healthy wildlife but with cheaper, more certain permitting and regulations. To a state wildlife agency the vision might include abundant, reliable energy but with current wildlife populations and habitat intact. To a federal permitting agency, like the U.S. Bureau of Land Management (BLM), success might simply look like a budget that adequately provides for the legal obligations of planning. To NEPA, it may look like leasing, permitting and monitoring and may even allow local personnel to do some of the work they were hired for. Success varies widely among the nongovernmental organizations, but cheap, reliable energy is great as long as a certain species, area or value is maintained.

Without a tangible, common vision of success, all of us in the energy-wildlife arena are a lot like the miners in *Paint Your Wagon*: when you don't know where you are going, any road will get you there.

The Wyoming Compromise: I Get What I Want, and You Get to Give It to Me

Many of the key players at the agency, organization or corporation level don't have the ability or the willingness to negotiate. I have given a few talks to younger crowds—usually wildlife students or biologists, but it could be any group—where I have recommended reading two books before they get too engrossed in their professional careers. The first would be Also Leopold's classic *A Sand County Almanac* and the second would be *Getting to Yes: Negotiating Agreement without Giving in*, by Roger Fisher and William Ury with the Harvard Negotiation Project. After 30 years in the business, I am reasonably certain most wildlife professionals read the first book, at least up to the essay, "Thinking Like a Mountain," where Leopold laments the death of an old wolf as he watches, "a fierce green fire dying in her eyes." I am also reasonably sure that most wildlife professionals—the same is probably true of petroleum engineers, chief executive officers, governors, cabinet secretaries or ranchers—either never read *Getting to Yes* or forgot about it long before reaching a point in their career where it would do some good. I say this because the overriding theme of *Getting to Yes* is to negotiate on specific interests in order to reach mutually beneficial solutions that are agreeable to all parties rather than bargaining on positions (i.e., the old line in the sand, win-lose system of bargaining). Too often, the key players in the energy-wildlife arena start and finish negotiations with, "we absolutely have to (activity) right (location)," or, "you will (activity) right (location) over my dead body."

We have big issues to address—complex, but the components aren't too difficult—but we won't do better unless we work together. If a company, agency or organization thrives on positional bargaining rather than an interest bargaining they are part of the problem.

There Are Many Elements to a Campaign. Leadership Is Number One. Everything Else Is Number Two

This past November, 35 of our colleagues from government, nongovernmental organizations and natural resource industries were selected as fellows to attend the inaugural session of the National Conservation Leadership Institute. The institute was created to address the impending loss of leadership in national resource conservation as we baby boomers retire. The institute presented fellows with case-history lectures from some of the country's most recognized conservation leaders, past and present. Leadership experts from the Kennedy Business School at Harvard wove the whole program into a cohesive package based on the concept of adaptive leadership; i.e., we have technical problems that can be solved by applying existing knowledge and skills, and we have adaptive problems that require leadership to craft new solutions.

We have had energy development in the past. And, we have good techniques for drilling better, less-intrusive wells, for issuing permits, leasing land, improving habitat and so on. However, we have never had energy development on such a broad, varied and intensive basis. We are addressing the current situation by trying to do the same things we have always done only faster and often with less money and manpower; i.e., we have been trying to apply a technical solution. Einstein said it best: "We can't expect to solve today's problems with the same level of thinking that created them."

Leadership is defined as the ability to get people to willingly do something that you think must be done. Certainly in the energy-wildlife arena, there is plenty of room for leadership at all levels, but if we really want to be successful at a state and national level it will require the sustained commitment of those who have the authority and are willing to exercise the leadership to implement change. From my perspective, industry and the conservation and environmental community absolutely must be involved, but the Secretary of the Interior (in some cases the Secretary of Agriculture) and the governors of the respective states working through their agency directors are the folks who can, should and might make it happen.

As I said earlier, there are some positive signs. The Wyoming Landscape Conservation Initiative is one of these, where Secretary Kempthorne and Governor Freudenthal—working with Kathleen Clarke and Jim Hughes of BLM and with Terry Cleveland and John Emmerich of the Wyoming Game and Fish Department—put together a major initiative to capitalize on the assets of regional energy development and to actually enhance wildlife habitat, potentially over millions of acres.

None of us should proclaim victory and move on to other issues, like wolf and grizzly bear management, because the ultimate success of this initiative and similar efforts will depend on the continued commitment of those who can make things happen, the dedicated engagement of the right people in the energy industry and the conservation and environmental communities, the establishment of lasting and productive, working relationships and of measurable results on-the-ground. I am willing to proclaim that efforts like the Wyoming Landscape Conservation Initiative—and there are others—are a big step in the right direction.

There is a quote by Bertold Brecht on the flier for the National Conservation Leadership Institute: “There are many elements to a campaign. Leadership is number one. Everything else is number two.”

Everyone I know wants cheap, reliable energy and a healthy environment. Almost everyone would agree that we can and should improve leasing, siting and permitting, reclamation, mitigation, monitoring, site management, etc. Leadership—leadership at all levels—will dictate our success or failure.

Learning from Experience: How to Enhance the Future for Wildlife during Prolonged Energy Development

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Since the current energy boom began in the Rocky Mountains in the late 1990s, wildlife has been largely treated as an impediment to energy development. This is borne out by past congressional testimony, industry, the U.S. Department of the Interior's Bureau of Land Management (BLM), expression in media, industry associations, the Administration and by actions in authorizing and developing major energy fields, such as Wyoming's Pinedale Anticline and Jonah gas field and the coal-bed natural gas fields in Powder River Basin. Project-decision documents have recognized the high value of wildlife resources, and the BLM has set forth measures for wildlife protection, usually through seasonal timing limitations and controlled surface-use activity buffers. The BLM also has promised monitoring and the use of adaptive management to adjust well-field operations, but changes to the promised, protective management have not taken place. This is evident by some of the recent reports that have come to light exposing the BLM's failure to adhere to commitments made in project authorizations. These decision documents should be contracts with the U.S. people to practice true multiple use of the public's natural resources, but, unfortunately, they are not.

Industry has made some selective, responsible efforts in reclamation, reduction of infrastructure and disturbance, funding of research, and monitoring efforts. And, some companies are willing to consider more actions to lessen impacts. But, some companies also have invested in attempts to discredit research results they perceive as unfavorable to their mission. To be clear, however, their job is to develop gas and oil and to produce as much as possible, not to manage habitats or wildlife populations. Their trade associations and company lobbyists have presented the wildlife question as an impediment and our government has listened to them and largely has ignored our many appeals to slow down and do this right. A paradigm shift has occurred where responsibility for public land and resource management has been transferred to the energy companies, away from the very agency that should be the caretaker.

History is a great teacher, and proof that wildlife is receiving little protection lies in past and proposed actions by the BLM. Pressures to accelerate approval of thousands of applications for permits to drill (APDs) and to otherwise expedite development have led to abandonment of other land-management responsibilities for wildlife on many BLM trust lands. BLM resource managers have been reprogrammed to assist in processing drilling permits as their first priority and, in some instances, as their only priority. For example, BLM issued more than twice the number of drilling permits in 2005 as it did in 2000. Funding and staffing have been shifted away (and reduced) from the multiple-use management mandate we expect from the BLM as one of its core missions.

Of course, much of this shift has been responding to directives from the Administration and Congress, but BLM seems to go the extra mile in unique interpretations of policy and law. "Minerals trump everything" has been a mantra repeatedly stated by BLM staff, even in public meetings, while top administrators have extolled their great attention to balanced development even while issuing directives to the contrary.

Specific wildlife resources are suffering from this neglect. Greater sage-grouse were recently proposed for listing as threatened or endangered under the Endangered Species Act, but the U.S. Fish and Wildlife Service decided not to list them partly because BLM had developed a very broad, national sage-grouse plan and promised to conserve what's left of occupied sage-grouse habitats. However, 8 years of experience in monitoring the effects of intensive development on sage-grouse habitat in Wyoming and Montana, plus 20 years of sage-grouse research in other states clearly indicates that many actions designed to prevent adverse impacts are not adequate. The most apparent inadequacy is the continued use of a one-quarter-mile (0.4-km) disturbance buffer around sage-grouse lek sites. Disturbance effects on breeding and nesting occur out to 3 miles (4.8 km), yet current and proposed management plans and actions by BLM continue to use smaller, ineffective buffers. Additionally it has been getting easier and more common for many sage-grouse protections and stipulations to be waived, excepted and not enforced because of the perceived impediment they cause to development. How will these failures and actions prevent the loss of more sage-grouse and a future sage-grouse listing?

At the famous Pinedale Anticline in the Upper Green River Basin, an important winter range for a significant mule deer herd has experienced over 46 percent fewer animals in the first 5 years of development. This has been compounded by deer displacement from more favorable to, as previously documented, less favorable habitats. In effect, much of the winter habitat necessary for survival during harsh winters is not usable because of the presence of intensive industrial activity and because the deer's ability to use habitat is reduced. To make matters worse, signs are emerging of reduced reproductive success for this wintering herd, compared to nearby herds (Sawyer et al. 2006). This response occurred with 500 wells and approximately 5,000 acres (2,023.4 ha) of disturbance. A pending proposal would add over 4,000 wells (some on the same pads) and 12,000 acres (4,856.2 ha) of new disturbance. What would all this mean for mule deer given there is no clear plan for their future conservation?

BLM has suggested that the Pinedale Anticline project is an unusual juxtaposition of world-class wildlife with world-class energy resources (the Green River Basin in Wyoming, for example, supports 100,000 mule deer, 40,000 elk, 100,000 pronghorn, 8,000 moose, 1,400 bighorn sheep and the highest density of sage-grouse within their western range). Another new project in another part of Wyoming, the Atlantic Rim in the southcentral part of the state near Rawlins, will affect over 140 sage-grouse leks, plus an important, large, mule deer herd, significant elk and pronghorn herds along with a high population of other desert wildlife. The decision document overtly predicts the project will greatly reduce wildlife and will lead to the area being unsuitable for hunting, outfitting and bird watching. Can this approach be properly mitigated or replaced?

The same is happening in the northwestern part of Colorado in the Hiawatha, Vermillion and Piceance regions, in the Powder River Basin in Montana and northeastern Wyoming—the Powder River Basin of has over 30,000 wells and up to 30,000 more are planned—in the Book Cliffs and in other important wildlife habitats in Utah. An unusual juxtaposition seems to be happening quite a bit these days.

A 2003 congressionally mandated study of impediments to access to oil and gas (Energy Policy Conservation Act I), led by BLM, concluded that a high percentage of western public lands in five major river basins were not tied up with excessive restrictions and that access was adequate to develop the mineral reserves (the five basins studied in 2003 produce 18 percent of the nation's natural gas). Recently, a second report (Energy Policy Conservation Act II [EPCA]) was issued by BLM that contradicts the first study, concluding that much more federal land is off limits to drilling or is unavailable for large parts of the year due to wildlife restrictions. What's the significance of these two reports that contradict each other? The significance is that there is greater demand to access the mineral reserves and that wildlife is now seen as an impediment. One could interpret, particularly from the press the EPCA report received, that mineral development has become the main mission of the BLM.

National Environmental Policy Act (NEPA) documents are supposed to inform and disclose an agency's action and to make sure that the action does not result in unacceptable impacts. A chronic problem with NEPA documents is that predictions and estimates of the size and time to develop energy fields has not been accurate. In three large fields in Wyoming's Green River Basin, initial authorization of a few hundred wells later led to addition of thousands of wells and projects going from exploratory to full-field to infill in very short time frames. Additionally, NEPA documents for energy projects do not address operation, maintenance and production of the energy field. Therefore, wildlife and environmental costs escalate and are dealt with in a reactive mode.

Currently, there are plans for extensive development in the five Rocky Mountain states of Montana, Wyoming, Colorado, Utah and New Mexico (Figure 1). There has been little serious attention to how these widespread project impacts relate to each other and no attempt to quantify the severity of the public-resource values that will be lost or degraded if the projects are authorized. There is also a question of whether project impacts can be effectively mitigated across the region. Our concern is about how mitigation might be pursued and implemented, given that many areas will already have impacts from development. How these projects progress will determine whether important wildlife, its habitat and traditional uses, like hunting and fishing, can be sustained through prolonged development periods. Where well fields started between 15- and 30-year projections, new technology and market factors now suggest a project life of 75 years for some areas. One needs only to take a look at some of the old fields in Wyoming and New Mexico that are still active well past 50 years as examples of how long these fields can operate. That is a long time to sustain wildlife and public use, especially lacking comprehensive fish and wildlife planning. This

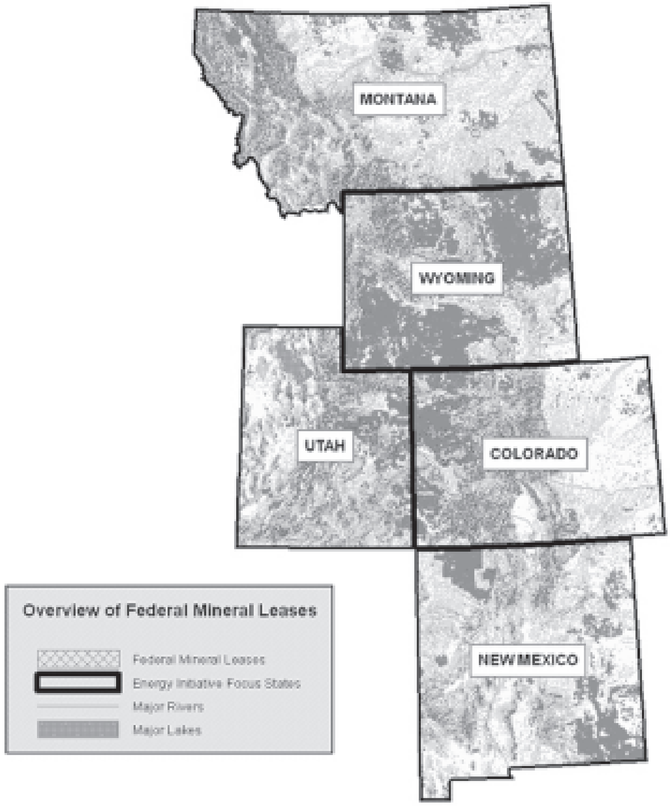

Figure 1. Federal mineral leases in the Rocky Mountain West.

seems like the authorization of one use in favor or exclusion of other existing, valid uses of public land. There have to be other approaches or ways to develop the mineral resources and to conserve fish and wildlife.

The appearance of several new landscape-scale habitat initiatives is welcomed and long overdue. Recent press releases, meetings and presentations, even at this conference, have highlighted their promise. From our experience, rangewide conservation of sage-grouse habitat is the only way a listing is likely to be avoided. However, the Collaborative Sagebrush Initiative, Wyoming Landscape Conservation Initiative and the Healthy Lands Initiative in President George W. Bush's 2008 budget proposal is cause for great caution. The language used in all these efforts seems to accept that serious fish and wildlife losses are inevitable at development sites and that the solution is to somehow broadly enhance sagebrush and other habitats across western landscapes. This could be read as give up on developed areas even where serious wildlife losses will occur and mitigate elsewhere. Does this approach make the conservation of one species a panacea for the conservation problems we encounter with another? We suggest that not enough has been done to manage development as a whole and that management that specifically balances dual goals of extraction and conservation of renewable resources can make a major difference in how severe the losses will be. Prevention of damage is at least as cost effective as broad restoration efforts across the landscape. We need to plan our actions more effectively to reduce near-term loss and, over a much longer time frame, to work on a landscape scale to conserve species integrity. Help us seek that balance.

One recent answer to the problem was to promote the expanded use of mitigation, particularly off-site (compensatory) mitigation, as a way out of the situation. One must look at mitigation much more closely to understand its role in managing the impacts of energy development. Mitigation is a process, not a one-time liability to write a check to pay for damage. We have strong existing guidance from the Council on Environmental Quality which should provide guidance for federal agencies in the planning for mitigation. They call for (a) avoiding the impact altogether by not taking a certain action or portions of an action, (b) minimizing impacts by limiting the degree or magnitude of the proposed action and its implementation, (c) rectifying the impact by repairing, rehabilitating or restoring the affected environment, (d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action and (e) compensating for the impact by replacing or providing substitute resources or environments (Council on Environmental Quality Regulations. Title 40, Sec. 1508.20). We suggest, from direct experience, that avoidance and minimization are the best approaches, especially by giving up some development prerogative, to protect wildlife and have not been given enough consideration.

Our intent has been to paint a picture of the challenges being presented for the future of important fish and wildlife populations and for the traditional outdoor uses over a vast area of the Rocky Mountains. Our punch line, though, is that there is much that can be done to prevent or lessen impacts, to protect important habitats and to not lose as much in the end. This process will challenge wildlife resource managers for decades beyond our lives.

What does the future of energy-development effects on fish and wildlife look like? There are some major principles that, if followed, would brighten the outlook and conservation of these resources better than what has been happening in the past. One concept that we promote is the use of a set of principles we call FACTS for Fish and Wildlife (http://www.trcp.org/issues/energy/246.html). FACTS stands for funding, accountability, coordination, transparency and science. These key principles were developed from almost two decades of experience, knowledge and expertise about the needs of wildlife management and energy development.

Funding

A core tenet for any program to succeed is that adequate funding is provided and available. Funding for fish and wildlife management to the natural resource agencies through the federal appropriations process has been chronically short for quite a long time. Rarely is enough funding provided for staffing requirements and for properly managing resources. BLM has been chronically understaffed and underfunded for its wildlife resource work. Recent emphasis has been on funding energy permitting and planning. State wildlife agencies are constantly trying to find extra funds to accomplish their growing mandate to manage all wildlife. Coping with the pressures of energy development is eroding their limited funding base.

To address this problem, permanent funding sources must be established and maintained for fish and wildlife management. This is even more important with the increased burden that expanded energy development puts on fish and wildlife managers. These funds can be established at the federal, state and local level and should be dedicated to management of fish and wildlife.

Another problem that plagues agencies is the funding that is available is often not used to manage fish and wildlife but is used for other purposes instead. Where energy demands have increased, funding intended for resource management has been used for administrative uses (e.g., for processing permits). Additionally, resource staff who were hired to manage fish and wildlife have had their priorities and duties shifted to work on energy workloads.

Recent funding increases to address energy demands have not been met with commensurate increases for fish and wildlife management; in fact, some have been cut. At times when the impacts to fish and wildlife resources are increasing, more attention and funding is needed, not less.

Accountability

The public expects the federal agencies to manage federal land as a public trust. Recently, the faith the public has in the management agencies meeting this goal has eroded and must be restored. By following true multiple-use policies and by balancing energy development and resource management, the trust has a much better chance of being restored. But, that is going to take some measures to accomplish.

Managers, industry and other decision-makers must be held accountable and responsible for following laws, regulations and policy, including commitments made in decision documents. A process for accountability should be established that allows the public to track compliance with law, policy, plans and, most importantly, commitments in decision documents. With the advancement of electronic communication and the Internet, there is no reason that the public should not have up-to-the-minute information on how commitments are being met.

Compliance with and enforcement of requirements from records of decision and other contracts with the U.S. people for the efficient development of their resources should be included in written performance standards for the BLM employees responsible for each phase of the development process. Without incentives and repercussions for misdeeds, it has become too easy to not follow commitments.

Mineral leasing should account for future impacts from development on fish and wildlife resources. Therefore, we recommend changing the current leasing process to assess impacts from lease development before leasing occurs and to balance the needs of fish and wildlife resources. To that end we recommend a specific conservation strategy for each energy field or project that goes beyond the NEPA-level evaluations and plans currently in progress. Such strategies should be used to proactively address fish and wildlife management and need for current and future objectives. This conservation strategy should be finalized before development starts and must provide specific recommendations and actions to minimize impacts while establishing plans for detailed monitoring, for the use of adaptive management and for mitigation.

Proper planning and compliance, along with learning from the past, can lead to better conditions for fish and wildlife while still developing the mineral resources.

Coordination

Coordination means more than just providing information. It means entities working together towards common goals for a better outcome. Much effort has been put on the appearance of coordination through public meetings, listening sessions and NEPA-required, public-comment periods. But, is this the coordination needed for a better future? Has anyone seen a major change in project implementation in response to public comment?

The federal government should improve coordination with all interested parties when planning and implementing energy development. Public involvement from all stakeholders, including local and state governments, nongovernmental organizations, industry, sportsmen, sportswomen, and others, is important and should be assured.

State wildlife agencies that have the authority to manage wildlife and fish populations which are affected by energy development should be given stronger legal standing in the process, rather than only being given cooperating agency status. The goals set by state agencies for fish and wildlife populations should be incorporated into habitat-management planning by the federal agency during energy development plans and land-use plans.

Adaptive management based on the best-available monitoring information and coordination with state agencies must be used by federal officials. An effective, adaptive-management process includes regular reviews of both state and federal findings from research and monitoring, consideration of alternative-energy field management, and the means for making management changes for future development when needed to lessen impacts on fish and wildlife. Federal officials and state wildlife agencies must coordinate activities to lessen or avoid impacts on fish and wildlife. Lack of coordination and data-sharing often means that the same approach to development is continued, despite monitoring that has shown it is detrimental to wildlife.

Without coordination between habitat and populations and between federal and state agencies, proper wildlife management cannot occur, and the precious balance between energy development and resource management cannot be met.

Transparency

The days of closed door bargaining sessions between a commercial user and agency officials should be at an end. As mentioned previously, the trust of the public has been severely eroded and cannot be improved unless the public and other interested parties know what's going on. Transparency is essential and must be followed; therefore, some actions are recommended.

A clear, transparent federal planning process and decision-making process that follows administrative law and policy is essential. Federal land managers must make decisions on energy development following processes that allow for adequate public review. Decisions made by public officials and the processes leading to them must be part of the record and be made available. Laws, policies and proper procedures must be followed at all times.

Sufficient information, including maps and other data, about proposed energy leasing and development must be provided to the public to allow for understanding and reasonable comments. And, the time provided for public comments must be commensurate with the complexity of the proposals. Meetings, with all parties, related to energy development on public land need to be recorded and should be part of the public record. One should not have to go through what has become a burdensome and time-consuming, Freedom of Information Act request for this information. We have existing administrative processes and laws that require all this, but they too often are violated.

Science

Science is the foundation of all resource management, in the past, present and future. Recently there have been concerted efforts to marginalize scientific findings and to focus on the small amount of uncertainty that is inherent in all scientific process. The fact is that there is much known about how fish and wildlife are impacted from human activities. That information needs to be used to address and solve some of the problems we face today and will face tomorrow. The benefit of using science relies on professional judgment and discretion, not on arguing whether research is relevant because it was done 200 miles (321.8

km) away. Science has to have a place and, therefore, the following is recommended.

Science must be used to inform all fish and wildlife management decisions, particularly when specific research has been conducted on the impacts of energy development. Ignoring or discounting this research will not cause the impacts to go away but could prevent addressing the problem in the future. Adaptive management needs to be more than just a platitude but a process based upon monitoring data so that a systemic approach to adjusting development can be made when other natural resources are affected.

Mitigation of impacts is essential, but it is important to remember that we are not going to mitigate our way out of the enormous impacts that are expected in the next 30 years. Mitigation is not a one-time commitment of actions or funds but a process that needs to be based on science. Mitigation must be planned by using rigorous methods and an adaptive-management process that addresses changing conditions. Off-site mitigation is essential when on-site mitigation cannot be used or is not appropriate to offset resource values impacted at the project location. We must always remember that mitigation is not a substitute for proper fish and wildlife management.

Finally, we propose identification and recognition of unique or special places that are too valuable to be developed at this time. There are certain special and unique places in the West that should be either entirely off-limits or extremely limited to oil and gas drilling. The federal government should set aside these important areas to ensure that valuable fish and wildlife resources and these special habitats are appropriately protected. Such places can be identified from a fish and wildlife habitat standpoint by using available science and data on population numbers and other factors. The recently completed, state-comprehensive, wildlife management plans can also provide guidance. As far as we can tell, they are not making any more of these places.

The extent of the near-future energy development on public land in the Rocky Mountains is extensive (Figure 1). Some estimates have over 100,000 wells being drilled in the next 10 years. Even with the best, most comprehensive planning and implementation of the development of these fields, the impacts on the fish and wildlife resources are going to be tremendous. The landscape as we have known it will be forever changed and what were once the wide open spaces of the Rocky Mountains will have the influence of energy development felt across the region. History and recent experience have shown us that the current way of doing business will not be adequate if we are to conserve our precious wildlands and wildlife, a new approach is needed. Federal agencies, state agencies, industry, hunters and anglers, the public, and all other stakeholders need to work together to address the issues. State wildlife agencies and resource managers need to properly prepare for what's coming so that we are not continuing to try and put the pieces back together again.

We owe it to our children and future generations to make sure the development is done right. In doing it right, we can be proud of the conservation legacy we will have left. The future is ours. Let's make it happen.

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Renewable Energy Resources and Wildlife: Impacts and Opportunities

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Introduction

Fossil fuels currently provide more than 85 percent of all energy consumed worldwide. And, nearly two-thirds of electricity and virtually all transportation fuels used in the United States are derived from fossil fuels (Environmental Information Administration 2007, U.S. Department of Energy 2007a). Conventional power generation from fossil fuels has a host of well documented environmental impacts, the most notable being emissions of carbon dioxide (CO_2). Many climate-change models predict that increased atmospheric CO_2 concentrations could pressure flora and fauna to adapt to changing environmental conditions (Inkley et al. 2004). With rising costs and long-term environmental impacts from use of fossil fuels, the world increasingly is looking for alternatives to supply electricity and fuel for transportation (McLeish 2002, Bernstein et al. 2006, Kunz et al. 2007). Alternatives frequently considered are nuclear, coal with CO_2 sequestration (i.e., capture and storage of CO_2 and other greenhouse gases that otherwise would be emitted into the atmosphere), conservation and renewable energy.

Wind energy and production of biomass (e.g., agricultural crops, animal wastes, wood chips) are two fast growing renewable energy sources under development, in part due to recent technological advances and cost-competitiveness with conventional sources (Bernstein et al. 2006). Wind turbines are able to generate electricity without many of the negative, long-term environmental impacts associated with other energy sources (e.g., greenhouse gas emissions). The National Energy Modeling System (NEMS) model projects that installed capacity of wind turbines will grow to about 100,000 megawatts (100 billion j/s) over the next 20 years, but some wind experts project that wind energy could ultimately contribute 20 percent of the United States' electrical energy needs, as Denmark has already achieved (National Economic Council 2006). This would amount to more than three times the installed capacity projected by the NEMS model. Some energy analysts suggest, however, that while wind energy is growing exponentially in the United States, fossil-fuel-burning power plants also continue to grow exponentially, which raises questions about reduction of greenhouse gas emissions over time. Indeed, the proportion of fossil fuels in the world's energy mix, currently at 86 percent, is not projected to change by 2030 (Environmental Information Administration 2007).

Generally, biomass can generate energy in two forms: it can be burned directly for heat and the production of electricity or can be converted into solid, gaseous and liquid fuels using conversion technologies (Hall 1997). Biofuels produced from renewable feedstock are primarily used for transportation vehicles and include ethanol and biodiesel (Schnepf 2006); the primary source of ethanol in the United States is corn (Bernstein et al. 2006, Schnepf 2006). Corn-based ethanol production has increased dramatically in recent years and is expected to grow from nearly 4.5 billion gallons (17 million l) produced by the beginning of 2006 to 6.7 billion gallons (25.4 billion l) in 2007, a 49-percent increase in just one year (Schnepf 2006). Cellulose-based ethanol, produced from cellulose in plant-cell walls, is chemically identical to corn- or sugar-based ethanol, but it differs in the processing required to break cellulose down to sugars suitable for fermentation (U.S. Department of Energy 2007b). Cellulose-based ethanol can be derived from agricultural residues, such as wheat straw, from forestry residues, such as sawdust or logging slash, from municipal solid waste, from pulp and paper mill sludge, from other cellulose biomass feed, or from stocks, such as switchgrass (*Panicum virgatum*) (U.S. Department of Energy 2007b). The role of biomass fuel production is anticipated to expand considerably in future years. Congress recently established a technical advisory committee that envisions a 30-percent replacement of current petroleum consumption in the United States with biofuels by 2030 (Perlack et al. 2005).

Wind and biomass energy production offer more environmental benefits than other energy sources (e.g., less air and water pollution, less greenhouse gas emissions), potentially benefiting biodiversity. However, wind and biomass energy development is not environmentally neutral. Here, we present a synthesis of known and potential impacts of wind and biomass energy development on wildlife and, based on the current state of knowledge, offer suggestions for advancing these energy sources while avoiding, minimizing and mitigating impacts on wildlife.

Wind Energy and Wildlife

We discuss impacts of wind-energy development on wildlife resulting from collision fatality and habitat-related impacts. Much of our discussion on impacts of wind energy on wildlife comes from a recent review of the subject by The Wildlife Society (Arnett et al. 2007).

Wildlife Collision Fatality

Birds. Although fatalities of many bird species have been documented at onshore wind facilities, raptors have received the most attention (e.g., Orloff and Flannery 1992, Erickson et al. 2001). Initial observations of dead raptors at the Altamont Pass Wind Resource Areas (APWRA) (Orloff and Flannery 1992) triggered concern from regulatory agencies, environmental groups, wildlife resource agencies, and wind and electric utility industries about possible impacts to birds from wind-energy development.

Early studies on fatalities at wind facilities occurred in California because most wind power was produced by three California facilities (APWRA, San Gorgonio and Tehachapi) using small early generation turbines ranging from 40 to 300 kilowatts (40,000–300,000 j/s), with the most common turbine rated at approximately 100 kilowatts (100,000 j/s). Contemporary wind-power developers use a much different turbine than the older facilities discussed above. In addition, many facilities have been constructed in areas with different land use than existing facilities in California. Results from 14 avian fatality studies, where surveys were conducted using a systematic survey process for a minimum of 1 year and scavenging and searcher efficiency biases were incorporated into estimates, report a mean fatality rate of 0.04 raptors per megawatts per year (Table 1). Regional fatalities of raptors per megawatts per year were similar, ranging from 0.07 in the Pacific Northwest region to 0.02 in the East (Table 1). With the exception of two eastern facilities in forested habitats, the land use and

Table 1. Avian fatality rates from new generation wind facilities where standardized fatality monitoring was conducted.

	Project size		Turbine characteristics			Raptor fatality rates		All bird fatality rates		
Wind project	Number turbines	Mega-watts	Rotor diameter	rotor-swept area	Per megawatt	Per turbine	Per megawatt	Per turbine	Per megawatt	Source
Pacific Northwest										
Stateline, Oregon/Washington	454	300	47	1735	0.66	0.06	0.09	1.93	2.92	Erickson et al. 2004
Vansycle, Oregon	38	25	47	1735	0.66	0.00	0.00	0.63	0.95	Erickson et al. 2000
Combine Hills, Oregon	41	41	61	2961	1.00	0.00	0.00	2.56	2.56	Young et al. 2005
Klondike, Oregon	16	24	65	3318	1.50	0.00	0.00	1.42	0.95	Johnson et al. 2003b
Nine Canyon, Washington	37	48	62	3019	1.30	0.07	0.05	3.59	2.76	Erickson et al. 2003
Overall	586	438	56	2554	1.02	0.03	0.03	2.03	2.03	
Weighted averages	586	438	49	1945	0.808	0.05	0.07	1.98	2.65	
Rocky Mountain										
Foote Creek Rim, Wyoming phase I	72	43	42	1385	0.60	0.03	0.05	1.50	2.50	Young et al. 2003
Foote Creek Rim, Wyoming phase II	33	25	44	1521	0.75	0.04	0.06	1.49	1.99	Young et al. 2003
Totals or simple averages	105	68	43	1453	0.675	0.04	0.05	1.50	2.24	
Totals or weighted averages	105	68	43	1428	0.655	0.03	0.05	1.50	2.31	
Upper Midwest										
Wisconsin	31	20	47	1735	0.66	0.00	0.00	1.30	1.97	Howe et al. 2002
Buffalo Ridge phase I	73	22	33	855	0.30	0.01	0.04	0.98	3.27	Johnson et al. 2002
Buffalo Ridge phase II	143	107	48	1810	0.75	0.00	0.00	2.27	3.03	Johnson et al. 2002
Buffalo Ridge Minnesota phase III	139	104	48	1810	0.75	0.00	0.00	4.45	5.93	Johnson et al. 2002
Top of Iowa	89	80	52	2124	0.90	0.01	0.01	1.29	1.44	Jain 2005
Totals or simple averages	475	333.96	46	1667	0.67	0.00	0.01	2.06	3.13	
Totals or weighted averages	475	333.96	46	1717	0.53	0.00	0.00	2.22	3.50	

Table 1 (continued). Avian fatality rates from new generation wind facilities where standardized fatality monitoring was conducted.

Wind project	Project size: Number turbines	Project size: Mega-watts	Turbine characteristics: Rotor diameter	Turbine characteristics: rotor-swept area	Turbine characteristics: Per megawatt	Raptor fatality rates: Per turbine	Raptor fatality rates: Per megawatt	All bird fatality rates: Per turbine	All bird fatality rates: Per megawatt	Source
Paast										
Buffalo Mountain, Tennessee	3	2	47	1735	0.66	0.00	0.00	7.70	11.67	Nicholson 2003
Mountaineer, West Virginia	44	66	72	4072	1.50	0.03	0.02	4.04	2.69	Kerns and Kerlinger 2004
Totals or simple averages	47	68	60	2903	1.08	0.02	0.01	5.87	7.18	
Overall (weighted average)	47	68	70	3922	1.45	0.03	0.02	4.27	2.96	

land cover in these studies were agricultural, Conservation Reserve Program (CRP) land, or shortgrass prairie.

Factors commonly associated with raptor collision risk are turbine type, turbine location and bird abundance; fatality rates for older turbines are unadjusted for searcher detection and scavenger removal, while rates from the 17 sites with newer generation turbines are adjusted for these biases (Figure 1). Three of the four studies at older generation sites report higher fatality rates than newer, larger turbine sites, even without bias adjustment. It is noteworthy that even though reported raptor fatalities are higher on average at older facilities, there is a rather dramatic difference among older facilities. Because the three facilities have similar technology, this difference may be influenced by other factors, likely raptor abundance (Figure 2). Additionally, it appears that siting of individual turbines may relate to risk of collision and raptor fatalities (e.g., Orloff and Flannery 1992, Young et al. 2003a, Smallwood and Thelander 2004) and turbine siting decisions during construction of a facility are important.

Fatalities of passerines from turbine blade strikes likely is not

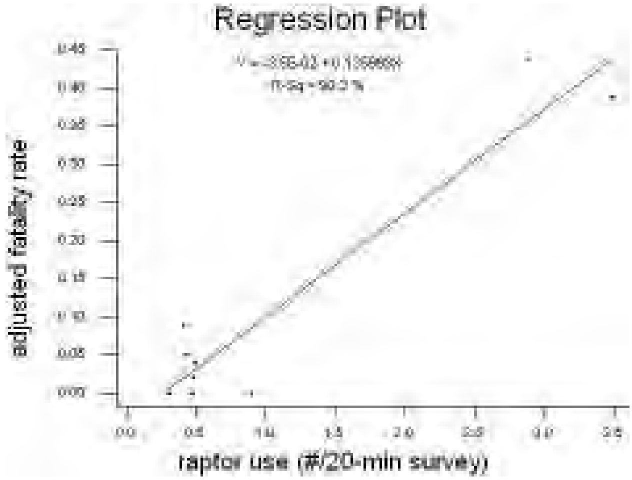

Figure 01. Fatality rates, adjusted for searcher efficiency and carcass removal bias, for raptors at four older generation turbines in California—Altamont Pass, Tehachapi Pass, Montezuma Hills and San Gorgonio (Howell 1997, Anderson et al. 2004, 2005,Smallwood and Thelander 2004)—and fatality rates, adjusted for searcher efficiency and carcass removal at 17 wind projects (Erickson et al. 2000, 2003, 2004; Howe et al. 2002; Johnson et al. 2002; Johnson et al. 2003b; Nicholson 2003; Young et al. 2003; Kerns and Kerlinger 2004; Young et al. 2005; Jain 2005) with newer generation turbines.

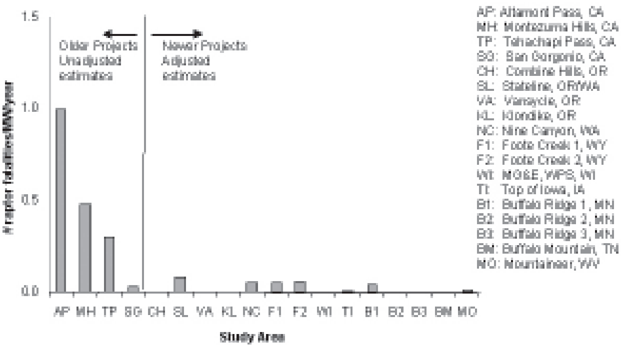

Figure 02. Relationship between raptor use and fatality at 12 facilities in North America (W. P. Erickson, personal communication)

significant at the population level (Erickson et al. 2001, Strickland et al. 2001). Erickson et al. (2001) reported that 78 percent of carcasses found at wind plants outside of California were passerines. And, the balance of fatalities was waterfowl (5.3 percent), waterbirds (3.3 percent), shorebirds (0.7 percent), diurnal raptors (2.7 percent), owls (0.5 percent), gallinaceous (4.0 percent) and others (2.7 percent)—protected under the Migratory Bird Treaty Act (MBTA) or state law—and unprotected birds were 3.3 percent. Estimates of bird fatality vary considerably among studies conducted at new-generation facilities (Table 1), but fatalities per turbine and per megawatts per year are similar for all regions represented by these studies. With the exception of raptors, most studies report that fatalities occur throughout the facility with no particular relationship to site characteristics. Approximately half the reported fatalities at new-generation, wind-power facilities are nocturnally migrating birds, primarily passerines.

Perhaps the most difficult task in interpreting fatalities is the estimation of exposure. For example, corvids are a common group of birds observed flying near the rotor-swept area of turbines (e.g., Erickson et al. 2004, Smallwood and Thelander 2004) yet are seldom found during carcass surveys. Clearly, the role of abundance relative to exposure of birds to collisions with wind turbines is modified by behavior within and among species and likely varies across locations.

Inclement weather has been identified as a contributing factor in avian collisions with other obstacles, including power lines, buildings and communication towers (e.g., Manville 2005). Johnson et al. (2002) found that most bird fatalities discovered at the Buffalo Ridge wind facility may have occurred in association with inclement weather, such as thunderstorms, fog and gusty winds. Federal Aviation Administration (FAA) lighting has been associated with an increase in avian fatalities at communications towers and other tall structures (e.g., Manville 2005), yet there is no evidence suggesting a lighting effect for passerine fatalities associated with wind power (Erickson et al. 2001).

Fatality studies almost universally report very few fatalities of waterfowl, shorebirds or gallinaceous birds, as previously noted by Erickson et al. (2001). In a review of five wind facilities, J. Fernley, J., S. Lowther, and P. Whitfield (unpublished report 2006) reported that (1) collision of medium to large species of geese with wind turbines is an extremely rare event (unadjusted rates of 0 to 4 per year for the 5 sites reviewed), (2) there appears to be no relationship between observed collision fatality and number of goose flights per year and (3) geese appear to be adept at avoiding wind turbines.

Bats. Recent surveys have reported large numbers of bat fatalities at some wind-energy facilities, especially in the eastern United States (e.g., Fiedler 2004, Kerns and Kerlinger 2004, Arnett 2005) and, more recently, in Canada (Brown and Hamilton, unpublished report 2006) and Oklahoma (Piorkowski 2006). Although bats collide with other tall anthropogenic structures, the frequency and number of fatalities reported is much lower than those for bat fatalities observed at wind turbines. Several plausible hypotheses relating to possible sources of attraction, to density and distribution of prey, and to sensory failure (e.g., echolocation), for example, have been proposed to explain why bats are killed by wind turbines (Arnett 2005, Kunz et al. 2007).

Estimates of bat fatalities from wind facilities in North America range from 0.2 to 53.3 bats per megawatt per year (Johnson 2005, Kunz et al. 2007). These estimates vary due, in part, to region of study, habitat conditions, sampling interval and bias corrections used to adjust estimates. Currently, two studies on forested ridges in the eastern United States at Mountaineer, West Virginia, and at Buffalo Mountain, Tennessee, and one study from open prairie habitat in southern Alberta have documented the highest fatalities of bats reported in North America (Kunz et al. 2007) and are higher than those reported from European studies (Dürr and Bach 2004, Brinkmann 2006). Eleven of the forty-five species of bats occurring in the United States and Canada have been among fatalities reported at wind facilities (Johnson 2005), and 10 species of bats have been reported killed by turbines in Europe (Dürr and Bach 2004). Bat fatalities appear heavily skewed to migratory tree roosting species that include the hoary bat (*Lasiurus cinereus*), eastern red bat (*Lasiurus borealis*) and silver-haired bats (*Lasionycteris noctivagans*; Johnson 2005, Kunz et al. 2007). In Europe, migratory species also dominate fatalities (Dürr and Bach 2004). No studies have been reported from wooded ridges in the western United States or in the Southwest (e.g., Arizona, Texas), where different species of bats may be more susceptible (e.g., Mexican free-tailed bats [*Tadarida brasiliensis*]). The only two investigations at wind facilities within the range of the Mexican free-tailed bat report high proportions of fatalities of that species (31.4 and 85.6 percent in California [Kerlinger et al. 2006] and Oklahoma [Piorkowski 2006], respectively). To date, no fatalities of a threatened or endangered species of bat (e.g., Indiana bat [*Myotis sodalis*]) have been found at existing wind facilities.

Bat fatalities appear to be higher during late summer and early fall when bats typically begin autumn migration (Griffin 1970, Cryan 2003, Fleming and Eby 2003); although, fatalities during spring have been reported (Fielder 2004). Migratory tree bats may follow different migration routes in the spring and fall (Cryan 2003), and behavioral differences between migrating bats in the spring and fall also may be related to fatality patterns (Johnson 2005). Kerns et al. (2005) found that timing of bat fatalities over a 6-week period at two sites located in Pennsylvania and West Virginia were highly correlated. These findings suggest broader landscape, perhaps regional, patterns of activity and migratory movement dictated by weather and prey abundance and availability.

Bats do not appear to strike the turbine mast, nonmoving blades, or meteorological towers (Arnett 2005). Bats have been observed with thermal imaging cameras attempting to and actually landing on stationary blades and investigating turbine masts (Horn et al. 2007), and they may be attracted to turbines. Activity and fatality of bats do not appear to be influenced by FAA lighting (Arnett 2005), and higher fatalities have been reported on nights with relatively low wind speed (Fiedler 2004; Kerns et al. 2005; Reynolds 2006; Horn et al. 2007). Studies in Europe also corroborate these findings (Brinkman 2006). These observed patterns offer promise toward predicting periods of high fatality and warrant further investigation to determine if risk can be reduced by curtailing turbine operation during high-risk periods.

Conclusions

Raptor fatalities are relatively low at most facilities studied, with the exception of APWRA, and are lower at new-generation wind facilities. Turbine characteristics, turbine siting, and bird behavior and abundance appear to be important factors determining raptor fatalities at wind-power facilities. Nevertheless, the number of studies of new-generation wind facilities is relatively small, and most have occurred in areas with low raptor density. In comparison with other sources, wind turbines appear to be a minor source of passerine fatalities, particularly for migrants, at current levels of development. Thus, thorough site evaluation during the site-selection process and site-development plans that consider bird use and bird habitats at the site should allow development that reduces risk to raptors and other birds. As turbine size increases and development expands into new areas with higher densities of passerines, the risk to passerines could increase. Therefore, it should continue to be evaluated, particularly in regard to migration during inclement weather.

While bat fatalities have been recorded at almost every wind facility where postconstruction surveys have been conducted, efforts to specifically estimate bat fatality rates have been rare. Bat fatalities vary by region and at some locations are sufficient to raise concern about potential population effects as many species of bats are believed to be in decline (Pierson 1998). Migratory tree roosting bats killed most frequently by turbines are not protected under federal law. Bats usually are protected under state laws pertaining to nongame animals, but most states do not enforce take of bats. Bats are long-lived and have exceptionally low reproductive rates (Kunz 1982). And, population growth is relatively slow, and their ability to recover from population declines is limited, thereby increasing the risk of local extinctions (Barclay and Harder 2003, Racey and Entwistle 2000, 2003). Although population impacts are unknown, given the level of fatalities at some wind facilities, biologically significant additive mortality must be considered for some species as wind power development expands and fatalities accumulate (Kunz et al. 2007).

Estimating exposure, particularly for migrating passerines and bats, is problematic. Radar studies to date have primarily been conducted preconstruction, in an effort to estimate potential impacts. Past studies using radar could not distinguish bats from birds, but modern equipment and software has advanced enough to accommodate this important information need. Those studies, if run concurrently with fatality studies, would help address the relationship of density and location of turbines with risk to nocturnal migrant birds and bats as a group. Model-based analysis of risk also may be helpful, but empirical data generally are lacking. Evidence suggests that risk to birds can be reduced through selection of development sites with reduced densities of birds at risk, particularly raptors. More research is needed on fatalities in regions with existing wind facilities that have been poorly studied (e.g., eastern forested ridges, the Southwest) and regions with new developments (e.g., coastal areas).

Wildlife Habitat Impacts

Little is known about habitat impacts from the development of wind facilities. Wildlife habitat impacts can be considered direct (e.g., vegetation removal or modification and physical landscape alteration, direct habitat loss) or indirect (e.g., behavioral response to wind facilities, hereinafter referred to as displacement or attraction). Impacts may be short-term (e.g., during construction and continuing through the period required for habitat restoration) and long-term (e.g., surface disturbance and chronic displacement effects for the life of the project). Duration of habitat impacts vary depending on the species of interest, the area impacted by the wind facility (including number of turbines), turbine size, vegetation and topography of the site, and climatic conditions in a particular region. Road construction, turbine pad construction, construction staging areas, installation of electrical substations, housing for control facilities and transmission lines connecting the wind facility to the power grid also are potential sources of negative habitat impacts. Presence of wind turbines can alter the landscape to change habitat-use patterns of wildlife, including avoidance or displacement of wildlife from areas near turbines.

Wind facilities can influence relatively large areas (e.g., several square kilometers) but have relatively low direct impact. The U.S. Bureau of Land Management programmatic environmental impact statement (U.S. Bureau of Land Management 2005) estimated that, on average, the permanent footprint of a facility is about 5 percent of the site, including turbines, roads, buildings and transmission lines. Some direct impacts are short-term, depending on the length of time required to reclaim a site, which varies depending on the climate, vegetation and reclamation objective. Ultimately the greatest impact from habitat modification may be reduced effectiveness due to displacement of wildlife. The degree to which this displacement results in impacts depends on the abundance behavioral response of individual species to turbines and human activity within the wind facility.

Relatively little work has been done to determine the effect of wind facilities on use of habitat by wildlife. Leddy et al. (1999) found that densities of birds along transects increased with distance from turbine strings with densities markedly lower at fewer than or equal to 80 meters (87.5 yds). Reduced avian use near turbines was attributed to avoidance of turbine noise and maintenance activities. And, the presence of access roads and large gravel pads surrounding turbines reduced habitat effectiveness (Leddy 1996, Johnson et al. 2000a). Other studies (e.g., Johnson et al. 2000b, Erickson et al. 2004) suggest that abundance of shorebirds, waterfowl, gallinaceous birds, woodpeckers and several groups of passerines is significantly lower at survey plots with turbines compared to those without turbines (Johnson et al. 2000b); although, grassland bird densities were reduced only within 100 meters (109.4 yds) of a turbine. Prairie grouse, which exhibit high site fidelity and require extensive grasslands, sagebrush and open horizons (Giesen 1998, Fuhlendorf et al. 2002), may be especially vulnerable to wind-energy development. Several studies indicate that prairie grouse strongly avoid certain anthropogenic features (e.g., roads, buildings, power lines), resulting in sizable areas of habitat rendered less suitable (e.g., Robel et al. 2004). The actual impacts of wind facilities on prairie grouse remain unknown but are currently under investigation.

Research on habitat fragmentation has demonstrated that several species of grassland birds are area-sensitive, prefer larger patches of grassland and tend to avoid trees. Area-sensitivity in grassland birds was reviewed by Johnson (2001); 13 species have been reported to favor larger patches of grassland in one or more studies. Other studies have reported an avoidance of trees by certain grassland bird species. Based on available information, it is probable that some disturbance or displacement effects may occur to grassland or shrub-steppe avian species occupying a site. The extent of these effects and their significance is unknown and hard to predict but could range from zero to several hundred meters.

While one study reported avoidance of wind facilities by raptors (Usgaard et al. 1997), other studies have found no impact on nesting raptors in California (Howell and Noone 1992), Wyoming (Johnson et al. 2000a) and Oregon (Johnson et al. 2003a). In a survey to evaluate changes in nesting territory occupancy, Hunt and Hunt (2006) found that, within a sample of 58 territories in the APWRA and surrounding area, all territories occupied by eagle pairs in 2000 were also occupied in 2005.

Wildlife response to habitat modification will be species specific. For example, forest-dependent species may be negatively impacted by openings in the forest, while edge-dependent species may benefit. For example, bats may actually benefit from modifications to forest structure and the landscape resulting from construction of a wind facility. Bats are known to forage readily in small clearings (Grindal and Brigham 1998, Hayes 2003, Hayes and Loeb 2007) like those around turbines. Forest-edge effects created by clearing also may be favorable to insect congregations and to a bat's ability to capture them in flight (Verboom and Spoelstra 1999). However, the removal of roost trees would be detrimental to bats. Disturbance to tree- and crevice-roosting bats from wind turbines is not known.

During construction at a wind facility, it is expected that large mammals will be temporarily displaced from the site due to the influx of humans, the heavy construction equipment and the associated disturbance (e.g., blasting). Roads associated with oil and gas development fragment otherwise continuous patches of suitable habitat, effectively decreasing the amount of winter range, for example, available for ungulates (e.g., Van Dyke and Klein 1996, Sawyer et al. 2006). However, these impacts depend on the level and duration of activity associated with development, and studies at wind facilities in Wyoming and Oklahoma found no evidence that turbines had significant impacts on use of the surrounding area by pronghorn (*Antelocapra americanus*) and elk (*Cervus elaphis*), respectively (Johnson et al. 2000, Walter et al. 2004).

Conclusions

Often overlooked are impacts resulting from loss of habitat for wildlife due to construction, the footprint of the facility and increased human access. While the footprint of a wind facility is small relative to the absolute area of a wind energy development, the greatest impact to wildlife from habitat modification may be due to displacement of wildlife in proximity to turbines and to fragmentation of habitat for several species of wildlife; although, these impacts have not been empirically measured for most species. These impacts could be negative and perhaps biologically significant if facilities are placed in the wrong locations, particularly if the affected area is considered a critical resource whose loss would limit populations. Future development of transmission lines to facilitate wind generation will exacerbate the impacts of wind energy development on wildlife.

Habitat impacts could be avoided by careful placement of wind facilities. For example, wind energy development in agricultural areas may have fewer impacts because these areas tend to be less important to most species of wildlife. Habitat impacts also can be mitigated. For example, much of the native prairie in the Midwest has been lost to agriculture or has been degraded as wildlife habitat by grazing of domestic livestock. On private lands, native habitats could be protected from further development as long as revenue for the landowner can be maintained, perhaps by supporting a wind facility, while degraded habitats could be improved through cooperative ventures between landowners and wind energy developers.

Offshore Wind Energy Development and Wildlife

Interest in establishing wind-generating facilities along portions of the Atlantic Coast, Lower Gulf Coast (LGC) of Texas, and the Great Lakes has increased in recent years because wind speeds that make a wind-generating facility economically viable occur during at least part of every day. Also, the terrain offshore (coastal shelf) in these areas is shallow for a relatively long distance from shore, allowing placement of towers into the bottom substrate. No facilities have been constructed offshore in North America and all existing information on wildlife impacts from offshore wind development come from European studies that have been summarized by Winkelman (1994), Exo et al. (2003) and Morrison (2006). These authors conclude that offshore wind turbines may affect birds as follows: (1) risk of collision, (2) short-term habitat loss during construction, (3) long-term habitat loss due to disturbance by turbines, including disturbances from boating activities in connection with maintenance, (4) formation of barriers on migration routes and (5) disconnection of ecological units, such as between resting and feeding sites for aquatic birds.

Collisions of birds with wind turbines at offshore wind facilities has not been measured but is thought to be a minor problem in Europe (Winkelman 1990). Winkelman (1994) summarized findings on disturbance and effect of turbines on flight behavior and found that up to a 95-percent reduction in bird numbers has been shown to occur between 250 and 500 m (273.4–546.8 yds) from the nearest turbines. While further studies are needed to better define risks, precautionary measures to reduce and mitigate such risks exist. For example, careful siting of wind facilities away from bird migratory paths, bird habitats and large concentrations of species at higher risk is possible.

Three migratory bird corridors converge immediately north of Corpus Christi, Texas, funneling tens of millions of birds along the LGC to wintering grounds in southern Texas and Latin America. In light of the absence of natural islands or other terrestrial habitats in the Gulf of Mexico, it seems inevitable that the installation of thousands of artificial islands in the northern Gulf must affect migrants in some fashion. For example, Russell (2005) found that migrants would sometimes arrive at certain oil platforms shortly after nightfall and proceed to circle those platforms for variable periods ranging from minutes to hours. This behavior, if repeated around offshore wind turbines, could increase risk of collision. Russell (2005) concluded that this circling behavior was related to attraction of birds to platform lights. Concern also exists regarding loss of important habitat due to avoidance of offshore wind facilities by birds. There are many important bird areas—locations that harbor a high number of birds or species of special concern (e.g., federally designated birds of conservation concern and federally listed threatened or endangered birds)—along the eastern seaboard.

Although seasonal activities of birds generally are known in areas where birds migrate through or concentrate, the specific timing, routes and altitudes of movement within and between resting and foraging areas and altitudes that migrants use are poorly known. Such information is needed to conduct assessments of the potential risk to birds from offshore wind development. Consequently, the impacts of wind facilities located on the LGC and Atlantic Coast could be different from each other and also different than terrestrial sites throughout the United States simply because the behavior, abundance and diversity of birds that migrate or reside on any wind-generating facility may be much different than inland facilities.

Conclusions

Offshore wind facilities have been established throughout Europe, but few studies have been conducted to determine direct impacts on animals. A major concern with offshore developments has been loss of habitat from avoidance of turbines and the impact that boat and helicopter traffic to and from the wind facility may cause with regard to animal behavior and movements. Although little is known about such effects, resident seabirds and rafting (resting) waterbirds appear to be less at risk than migrating birds, as they may adapt better to offshore wind facilities. The effects on marine mammals are currently unknown but warrant study and clarification. It is important that the actual impact of the first few offshore wind facilities, if built, be evaluated both for fatalities and displacement effects. However, there is reason to believe that areas with high concentrations of birds would present more risk than areas with lower densities of birds. The potential impact of wind-power development on bats is unknown; although, anecdotal accounts of bats occurring offshore suggest impacts are possible.

Biomass Energy Production and Wildlife

Potential impacts from the production of biomass energy sources were recently summarized by Bies (2006). These impacts include, but are not limited to, loss of habitat from land-use conversion, increased fragmentation, changes in structural complexity, increased demand on water supplies and potential increases in pollution from increased use of fertilizer.

Land Conversion

The potential for loss of habitat could result from converting (1) idle lands in the CRP, or other set asides, back to cropland (2) traditional crops to other biomass plants (e.g., switchgrass, hybrid poplar [*Populus* spp.]) and (3) native habitat to cropland or monocultures of biomass plants. Currently, nearly 36.4 million acres (14.7 million ha) are enrolled in the CRP program; the importance of these lands to a wide range of wildlife is well documented (e.g., Dunn et al. 1993, Best et al. 1997). Increasing corn ethanol production will require more land than currently is in production if other economic tradeoffs are to be balanced; expansion has limits before impinging on food supply, for example (Bernstein et al. 2006). The Biofuels Journal (2006) reported that 55 new ethanol production facilities are currently under construction in 17 states that will produce an estimated 3.7 billion gallons (14.7 billion l) of corn ethanol per year. Assuming that each bushel of corn produces 2.7 gallons (10.2 l) of ethanol (Schnepf 2006) and using the 2006 national average of 149 bushels of corn harvested per acre (U.S. Department of Agriculture 2007), approximately 9.3 million acres (3.8 million ha) of corn would be required to produce enough corn just for these new facilities alone. Based on this example, it seems plausible to expect major changes in land-use practices, including conversion of CRP lands into corn production to meet demands for ethanol.

Brown et al. (2000) suggested that biomass production on a scale permitting significant substitution of fossil fuels cannot be accomplished on marginal lands alone and will require large areas of prime agricultural land and the substitution of biomass crops for crops currently grown in some regions. Converting land from traditional crop production to mixed grasses or monocultures of switchgrass or hybrid poplars could result in positive or negative impacts on wildlife, depending on the type of biomass crop used, on what traditional crop is being replaced and on land use and habitat conditions prior to conversion. Converting croplands to a highly diverse mixture of native prairie plant species should provide better habitat for many species of wildlife. In Minnesota, degraded agricultural land planted with a diverse mixture of prairie grasses and other flowering plants produced 238 percent more bioenergy on average, than the same land planted with various single prairie plant species, including monocultures of switchgrass, potentially providing both energy and wildlife benefits, depending on timing and intensity of management. Bies (2006) suggested that frequency and timing of mowing grass fields would influence impacts on wildlife, particularly nesting and wintering birds, and that strip harvesting might reduce impacts and provide habitat for a diversity of species. By leaving some switchgrass or mixed-grass fields unharvested and by partially mowing others, a mosaic of grassland habitats could be managed with different physical characteristics to meet needs of diverse species of birds (Horn and Koford 2000).

In some areas, monocultures of switchgrass or hybrid poplars may benefit some species of wildlife (Bies 2006). Christian et al. (1997) reported few negative site-level effects on songbirds or small mammals resulting from replacement of rowcrop or small-grain fields with hybrid poplar, but they noted that their study did not address fragmentation or other landscape-level issues. Also, Christian et al. (1997) reported that birds appeared to be more strongly attracted to poplar plantations in agricultural regions than in forested landscapes. Moser et al. (2002) found that 1- to 3-year-old hybrid poplar plantations provide suitable habitat for certain small mammals, probably due to abundant understory vegetation. They suggested that creating habitat heterogeneity by maintaining a diversity of plantation ages within the complex may enhance small-mammal species diversity. Moser and KeithHilpp (2004) suggested that maintaining an older component of interior plantation habitat within a poplar plantation complex will likely create suitable wintering habitat for owls and other species.

Conversion of native habitats into biomass production will result in further loss of habitat and will extend fragmentation of landscapes. Area planted to dryland corn in northeastern Colorado increased from about 20,000 acres (8,093.7 ha) per year prior to 1990 to nearly 220,000 acres in 1999 (Agronomy News 2002). Current research and development of traditional crops requiring little or no irrigation could increase conversion of native habitats once considered unsuitable for agriculture. Converting native habitat to monocultures of switchgrass or a mixture of native grasses would likely have varying impacts on wildlife depending on management actions and intensity (Bies 2006).

Crop residues, sometimes referred to as stover in regard to corn (Sheehan et al. 2004), are left behind after harvest of grain and provide valuable habitat and food for many species of wildlife. Sheehan et al. (2004) reported that under the assumptions of their model that maximized amount of collectible stover, Iowa alone could produce approximately 2.1 billion gallons (7.9 l) per year of stover-derived ethanol. Removal of crop residues can increase soil erosion, reduce soil fertility and moisture, and reduce benefits to wildlife, especially to upland game birds (Bies 2006). The height of remaining stubble following a harvest will have direct impacts on both winter cover and available breeding cover the following spring for resident and migrant wildlife (Rodgers 2002).

Forest Management

Course woody debris (snags, downed logs, logging slash) are critical components of forest structure because they provide numerous ecological functions relating to energy flow, nutrient recycling, hydrological processes and wildlife habitat (Harmon et al. 1986, Carey and Curtis 1996). It has been estimated that forestlands in the contiguous United States could produce 368 million dry tons (333 billion kg) per year of biomass for energy production annually, including 64 million dry tons (58 billion kg) per year of residues from logging and site clearing operations (Perlack et al. 2005), which normally would be left on site and provide ecological functions. Estimates of biomass from forests also include 52 million dry tons (47.2 billion kg) per year of fuelwood harvested from forests and 60 million dry tons (54.4 billion kg) per year of biomass from fuel treatment operations to reduce fire hazard (Perlack et al. 2005). Although Perlack et al.'s (2005) estimates excluded all forestland not currently accessible by roads and all environmentally sensitive areas, changes in forest-management practices and policy to meet projected targets for biomass production could be anticipated. The impacts on wildlife associated with removal of snags and downed wood are well documented in forests throughout North America (e.g., Ohmann et al. 1994, Laudenslayer et al. 2002, Stephens 2004) and continued removal of woody debris for biomass production could negatively impact wildlife. Reducing hazardous fuels to meet ecological restoration objectives could benefit wildlife (Bies 2006), but management should ensure that some coarse, woody debris be retained for wildlife.

Water

In regions requiring irrigation, increasing acreage for producing biomass, especially for crops such as corn, could increase water use, particularly ground water, and could influence meeting wildlife objectives. Increased use of fertilizer may result in water-quality issues (Bernstein et al. 2006) that may influence wildlife as well. In 2005, ethanol plants in the United States consumed nearly 18 billion gallons (68 billion l) of water, and estimates for 2008 approach 30 billion gallons (113 billion l) (Keeney and Muller 2006). Conversion from traditional crops to biomass crops may have an influence on water consumption as well. Switchgrass, for example, generally consumes more water than do traditional crops under all climatic conditions and also reduces runoff (Brown et al. 2000), potentially affecting stream flow. However prairie grasses also may increase water infiltration deeper into the soil profile resulting in net groundwater recharge rather than runoff (Brye et al. 2000).

Conclusions

While the amount of land that might be converted into biomass production remains unknown, potential for extensive habitat loss and fragmentation resulting from conversion and removal of structure is plausible given the projected increase of biomass production (Schnepf 2006). Biomass production can impact wildlife in a number of ways, but most notably due to habitat loss from land-use conversion, to changes in structural complexity and to fragmentation. The impacts of biomass energy production on wildlife and its habitat, while potentially enormous, do not appear to be represented in the dialogue on trade-offs of this fuel source. Indeed, authors discussing environmental impacts associated with biomass production have focused on impacts to soil, water and air quality, cropping practices, and on greenhouse gas emissions (e.g., Hall 1997). We suggest that impacts to wildlife habitat must be analyzed and articulated when modeling the trade-offs of biomass production. Failure to do so may jeopardize wildlife-habitat objectives and may impose substantial impacts to many species of wildlife.

Recommendations

Developing renewable energy sources is important for meeting future energy demands while reducing negative environmental impacts associated with other energy sources. Wind power and biofuels can contribute to renewable energy portfolios, but poorly planned developments will result in cumulative, biologically significant impacts for some species of wildlife. We offer the following eight recommendations to assist managers and decision-makers with meeting the challenges of developing wind and biomass energy responsibly.

Develop federal and state guidelines. Developing consistent guidelines for siting, monitoring and mitigation strategies among states and federal agencies would assist developers with compliance with relevant laws and regulations and would establish standards for conducting site-specific, scientifically sound biological evaluations. Renewable portfolio standards should account for wildlife impacts and inclusion of guidelines in the permit process, and they would strengthen agency participation and implementation of guidelines.

Conduct priority research. Immediate, unbiased research is needed to develop a solid, scientific basis for decision making when siting wind facilities, for evaluating their impacts on wildlife and their habitats and for testing efficacy of solutions. Research priorities have been suggested for addressing wildlife impacts at wind-energy facilities (e.g., Arnett et al. 2007, Kunz et al. 2007, National Research Council 2007). Priority research for impacts of biomass energy development is needed. Establishing research partnerships and cooperative funding mechanisms among diverse stakeholders (e.g., Arnett and Haufler 2003) will be a critical step for implementing priority research.

Avoid siting wind facilities in high-risk areas. Wind-energy developers should follow criteria and standards established within siting guidelines that include avoidance of high-risk sites determined using the best available information. Siting wind facilities in areas where habitat is of poor quality or already is fragmented, for example, will likely result in fewer habitat-related impacts.

Maintain existing conservation programs. Biofuels should be developed in a way that ensures the continued existence of conservation programs, such as CRP. It may become necessary to revisit existing regulations (e.g., state forest practices) to ensure wildlife and fisheries management objectives are being met as biomass energy continues to develop.

Develop new incentive programs. New conservation incentive programs should be developed to address changes in energy policy and demand. For example, the National Wildlife Federation's Biofuels Innovation Program is designed to create a new Farm Bill energy title program to promote sustainable development of biomass energy.

Develop mitigation strategies for integrating biomass production and wildlife habitat objectives. Careful planning and implementation of mitigation measures could reduce impacts of biomass-energy development in many instances. Identifying important habitats and modeling existing and projected landscape patterns would be useful for planning different strategies for mitigation.

Conduct regional assessments and forecast cumulative land-use impacts from energy development. Given projected increases in multiple sources of energy development, including biomass, wind, oil and gas development, future conflicts surrounding land-use, mitigation and conservation strategies should be anticipated. Habitat mitigation options, for example, when developing wind energy in open prairie may be compromised by development of other energy sources. Regional assessments of existing and future land uses and planning of regional conservation strategies among industries, agencies and private landowners could reduce conflicts and could increase options for mitigation.

Improve public education and information exchange. There is an immediate need to insert wildlife impacts, especially regarding biomass energy, into the political dialogue, so all tradeoffs can be considered during decision making. Maintaining relationships with private landowners and communicating the importance of conservation efforts and their benefits will be critical toward developing renewable energy responsibly.

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Session Two.
Future Change in U.S. Forests and Implications for Wildlife

U.S. Land-use Changes Involving Forests: Trends and Projections

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Issue of Rural Land Conversion

Land use over a landscape can be dynamic, and population growth increasingly is resulting in the conversion of forest and agricultural land to residential, commercial and industrial uses, resulting in impacts on forest and farmland habitat for a variety of wildlife species. Less forest area means less wildlife habitat, more impervious surfaces, less air and water filtration, and less area on which to sequester forest carbon to address global climate change. Land-use conversion is a primary determinant of environmental change in terrestrial ecosystems, and projections that are more than 50 million acres (20 million ha) of U.S. forest will be converted to developed uses (e.g., parking lots) over the next 50 years (Alig et al. 2004, Alig and Plantinga 2004) as the population grows by more than 120 million people. Looking beyond simple loss of area, land-use change can also lead to forest fragmentation—the transformation of a contiguous patch of forest into disjunct patches. Forest fragmentation is considered to be a primary threat to terrestrial biodiversity.

To date, more attention has been focused on biophysical aspects of land-use change and forest fragmentation than on socioeconomic and policy matters. If the country is facing the prospect of considerably more conversion of rural land and of forest fragmentation, exploration of socioeconomic and policy factors can aid in developing strategies for addressing negative effects of land-use conversion and in allowing society sufficient lead time to implement land-conservation measures. Although multidisciplinary research has strived to examine the impacts of historical landscape-level changes in wildlife habitat and other ecological conditions, managers and policymakers need enhanced ways to anticipate, describe and plan for these potential impacts.

National Trends

The U.S. Department of Agriculture's (USDA's) National Resource Inventory (NRI) (U.S. Department of Agriculture, Natural Resources Conservation Service 2001) estimates that 5.2 percent of the nonfederal land base in the United States' 48 contiguous states has been developed, i.e., converted to urban and other developed uses such as parking lots. The approximate 5 percent of developed, nonfederal land area is at least 10 times the percentage of developed land in Canada. Total developed area is about 100 million acres (40.5 million ha) for the United States' 48 contiguous states (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). The largest increases in U.S. developed area in recent decades have been in the southeastern region of the country (13 states from Virginia to Texas). Aside from the United States as a whole, this region provides more timber harvest than any other country in the world (Wear and Greis 2002). Between 1982 and 1997, the South had 7 of the 10 states with the largest average annual additions of developed area according to the USDA (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). The top three—Texas, Florida and North Carolina—each added more developed area than did the country's most populous state—California.

A major source of land area data is the NRI (U.S. Department of Agriculture, Natural Resources Conservation Service2001). The NRI estimate of U.S. developed area increased 34 percent between 1982 and 1997, with an acceleration in the 1990s that was more than 50 percent higher than that of the previous measurement. Between 1982 and 1997, developed area as a percentage of the total land area in the 48 contiguous states increased from 3.9 percent to 5.2 percent. Outside urban areas, the NRI also includes developed land occupied by nonfarm, rural, built-up uses, e.g., rural transportation land. The last NRI survey for the period 1992 to 1997 showed a rural land loss of 4 acres (1.6 ha) a minute or approximately 2 million acres (0.8 million ha) per year in the United States (http://www.nrcs.usda.gov/technical/nri). Within that national total is a net loss of 163,000 acres (65,965 ha) of wetland between 1992 and 1997, with conversions to developed uses (248,000 acres or 100,364 ha) representing about half of the total of 506,000 acres (204,775 ha) of converted wetland.

Although 80 percent of the U.S. population now lives in urban areas, a significant amount of low-density development has been part of the expansion in developed area. Between 1982 and 1997, the U.S. population grew by 17 percent, while urbanized area grew by 47 percent. The amount of area per person dedicated to new housing has almost doubled in the last 20 years. Since 1994, 55 percent of the total U.S. developed land has been developed as 10-or-more-acre (4-or-more-ha) housing lots and 90 percent as 1-or-more-acre (0.4-or-more-ha) lots. Eighty percent of new development has been outside existing urban areas (i.e., nonmetropolitan areas) and not used for farm housing (http://www.ers.usda.gov/briefing/landuse/urbanchapter.htm). For the South in particular, the region with a large amount of private timber harvest and substantial biodiversity, the increment in developed area for each new resident has been increasing (Alig et al. 2004), resulting in lower density development. A contributing factor there and in other regions is the decreasing number of people per household (Alig et al. 2003), due to decreasing family size, popularity of second homes, divorce rate and growing number of older adults living in single homes or alone.

Low-density development in rural areas means that development brings more people living closer to remaining forestland. Based on nationwide rural-urban continuum classes (Smith et al. 2004), 13 percent of U.S. forestland is located in major metropolitan counties and 17 percent in intermediate and small metropolitan counties and large towns, together making up 30 percent of all U.S. forestland (Smith et al. 2004). Between 1997 and 2002, the forest area in major metropolitan areas increased by 5 percent, or more than 5 million acres (2 million ha), as U.S. developed area expanded considerably. For the whole United States, more than one-quarter of counties are currently classified as metropolitan. That compares with less than one-tenth 50 years ago.

Conversion of Forests

The long-term historical loss in U.S. forest area since the early 1950s has been due to a combination of factors but, in more recent decades, has been primarily due to conversion to urban and developed uses (Alig et al. 2003, 2004). Deforestation is the conversion of land from forest to nonforest use, and between 1982 and 1997, 22 million acres (9 million ha) were deforested on nonfederal land in the United States. The destination of about half of the converted forest acres was to urban and developed uses, with more than 10 million acres (4 million ha) of U.S. nonfederal forests converted to developed uses, according to

NRI estimates. That is an area larger in size than the combined current forest area of five northeastern states (Connecticut, Delaware, Maryland, New Jersey and Rhode Island). Between 1992 and 1997, the proportion of urban and developed uses as a destination for deforested acres increased to 55 percent of the total deforestation (U.S. Department of Agriculture, Natural Resources Conservation Service 2001), with about 1 million acres (0.4 million ha) converted to developed uses per year. Some forestland is projected to be converted to agricultural uses, but opportunities also exist for substantial afforestation, including more if government farm programs are reduced (Alig et al. 1998).

Net changes (area into forest minus area out of forest) are typically much smaller than total or gross changes (area into forest plus area out of forest). Multiple pathways of land-use change for nonfederal forests for the contiguous 48 states between 1982 and 1997 resulted in gross area changes of about 50 million acres (20 million ha, U.S. Department of Agriculture, Natural Resources Conservation Service 2001). The gross change in forest area was 14 times as large as the net change in forest area. When forests are converted to other uses, any forest area added elsewhere does not necessarily provide the same ecosystem services because acres exiting (e.g., deforestation) or entering (e.g., afforestation) can represent quite different forest conditions. Therefore, distinctions between net and gross changes in forest area are important.

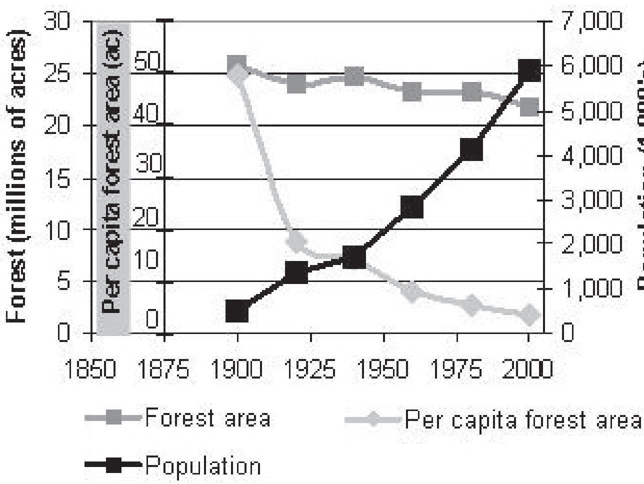
Regional Trends

Between 1990 and 2000, the population of the Pacific Northwest (Oregon and Washington) increased by 21 percent, well above the national average of 13 percent. Over the next 25 years, the region's population is projected to increase by 31 percent from its current level. Along with this increase in population comes a greater demand for land in residential, commercial and industrial uses. As in the past, the increase in urbanized land will occur at the expense of lands currently in forest, agriculture and other uses. The decline in the area of these rural lands reduces the habitat availability for a variety of wildlife species. Although some species can successfully adapt to the habitat offered by an urban environment, other populations will be adversely affected.

We next examine trends in land-use conversions and projections for western Washington, the most populous portion of the Northwest. Land-use changes occur most frequently on private land, driven by changes in population and personal income (e.g., Alig et al. 2004). Over three-quarters of the state's population live west of the crest of the Cascade Range in Washington. People, similar to wildlife, do not locate randomly on the landscape; about three-fifths of the state's population live within 10 miles (6.2 km) of coastline (including the Pacific Ocean and Sounds) (Alig and White 2007). People also migrate; between 1990 and 2000, the average annual net migration of humans into western Washington was approximately 52,000 individuals. In addition to the spatially dynamic distribution of humans, resources owned by people can vary over time and space. The highest household incomes are concentrated around the Seattle-to-Olympia corridor and around Vancouver in Clark County just north of Portland, Oregon. These areas, mostly of western Washington with larger personal incomes, have had a relatively large expansion in developed areas in recent decades.

Western Washington had a 52-percent increase in the area of urban and other developed land between 1982 and 1997, with 40 percent of that increase between 1992 and 1997 (U.S. Department of Agriculture, Natural Resources Conservation Service 2001). An area of particularly rapid development relative to effects on bird abundance and other biodiversity is the I-5 corridor, where housing density is higher than average (Alig and White 2007). Conversion of forestland to developed uses dominated either the amount converted to other uses or that converted to forests from other major land uses (Alig and White 2007). This resulted in a net loss of 313,000 acres (127,000 ha, or 4 percent) of nonfederal forest area in western Washington between 1982 and 1997. Washington has seen its population grow substantially over the last 100 years while forest area has been reduced, leading to a much smaller per-capita forest over time (Figure 1).

Figure 1. Washington population, forest area and per-capita area, 1900 to 2000 (Alig and White 2007).



Land use projections by Alig and White (2007) indicate an 8-percent loss of nonfederal forestland in western Washington between 1997 and 2027. Seventy percent of the land that is projected to transition from forest to other uses is expected to ultimately become urban and other built-up land. Other projections of urban and developed area also indicate a substantial expansion, consistent with the continued growth in population and personal net incomes.

Looking now at the whole West, the region has grown faster than the national average, due in part to amenity-based migration. For example, a growing number of ranchettes and subdivisions has been particularly evident in the Rocky Mountain Region. In migration has included a large number of residents who choose to live in forested settings, resulting in construction of primary or secondary homes in forests or on rangelands. The Rocky Mountain Region also had the highest amount of developed area per additional person between 1992 and 1997 (U.S. Department of Agriculture, Natural Resources Conservation Service 2001, Alig et al. 2004).

Projections

Urban and developed areas are projected by econometric models to continue to grow substantially, in line with the projected U.S. population increase of more than 120 million people over the next 50 years and higher average levels of personal income (e.g., Alig and Plantinga 2004, Alig et al. 2004). Developed land will also increase in other parts of the developed world because of the global increase in population from 6 to 9 billion by 2050. U.S. developed area is projected to increase by 79 percent, raising the developed proportion of the total land base from 5.2 percent to 9.2 percent (Alig et al. 2004).

Total forestland in the United States is projected to decrease on net by approximately 23 million acres (9.3 million ha) between 1997 and 2050 (Alig et al. 2003), examined as part of periodic national assessments of forest- and rangeland ecosystems. This would be a 3-percent reduction. The main reason for the projected reduction in forestland is the conversion to urban and developed uses. Along with that, housing density on remaining forestland is projected to be substantial (Stein et al. 2005), with an increase from either rural or exurban to urban (22 million acres or 9 million ha) or from rural to exurban (22 million acres or 9 million ha). Continued development will also further fragment forests (e.g., Alig et al. 2005, Wear et al. 2004).

Natural Resource Implications for Rural Land Conversions

Land-use change can reduce wildlife habitat, can fragment wildlife habitat and can impede movement of wildlife, among other impacts (Theobald et al. 1997). Conversion of rural land to developed uses by way of deforestation includes urbanization, a leading cause of wildlife-species endangerment in the United States (Marzluff 2006) as well as in Canada (Venter et al. 2006). Conversion of forests can threaten the ability of diverse forestland-based ecosystems to provide a variety of habitats for wildlife, but can provide other goods and environmental services, such as mitigation of global climate change (Alig et al. 2002). An increasing number of structures (e.g., houses) pose increased costs of fire suppression and potential loss of substantial asset values. Long-term assessment of the condition of forests and of the relationships between forest conditions and socioeconomic factors related to deforestation is key when defining policy questions and actions needed to sustain forest-based services.

Development can eradicate or alter the quality of wildlife and fish habitat, which, in turn, can impact the presence of certain wildlife and fish species. Forest fragmentation has a multitude of effects on forest ecosystems. On the negative side, forest fragmentation is considered to be a primary threat to terrestrial biodiversity (Armsworth et al. 2004). In the United States, approximately 20 percent of resident bird species have experienced significant population declines in recent years (National Audubon Society 2002). Although there are many possible causes of these declines, one central factor is thought to be the fragmentation of forested habitat (Askins 2000). Particularly at risk are migratory songbirds, many of which nest in forests. These species are of significant conservation interest because they serve as indicators of ecosystem quality and are of considerable value to recreationists. Human health may also be impacted by forest fragmentation; Lyme disease may increase as forest edge increases, due to increased contact with wildlife as vectors. Possible positive impacts include increased tree growth of many species (if additional sunlight reaches trees that are closer to forest edges) and habitat for any wildlife species that benefit from forest fragmentation.

The intent in this section is to point out examples of the many possible impacts of forest fragmentation, recognizing that not all are negative; it depends on one's point of view. The overall or aggregate impacts of forest fragmentation depend, in part, on the social weight given to the different components of forest ecosystems. Such aggregate analysis is outside the scope of this paper but could be useful for policy analyses. Forest fragmentation is a problem for many species, especially in the eastern United States (Matthews et al. 2002). Bird densities are typically much lower in small patches of forest than in larger ones. Fragmentation is considered a primary factor to neotropical migrant declines (Wear and Greis 2002). Neotropical migrants particularly affected by forest fragmentation (a lot nest in temperate forests) include the black-throated green warbler and the ovenbird.

A study that integrated land use, wildlife habitat and other policies was by Matthews et al. (2002). They evaluated subsidies that achieved conversion of 10 percent of the total agricultural land in each of three U.S. states (South Carolina, Maine and southern Wisconsin). Bird-density estimates were derived for 615 species with data from national breeding bird surveys. Despite considerable spatial variation in agricultural land-conversion rates and farmland-bird distribution within these states, statewide losses of farmland birds were relatively uniform between 10.8 and 12.2 percent. Increases in forest-bird populations, however, varied substantially between states: 0.3 percent in Maine, 2.5 percent in South Carolina and 21.8 percent in southern Wisconsin. Despite the prevailing wisdom as to bird-rich forests, surprisingly, a net loss in total bird populations results in all three states: -2.0 percent in Maine, -2.3 percent in South Carolina and -1.1 percent in southern Wisconsin. The loss is due to the coincidence of centers of high richness for farmland birds and low richness for forest birds with areas economically suited to conversion. Additional gains in forest species may result, however, if afforestation within the economically optimal counties is concentrated to fill in existing forest fragments presently suffering avian losses to edge predators. The results by Matthews et al. (2002) show that assessments of the biological consequences of afforestation for carbon sequestration must consider both current land cover and the distributional patterns of organisms as well as the policy's conversion goal.

An example of a wildlife and fish study in the Northwest that used land-use information was the Burnett et al. (2003) broad-scale identification of protected freshwater areas for Pacific salmon and trout in Oregon. Streamside areas adjacent to reaches with high intrinsic potential were characterized relative to land use and other attributes. Their human-development data layer was derived by interpolating structure densities (number of structures in a 13 acre [32 ha] circle around a photo point) among a grid of regularly spaced photo points from

1995 (Kline et al. 2003). Tailoring actions to the intrinsic potential of an area should enhance the efficacy and efficiency of broad-scale freshwater conservation strategies and may improve their societal support.

Globally, loss of habitat due to changing land use is a prime concern, as anthropogenic activities alter the natural world at an unprecedented rate, causing global extinction rates to rise. Venter et al. (2006) quantified the threats facing 488 species in Canada, with habitat loss the most prevalent threat (84 percent), similar to the United States. Agriculture (46 percent) and urbanization (44 percent) are the most common human activities causing habitat loss and pollution. For extant species, the number of threats per species increases with the level of endangerment. Introduced species are a much less important threat in Canada than in the United States, but the causes of endangerment are broadly similar for Canadian and globally endangered species.

Discussion and Conclusions

Concerns about reduction in forest area are long standing. Some of the earliest efforts in forest conservation were inspired by rapid loss of forests to agriculture and logging, by the desire to protect timber and water resources, and by the desire to conserve land of extraordinary beauty and uniqueness. One of the most striking and persistent ways that humans dominate Earth is by changing land use and land cover to accommodate a growing population. Urbanization and other development are increasing worldwide, with potentially important implications for biological diversity. Using the United States as an example, socioeconomic drivers of land-use change, such as population and personal income levels, have increased substantially on average since World War II and have driven marked increases in land development. Human land use is the primary force driving changes in forest ecosystem attributes. Nationwide, more than 60 percent of housing units built in the 1990s were constructed in or near wildland vegetation (Radeloff et al. 2005). More than 44 million acres (17.8 million ha) of private forest are projected to experience housing density increases, with the most heavily impacted watersheds in the East (Stein et al. 2005). Looking ahead, the U.S. population is projected to grow by more than 120 million people by 2050, with more than 50 million acres (20 million ha) projected to be deforested over the next 50 years (Alig et al. 2003).

Natural resource stewardship options are affected by the severity of conversions to developed uses. When an area is converted to urban or built-up uses, it is likely to be permanent conversion. Fragmentation due to development also affects the quality of remaining forests (e.g., Butler et al. 2004, Wear et al. 2004, Alig et al. 2005). Having more people on the forested landscape often results in loss of open space (e.g., wildlife habitat) and in concern over loss of the amenity values generally associated with open space. Growing concerns about the loss of forestland to development have also been reflected in public and private efforts to preserve forestland as open space (Kline et al. 2004). Because much of the growth is expected in areas that are relatively stressed by human-environment interactions, such as some coastal counties are, implications for landscape and urban planning include potential impacts on sensitive watersheds, riparian areas, wildlife habitat, open space and water supplies.

Impacts of human influences on North American wildlife and natural resources will continue to expand, including effects of global climate change. People will continue to be part of the problems as well as part of the solutions, so enhanced monitoring of human disturbances across landscapes and mitigation activities will be important. In the case of land-use changes, determining the extent of human settlements across developed countries presents a challenge, as definitions of "developed," "built-up," and "urban" land vary greatly (Alig and Healy 1987), particularly among nations. With a gradient of land use, human settlements vary widely in density (e.g., Alig et al. 2004), form and distribution. In North America, urban settlements, as they have been defined by the census bureaus of each nation, contain most of the population. Between 75 and 80 percent of the population of the continent is urban as defined by the census bureaus of the United States, Canada and Mexico; however, census definitions are not consistent across countries. Improved monitoring and coordination by major data collection agencies and countries would be valuable.

Land-use policies often are used to mitigate potential negative impacts of urbanization on wildlife habitat. For example, governments and private conservation groups purchase land and conservation easements preserving open space in urbanizing areas. Zoning is used to prevent land development in certain locations. To ensure that these policies are cost effective in design and implementation, managers and policymakers need information that allows them to anticipate, describe and plan for future land-development patterns and their associated impacts on wildlife. These land-use policies have developed incrementally, with the number and combination of land-use policy instruments varying dramatically across states.

Our country has a long history of natural resource policies designed to jointly pursue both economic and ecological objectives, often involving policy instruments designed to affect forest cover, such as agricultural conservation programs (e.g., Conservation Reserve Program of the Farm Bill) that have resulted in the nation's largest tree-planting efforts on a 5-year basis and that have led to additional planted forest cover. Afforestation and deforestation are part of the processes that impact forest cover and need to be analyzed alongside reforestation trends and projections. Ecological and economic consequences and ripple effects of such changes in forest cover across regions and other owner groups can be substantial. Policy impacts can be important when examining likelihood of land-use changes under alternative futures, given different possible outcomes for stressed wildlife habitats, for related impacts on regional economies and recreation, and for roles in policy to address global climate change and other natural resource issues. An opportunity exists with the renewal of the Farm Bill to increasingly integrate open space, wildlife habitat and environmental goals. Protection of wildlife habitat and other open spaces can involve interconnectedness across mixed land ownerships, as well as access questions. For example, wildlife or fish species dependent on privately owned bottomlands at certain times of the year may disappear as these private lands are developed, regardless of quality of habitat remaining on adjacent public land.

Human-induced stresses on natural systems are likely to increase in some areas, with human-related impacts possibly causing marked changes in biotic responses. Human footprints on the natural system are unprecedented, but opportunities exist to bolster the positive ones from a societal viewpoint.

Where will the future take us? Looking back to 1893, Frederick Jackson Turner called the U.S. frontier closed, with the United States evolving into an urban nation. In 1900, 34 percent of U.S. citizens lived in urban areas, By 2000, 80 percent of U.S. citizens lived in urban areas, with associated changes in the economy, culture, transportation, energy consumption and emissions, and wildlife habitat. The need to more closely examine the connections between conservation and development and how society makes choices within a context of strategic land conservation will intensify.

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Forest Development across the United States and Implications for Wildlife

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Overview of the Forests on the Edge Project

Lead by the Cooperative Forestry Staff of the U.S. Department of Agriculture, Forest Service (Forest Service), the Forests on the Edge Project uses geographic information systems (GIS), analytical tools and projections of future residential housing to identify areas across the United States where forest contributions, such as wildlife habitat, might change due to housing development and other pressures. Released in May 2005, the first Forests on the Edge study projected housing development on private forestland across the United States (2000 to 2030) and found that over 44 million acres (17.8 million ha) of rural, private forestland could be affected by residential housing increases (Stein et al. 2005a,b). Follow-up studies are examining underlying economic factors and local conditions leading to development and other pressures on private forests. A new Forests on the Edge study identifies the private land surrounding National Forest System land most likely to face increased residential development. It estimates that over 21 million acres (8.4 million ha) of rural, private land adjacent to national forests and grasslands will experience increased development between 2000 and 2030. This paper reviews each of these studies, as well as case studies, of selected areas and discusses their implications for at-risk species and other wildlife.

Implications of Residential Development for Wildlife

America's forests provide habitat for many wildlife species, including at-risk species. Housing development can reduce habitat, fragment remaining habitat into smaller, disjointed units, isolate wildlife species, inhibit wildlife movement and reduce the probability of recolonization in the event that a species disappears from a given patch of habitat (Theobald et al. 1997). Housing development is also associated with the removal and alteration of native vegetation as well as increased fencing. Each of these activities can impact the presence and movement of wildlife. Loss of forestland can lead to increased recreation on remaining forestlands, which, in turn, can cause some species to alter activity, like feeding patterns (Theobald et al. 1997).

Avian communities are especially sensitive to habitat fragmentation by urban development. Fragmentation is considered to be a primary factor to neotropical migrant declines (Wear and Greis 2002). Several large field studies have found a correlation between development and declines in species richness (Engels and Sexton 1994).

Private Forests under Future Development Pressures—National Assessment

The purpose of the first Forests on the Edge study was to determine the extent and location of future development on private forests across the conterminous United States. Three housing-density categories were used for this purpose:

1. Rural I: 16 or fewer housing units per square mile
2. Rural II: 16 to 64 housing units per square mile
3. Urban/Exurban: more than 64 housing units per square mile.

Our analysis identified all rural forestland (i.e., land categorized as Rural I or Rural II) across the United States that is projected to experience increased housing density. Results indicate that 44 million acres (17.8 million ha) of rural private forest will experience increased housing density from 2000 to 2030.

The study also identified watersheds with the highest percent of land to experience forestland development; watersheds had to be at least 10 percent forested and had to have at least 50 percent of their forests in private ownership to qualify. As indicated in Figure 1, watersheds across the eastern United States and in parts of California and the Pacific Northwest are projected to experience the most extensive increases in forestland development.

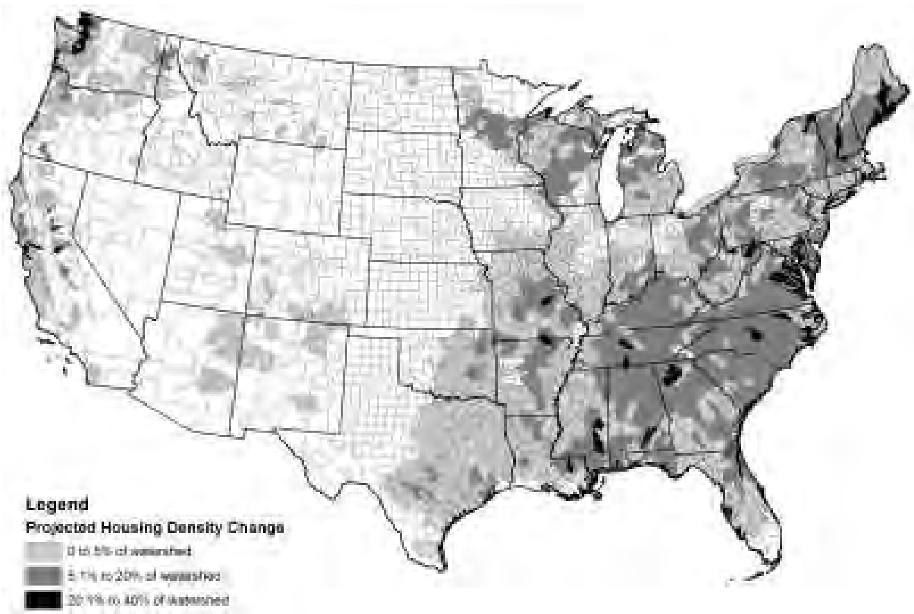


Figure 1. Watersheds in which housing density is projected to increase on private forests by 2030.

High-risk Watersheds with At-risk Species

Another Forests on the Edge study, entitled Private Assets/Public Benefits, involves ranking U.S. watersheds according to private-forest contributions and to threats to these contributions. The study identifies those watersheds where private forests are providing important resources, such as timber, clean water or at-risk species habitat, and that are most at-risk from future development, insect pests or air pollution. This paper will discuss an assessment of potential impacts of private-forest development on forest habitat for at-risk species. Data on at-risk species is provided by NatureServe and is based on a national assessment of at-risk species associated with private forestland in eight-digit watersheds across the conterminous United States. Note that the identification of at-risk species in this paper may be somewhat imprecise as it is based on coarse geographic analysis conducted on a national scale. Some of the species included in this analysis are freshwater or riparian species that do not occur directly on forestland but that are associated with and dependent upon healthy functioning forests. At-risk species descriptions throughout this paper are derived from information provided on the NatureServe Explorer Website (http://www.natureserve.org/explorer).

The Forest Service used the results of this assessment to rank watersheds according to the number of at-risk species associated with private forest in each watershed. In order to be included in the map displayed in Figure 2, watersheds had to be at least 10 percent forested and had to have at least half of their forests in private ownership. Watersheds with the highest numbers of private-forest-associated, at-risk species are located in the southeastern United States, coastal California and the Pacific Northwest. Private forests in watersheds found in the upper 10th percentile are associated with up to 101 at-risk species.

Next, the watersheds are ranked according to the percent of private forest projected to experience increased housing density (prepared using the same housing density categories described earlier in this paper). An overlay of these two layers produces a ranking of watersheds according to the presence of at-risk species and the percent of private forest to be developed. The results are displayed in Figure 3. Watersheds in the upper 10th percentile, where at-risk species' forest habitat is most likely to be affected by increased housing density, are scattered throughout the Southeast, New England, around the Great Lakes and along the West Coast. The highest ranked watershed is the Seneca Watershed, located in northwestern South Carolina and home to 66 globally ranked species, including Evan's Cheilolejeunea (*Cheilolejeunea evansii*), a liverwort ranked as critically imperiled (at a high risk of extinction) globally and within the three states where it occurs (South Carolina, North Carolina and Alabama). Also found in this watershed is the green salamander (*Aneides aeneus*), ranked as critically imperiled in South Carolina.

The Powell Watershed, a long, slender watershed bordering Kentucky and Virginia and running down into Tennessee, is ranked second of all U.S.

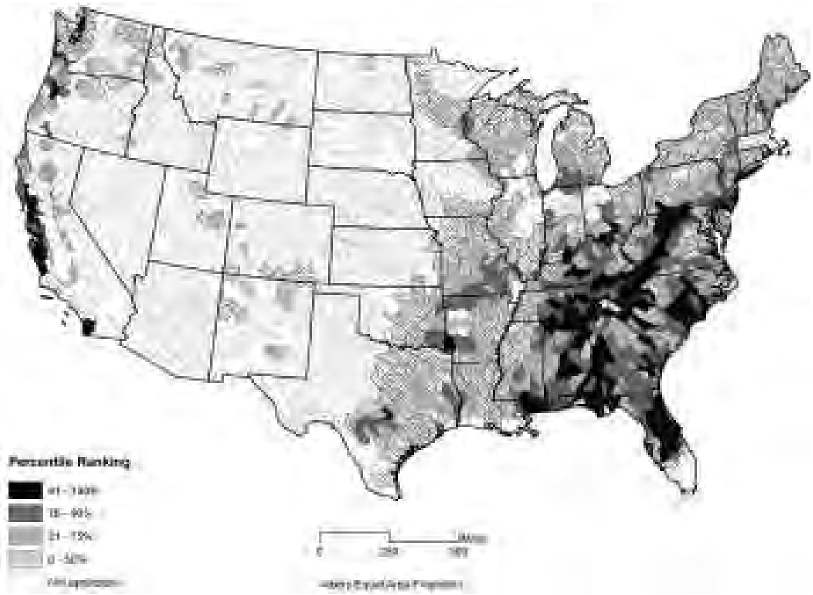


Figure 2. Percentile rankings of watersheds with respect to at-risk species.

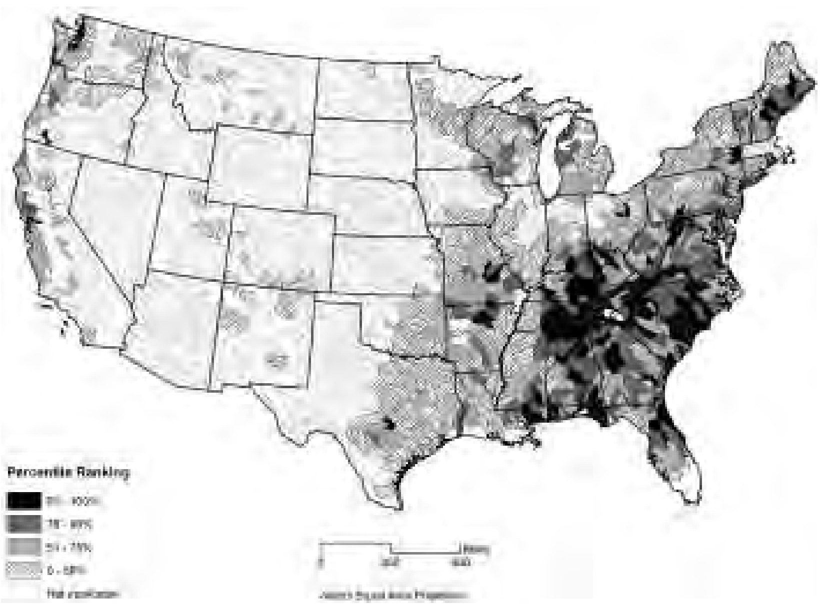


Figure 3. Percentile rankings of watersheds with respect to development threat to at-risk species.

watersheds with respect to at-risk species found in private forests likely to experience development. Its forests provide habitat for close to 80 globally ranked species, including 21 listed as critically imperiled. Forests in this watershed also provide habitat for the red-cockaded woodpecker (*Picoides borealis*), which is critically imperiled in Kentucky.

Private Forestland Development Case Studies

The development of rural forestland is a result of market forces. As populations, incomes and economic growth increase, so do the demand for land and the financial incentives for landowners to sell land for development (Kline et al. 2004). Demands for residential development also increase with people's lifestyle choices when, for example, people relocate to rural areas or buy second homes in scenic forest settings. Increased housing is accompanied by an increase in land converted to commercial use and public infrastructure.

In order to understand market forces responsible for increased development in selected watersheds, in-depth case studies were conducted in northwestern Washington, southern Maine and Georgia (White 2006 a, b). Summaries of the first two analyses are provided here. Watersheds studied in northwestern Washington include the Straight of Georgia, Nooksack, Lower Skagit, Stillaguamish and Snohomish watersheds (Figure 4). By 2030, an estimated 60,000 forestland acres (24,282 ha) in the Straight of Georgia Watershed alone are projected to experience increased residential development. Projections for the other watersheds range from 10,000 to 36,000 acres (4,046–14,568 ha). A look at past trends indicates that these watersheds have experienced considerable increases in population and residential housing over the past decades largely due to positive net migration, i.e., people are moving into Washington from other states. Additional factors include declining stumpage values for Douglas fir (*Pseudotsuga menziesii*, a key timber species), steady-to-declining timber harvests and a high market value for undeveloped land.

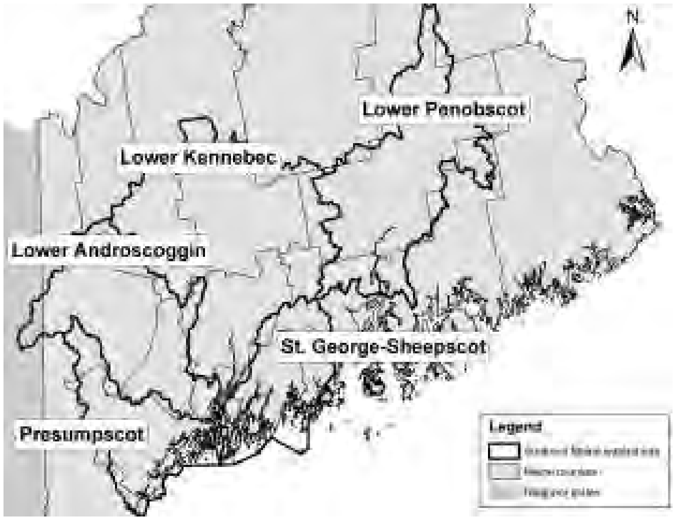
At-risk species that could be affected by an increase in forest development in the Northwest Washington case study watersheds include the tall bugbane (*Actaea elata*), considered vulnerable at the global and state level and ranked as critically imperiled in British Columbia. This vascular flowering plant species is limited to the Pacific Northwest; large populations are found in southern Oregon while smaller populations are scattered throughout western Oregon and Washington.

Figure 4. Case study of northwestern Washington watersheds.

The Maine case study focused on the Lower Penobscot and nearby watersheds in southcentral and southwestern Maine (Figure 5). Over 310,000 acres (125,452 ha) of forestland in the Lower Penobscot Watershed are projected to experience increases in housing density by 2030. Forestland acres projected to experience increased housing density in the other watersheds studied range from 84,800 to 213,800 acres (34,316–86,521 ha). A study of past trends indicates that both population and housing have been increasing in Maine and that a few towns in southern Maine experienced housing increases of over 40 percent in the 1990s (E. M. White, unpublished report 2006). The percentage increase in housing units (11 percent) was, in fact, far greater than the increase in population (4 percent). The area of timber harvested for land-use conversion has also been increasing (primarily on family-owned forests in southern Maine). Some of this increase is due to second-home construction. In fact, Maine has the highest percentage (16 percent) of housing units being used as second homes of any state. Average commute times have been increasing in parts of the state, including parts of our study area, suggesting that people are willing to commute farther to take advantage of the area's natural amenities, lower housing costs and lower taxes.

The Maine case study watersheds average roughly 13 at-risk species, including the small-whorled pogonia (*Isotria medeoloides*) and the hessel's hairstreak (*Callophrys hesseli*). The small-whorled pogonia is a member of

Figure 5. Case study of Maine watersheds.



the orchid family and is considered imperiled on a global scale. This species typically makes its home in deciduous or deciduous-coniferous forests. The primary threat to this species is habitat destruction for residential or commercial development or forestry. Other threats, such as herbivory, recreational use of habitat and inadvertent damage from researcher activities, have also been identified. The hessel's hairstreak is a small butterfly in the Lycaenidae family and is considered vulnerable on the global scale. The hairstreak butterfly typically inhabits cedar swamps. There are significant threats from habitat loss and suppression of cedar reproduction by deer in parts of its range. Well managed patchy logging is not considered a long-term threat, since species can recolonize, but development and biocide spraying are also threats to the population.

National Forests on the Edge

The purpose of the final study discussed in this paper, National Forests on the Edge, is to identify national forests and grasslands (lands managed by the Forest Service) adjacent to rural, private lands likely to experience a substantial increase in housing development. The study ranks the national forests and grasslands according to the percentage of adjacent, rural, private land (forest and nonforest) projected to experience increased development (again using the definitions provided at the beginning of this paper). In total, housing development is projected to increase on about 21 million acres (8.4 million ha) of rural, private land surrounding national forests and grasslands scattered across the country (from 2000 to 2030). A national map depicting these forests is still in production and is not included here but will be available in a future report.

The Bitterroot Forest in Montana and Idaho is one of the national forests with the highest percentage of surrounding land projected to experience increases in housing density—close to 50 percent of the land found within 3 miles (4.8 km) of its borders is projected to experience increased housing density. Much of this land is located within current elk and mule deer winter range (see Figure 6).

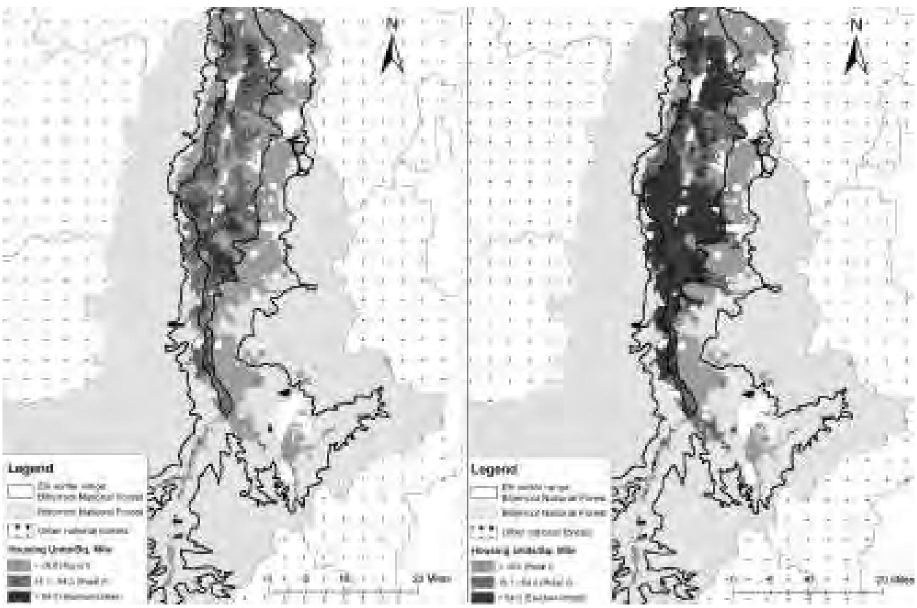


Figure 6. Land surrounding the Bitterroot National Forest (Montana and Idaho) projected to experience increases in housing density from 2000 (a) to 2030 (b).

Summary and Conclusions

Across the country, rural forestland is being developed, with likely consequences for at-risk species and other wildlife. Geographic information system technology is making it possible to identify areas where impacts to wildlife from projected future development may be greatest. This paper has presented three studies that can be used as examples for examining residential development in rural landscapes. Housing density projections can be combined with forest-vegetation data to locate areas where forestland is most likely to experience increased development. This data, in turn, can be combined with wildlife data, such as the NatureServe at-risk species database, to identify areas of potentially high wildlife impact. Lands protected from development, such as National Forest System land managed by the Forest Service, can be assessed to determine where they are most vulnerable to increased housing development along their borders.

Each of the assessments described here required nationally consistent data, which, as with most national data, is somewhat coarse and imprecise for use at the local level. The results of this data are, therefore, best used to inform broad policy analysis, to highlight areas of potential concern and to identify opportunities for further study.

As with most federal data, much of the Forests on the Edge data are available for use by others. We have responded to many requests for the data from the first Forests on the Edge report. Numerous groups, including universities, conservation organization and consulting firms, have used this data, alone or in combination with other GIS data, to support regional and statewide assessments. The Forest Service will continue its assessments of public and private forests and will look forward to making Forests on the Edge data available for public use. More information on Forests on the Edge can be found on http://www.fs.fed.us/projects/fote.

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Georgia's Wildlife Action Plan: Conservation Actions to Address Forest Development

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Introduction

A recent U.S. Census Bureau study ranked Georgia fourth in the country in terms of statewide population growth. Between 2000 and 2004, the population increased by more than 642,000 people (U.S. Office of Planning and Budget 2005). Projections are for Georgia's population to reach 10.8 million in 2015. This population growth has resulted in conversion of forest and farmlands to residential or commercial uses. These changes are most apparent in the Piedmont, where high- and low-intensity, urban land use increased from 4.9 to 9.6 percent of the landscape during the period from 1974 to 1998 (Kramer 2007).

Georgia has a rich biodiversity and ranks sixth in the nation in species richness of vertebrates, selected invertebrates and plants (Stein 2002). Maintaining this biodiversity in the face of rapid population growth and resulting development will be a significant challenge.

In 2005, Georgia completed a state wildlife action plan (SWAP), also known as a Comprehensive Wildlife Conservation Strategy, to address the conservation needs of imperiled animals and plants (Georgia Department of

Natural Resources 2005). Georgia's plan, like those in all 50 states and 6 territories, was developed in accordance with guidelines issued by the U.S. Fish and Wildlife Service (2004). Georgia's plan was approved by the Director of the U.S. Fish and Wildlife Service in October 2005.

Georgia's SWAP was developed by the Wildlife Resources Division (WRD) of the Georgia Department of Natural Resources with the assistance of a 30-member steering committee and with assistance of many other biologists and interested persons. Work on the SWAP began in December 2002 and was completed in August 2005. In accordance with federal guidelines, Georgia's SWAP addressed the following eight elements:

1. information on the distribution and abundance of species of wildlife, including low and declining populations as the state fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the state's wildlife
2. descriptions of locations and relative condition of key habitats and community types essential to conservation of species identified in 1
3. descriptions of problems, which may adversely affect species identified in 1 or their habitats, and priority research and survey efforts needed to identify factors, which may assist in restoration and improved conservation of these species and habitats
4. descriptions of conservation actions proposed to conserve the identified species and habitats and priorities for implementing such actions
5. proposed plans for monitoring species identified in 1 and their habitats, for monitoring the effectiveness of the conservation actions proposed in 4 and for adapting these conservation actions to respond appropriately to new information or changing conditions
6. descriptions of procedures to review the strategy at intervals not to exceed 10 years
7. plans for coordinating the development, implementation, review and revision of the plan with federal, state and local agencies and Native American tribes that manage significant land and water areas within the state or that administer programs that significantly affect the conservation of identified species and habitats
8. documentation of broad public participation during development and implementation of the strategy.

This paper describes the development of Georgia's SWAP and discusses how information in the plan can be used to address forestland development.

Georgia's State Wildlife Action Plan

Species of Greatest Conservation Need

Six technical teams reviewed information on the status of birds, amphibians, reptiles, mammals, fish, aquatic invertebrates, terrestrial invertebrates and plants. Funding for identification of high-priority plant species was obtained through sources other than the state's Wildlife Grant Program (SWG) because plant assessments are not eligible for SWG funding. The teams identified 296 animal species of concern and 323 plant species of concern based on global and state rarity, range in Georgia, endemism, threats, population trends and importance of Georgia efforts to conservation of the species. The animal list included 33 birds, 23 mammals, 22 amphibians, 22 reptiles, 74 fishes, 75 mollusks (freshwater mussels and gastropods) and 47 aquatic arthropods (insects and crustaceans).

Key Habitats and Community Types

Four approaches were used to identify habitats important for the conservation of species of greatest conservation need. Species technical teams developed descriptions of high-priority habitats that support the species of greatest concern. In some cases, these high-priority habitats represent small-patch habitats or edaphically controlled communities that are not easily mapped. Technical teams also assigned each species to one or more habitat association using a hierarchal classification system contained in Biotics, the biodiversity database system used by the Georgia Natural Heritage Program of the WRD. In addition, the land-cover types developed by the Georgia Gap Analysis Program (GAP, Kramer et al. 2003) derived from 1998 satellite imagery with augmentation from aerial photographs and other sources were used for broad-scale mapping and assessment of vegetation types and land-use changes. Land-cover data from this analysis, along with GAP species, habitat models for high-priority species and known occurrences of rare species from WRD's Biotics database were analyzed to identify conservation-opportunity areas where conservation actions were expected to have the greatest benefit (Figure 1.) Finally, aquatic habitats were assessed by identifying stream reaches and watersheds that support documented occurrences of species of concern. They were identified by The

Figure 1. Conservation-opportunity areas in Georgia.

Nature Conservancy as high-priority, aquatic-resource areas (Smith et al. 2002) or were identified as priority streams by the WRD Stream Team based on the high index of biological integrity scores (Georgia Department of Natural Resources 2003) (Figure 2).

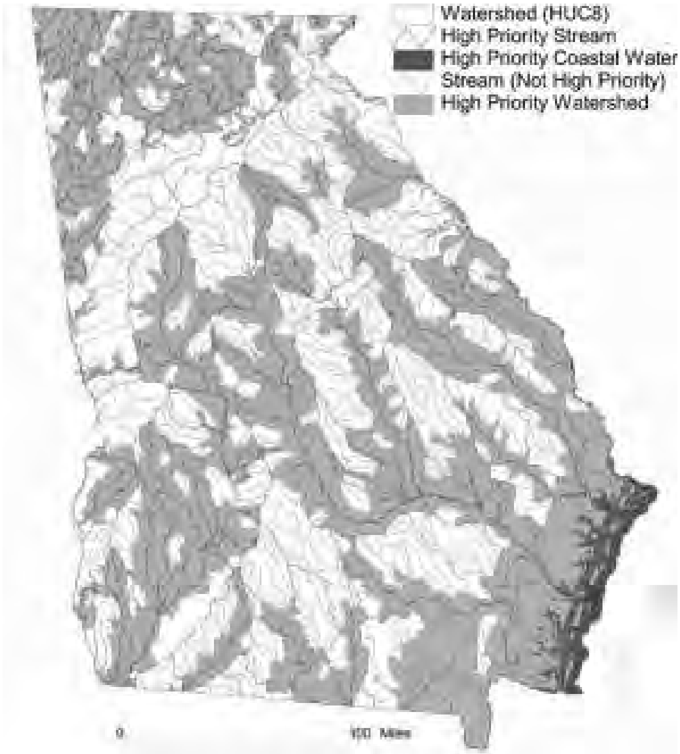
Problems Affecting Species and Habitats

In order to assess the historic, current and potential impacts of various sources of stress on priority species and habitats, a list of 25 problem categories was developed from several assessment approaches found in the literature, such as Salafsky et al. 2003. Technical teams assigned each species and habitat to one or more of these problems.

Conservation Actions

Technical-team leaders, steering-committee members and other stakeholders contributed draft recommendations for conservation actions

Figure 2. High-priority streams and watersheds in Georgia.



including high-priority land protection, habitat restoration, rare-species recovery, research, survey, database development and education efforts. Each conservation action included target species or habitats, watershed, and ecoregions. Information on lead organization, potential partners, funding sources and performance measures were included for each action. Draft conservation measures were reviewed, revised and ranked by the steering committee. Each action was assigned an importance score based on seven criteria: (1) providing multiple benefits for high-priority species and habitats, (2) addressing un(der)funded needs, (3) overall importance of Georgia efforts, (4) timeliness or urgency, (5) connections with other conservation actions, (6) building public support for wildlife conservation and (7) probability of success. A system of rating and weighting values was used for these criteria to develop ranking system for conservation actions. Those conservation actions ranked as very high, high or medium priority were included in the SWAP.

Monitoring

Monitoring actions were identified for each conservation action including focal species and habitats, lead and partner organizations, types of data to be collected and performance measures. More work will be required to develop final monitoring plans, but, given the diverse species, habitats and array of conservation actions, monitoring will be required at multiple scales and will involve partnerships with many organizations.

Revision and Review

The WRD will begin revision of the SWAP in 2010 and will complete the revision process by 2012.

Coordination with Other Agencies and the Public

Extensive interagency coordination was obtained through the steering committee and technical teams as well as stakeholder meetings and public meetings. In addition, the draft SWAP was posted on WRD's Website for public comment. Development of Georgia's strategy included a series of stakeholder meetings and public meetings to obtain public input for development of the strategy. A total of 127 individuals from 60 organizations attended the meetings.

Implementation of Georgia's State Wildlife Action Plan

The WRD is implementing Georgia's SWAP with guidance from an implementation committee that includes representation from agencies and organizations that assisted in development of the plan. These groups include organizations that WRD has worked with for many years as well as new partners in conservation. The implementation committee currently includes representatives from 22 organizations. Developing and maintaining partnerships is one of the most important outcomes of the planning process.

Our assessment of high-priority habitats identified more forested habitats (36) that were important for conservation of species of greatest concern than any other broad-scale habitat type. Given that many priority, aquatic habitats originate in forested watersheds and that many high-priority edaphic and wetland habitats exist in a forest matrix, conservation of forest habitats will be critical to the success of Georgia's SWAP.

We selected five high-priority conservation actions to focus our efforts on and to engage the implementation committee. These action included: (1)

increasing the use of prescribed fire for habitat restoration, (2) improving wetland protection and mitigation banking programs, (3) expanding technical and financial assistance to private landowners, (4) developing a statewide strategy for assessment and control of invasive exotic species and (5) facilitating the Georgia Land Conservation Program (GLCP) and other programs for permanent protection of wildlife habitat.

Although all five of these high-priority conservation actions address impacts to forest habitat, two actions—working with private landowners and implementation of the GLCP—have specific emphasis on forestland conservation. The WRD has expanded its involvement in the Sustainable Forestry Initiative Implementation Committee, working to emphasize consideration of imperiled wildlife, specifically species of greatest conservation need, in development of forest-management plans. This activity includes a broad range of education and outreach components for individuals ranging from forest managers to harvesting crews. We are developing new Web-based abstracts on species of concern that will be available to land managers and that will provide information on management needs of these species. We also considered species of concern into a wide range of existing technical assistance programs such as our Forestry for Wildlife Program, Farm Bill programs and forest stewardship programs.

Implementation of the GLCP is an ongoing, priority, conservation action. The GLCP was created in 2005 to acquire conservation lands or interest in lands by the state. Criteria used to evaluate projects for the GLCP include information developed in the SWAP. To focus conservation actions in those areas of Georgia that supported the extensive areas of priority habitats and species of greatest conservation concern, WRD staff developed a map of six priority conservation focus areas from our conservation opportunity analysis (Figure 3). Land conservation projects are underway in each of these areas. During 2005 to 2006, Georgia acquired fee or easements for over 36,000 acres (14,568 ha) valued at $58,000,000.

Summary

Forestry and forest ownership in Georgia are undergoing a period of tremendous change as industry divests lands to other ownerships, such as timber-management organizations (Wallinger 2005). In many parts of Georgia, land

Figure 3. Priority-conservation areas in Georgia 2006.

prices exceed values that can support forestry, and conversion to development at the urban-wildland interface or to recreational use in rural areas is expected to increase (Wear and Newman 2004). At the same time, global competition is expected to place continued pressure on prices of U.S. forest products such that demand for U.S. wood products is expected to remain stable or perhaps decline (National Commission on Science for Sustainable Forestry 2005).

Collectively, these trends will likely result in forest landowners seeking new sources of income and new opportunities. This may include payments for ecological services or expanded programs to provide property-tax benefits to forest landowners. SWAPs contain information on imperiled species and their habitats that could increase the effectiveness of new programs for conservation of wildlife. State wildlife managers should seek to engage forest managers and landowners in the development of new tools and programs for conservation of forestlands.

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Session Three.
Targets of Opportunity: State Wildlife Action Plans

Wildlife Action Plans: An Unprecedented Opportunity for Wildlife Conservation Partnerships

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In 2005, all 50 states and 6 territories completed comprehensive wildlife conservation strategies, now referred to as wildlife action plans. These strategies were completed as a congressional requirement for access to federal funds through state wildlife grants (SWG). This program is ultimately intended to keep common species common and to conserve and manage species before they go into decline or become endangered. It is possibly the most extensive, nationwide, comprehensive strategy for wildlife conservation to date. The purpose of this paper is to give a brief history of this process, as well as to discuss the benefits and opportunities that implementation of these plans can provide.

History and Background

In 1980, Congress acknowledged a shift in public awareness and interest toward broader wildlife programs by passing the Fish and Wildlife Conservation Act, also known as the Nongame Act. This act authorized financial and technical assistance to states for the development, revision and implementation of conservation plans and programs for nongame fish and wildlife. However, federal funding to assist with conservation of nonhunted wildlife lagged far behind resource needs and public demand. It was not until 1994 that the states collectively approached Congress with a serious proposal to provide matching funds to conserve all those species and their habitats not covered by previous funding programs for game and commercial species.

In 1998, the International Association of Fish and Wildlife Agencies (now the Association of Fish and Wildlife Agencies, AFWA), in partnership with state wildlife agencies, initiated Teaming with Wildlife, a national campaign to document the need for additional wildlife funding and to secure a reliable source of federal matching funds for species and habitat conservation. The original source of revenue investigated for the campaign was a new federal excise tax on outdoor equipment, similar to taxes imposed on fishing tackle and firearms, to be administered by the U.S. Fish and Wildlife Service (USFWS). However, in 1999, the Teaming with Wildlife campaign became part of a much larger effort to restore and expand funding from offshore oil and gas revenues for a range of conservation, outdoor recreation and historic preservation programs. Although the Conservation and Reinvestment Act of 1999 (CARA) was not passed by Congress as proposed, it did result in significant additional funds from the federal budget for certain programs, such as a new SWG program to assist state wildlife agencies with the conservation of species and habitats of greatest conservation need.

The first congressional SWG appropriations were made in 2001, and both planning and implementation grants have been made to state wildlife agencies since then. Funds are allocated according to a formula based on the size and population of each state.

All SWGs funded by Congress were contingent on the completion and acceptance of state comprehensive wildlife conservation strategies by October 2005. Acceptance of these state strategies by the USFWS satisfies the funding requirements of the current planning grants and establishes eligibility for further funding of state wildlife conservation programs under the SWG program.

To meet the requirements for future SWGs, state comprehensive wildlife conservation strategies must adequately address eight essential elements established by Congress:

- element 1: include information on the distribution and abundance of priority wildlife species that reflect the diversity and health of state wildlife
- element 2: identify the extent and condition of wildlife habitats and community types essential to the conservation of priority species

- element 3: identify problems that may adversely affect priority species or their habitats
- element 4: determine actions to be taken to conserve priority species and their habitats
- element 5: provide for periodic monitoring of priority species and habitats, as well as for the effectiveness of conservation actions
- element 6: coordinate all stages of the comprehensive wildlife conservation strategies with federal, state, tribal and local agencies
- element 7: incorporate opportunities for public involvement into the development, revision and implementation of the comprehensive wildlife conservation strategies
- element 8: provide for review of the comprehensive wildlife conservation strategies and appropriate revision at intervals of not more than 10 years.

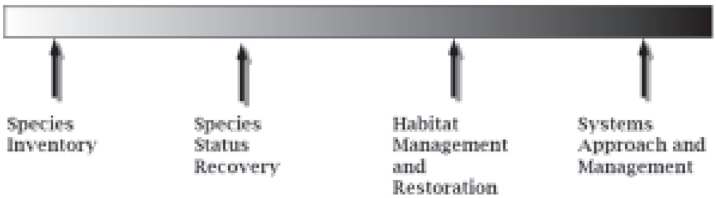
To ensure consistency with these eight elements and to meet congressional intent, the USFWS convened the National Advisory Acceptance Team (NAAT). The NAAT was comprised of the Assistant Director for Migratory and State Programs and an AFWA representative, as well as directors representing each of the four regional fish and wildlife associations. The NAAT provided compliance guidance and procedures to the states and territories. This group met periodically over a 2-year period, during which they reviewed and recommended approval of all 56 plans to the Director of the USFWS.

Washington Department of Fish and Wildlife Director Jeff Koenings represented the Western Association of Fish and Wildlife Agencies on the NAAT. He enlisted us to review all 56 comprehensive wildlife conservation strategies and to provide technical support at NAAT meetings. The following observations are the result of our participation in this review process and do not necessarily represent the opinion of the NAAT.

Different Approaches to the Same Goal

Congress mandated that the conservation strategies contain all major components of conservation planning and public involvement. Although all states and territories were required to include the eight essential elements, their approaches varied greatly, resulting in both benefits and challenges. The elements were flexible enough to allow states to design their plans to address unique wildlife conservation problems, as well as local culture and constituencies. However, since the states' approaches vary so widely, they are difficult to roll up into an integrated national strategy. Some states focused on species, while others employed an ecosystem approach. Most states fell somewhere in the middle of this continuum (Figure 1).

Figure 1. Conservation management continuum.



NAAT members and support staff were often asked which of the plans were the best. Procedural and ethical considerations prevented comment during the NAAT review period. At the end of the process, the NAAT considered highlighting some of the most innovative approaches to conservation planning; however, it chose not to do this because it generally agreed that all states had done well and that the nation had greatly benefited from this process. The states and territories that had relatively lower capacity and resources for conservation and biodiversity planning may have benefited most from this new source of federal funding. However, states with existing sophisticated planning and management systems benefited as well because they were able to develop new management techniques that moved them toward the goal of ecosystems management.

A more intensive analysis and synthesis of all 56 plans is being conducted by AFWA and, from an academic perspective, by the University of California at Santa Barbara. These studies are to be completed within 1 year.

Interestingly enough, all states and territories agreed that the top stressors for wildlife are invasive species and habitat loss and fragmentation. Other stressors, such as water quantity, allocation and diversion of surface water, water-quality issues, improper forest, agricultural and livestock grazing management practices, disease and pathogens, and inadequate data on wildlife species, populations and habitat were included in all plans but varied in their priority. How states chose to address these and other stressors depended largely upon where they fell along the continuum of approaches to wildlife conservation and management issues.

Wildlife Action Plan Benefits and Future Implementation

This unprecedented national wildlife conservation planning effort provided many benefits, including the development of new partnerships and integration with other major national, state and local conservation planning entities, solid justification for gaining additional resources for fish and wildlife conservation and management, and a legacy or blueprint of biodiversity and species and habitat conservation for future generations of fish and wildlife managers.

The eight essential elements included a requirement that states build their strategies to address a wide scope of actions that could be expanded by stakeholder and partner participation. Virtually all state plans were in agreement on the importance of partnership opportunities for conservation management. An additional guiding principle was that the plans were written to be comprehensive, not just a plan for a particular state or territory fish and wildlife agency. Thus, effective implementation of strategies will require multiple partnerships and multiple levels of geographic scale, including the private, government and tribal sectors.

A stark example of this point, viewed solely from fiscal resources needed to adequately implement these plans, is shown in Figure 2. The example used is for Washington, a medium-sized state with a human population of 6 million that contains diverse wildlife and habitats. It is conservatively estimated that it would take $12 million per year to implement the Washington Wildlife Action Plan. At this time, the federal SWG provides an allocation of approximately $1.2 million per year to Washington; under new federal and congressional guidelines, this amount is to be matched by state funds. That leaves a gap of approximately $9.6 million.

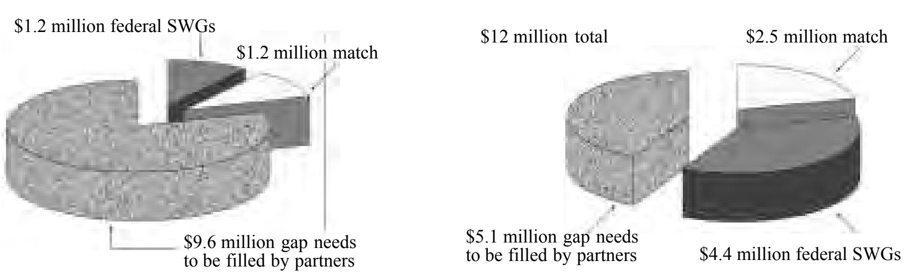


Figure 2. Estimated fiscal reources needed to implement Washington's wildlife action plan and enhanced funding.

Currently, states and AFWA is emphasizing a stable, predictable and large funding base similar to CARA. Ideally, this would provide a funding stream of at least $250 million per year with a 75-percent-federal and 25-percent-state match. Even under this enhanced funding scenario, Washington would still have a gap of an estimated $5.1 million per year to fill in order to fully implement its wildlife action plan. The bottom line is that working with partners is an absolute necessity. Moreover, even with additional funding, wildlife conservation is almost always more effective when accomplished through partnerships with other public, land-management agencies, Native American tribes, conservation groups, local governments and the private sector, especially agriculture and forest landowners.

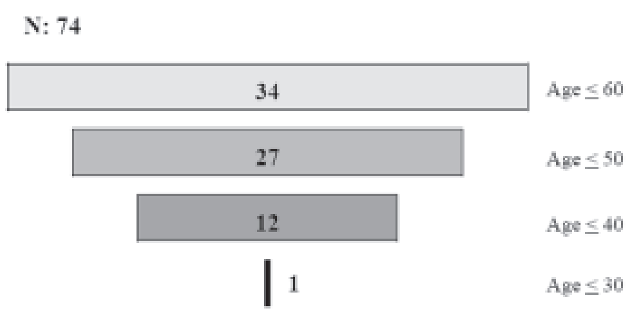
The philanthropic community is a new frontier in partnerships for the wildlife action plans. For example, the Doris Duke Charitable Foundation's (Foundation's) support for state wildlife action plans includes grants for identifying critical lands, implementing land protection and building conservation knowledge. In support of the state wildlife action plans, the Foundation has approved a total of $43 million in grants to AFWA, The Conservation Fund, Defenders of Wildlife, Environmental Defense, Environmental Law Institute, Land Trust Alliance, Massachusetts Audubon Society, National Council for Science and the Environment, National Fish and Wildlife Foundation, National Wildlife Federation, The Nature Conservancy, NatureServe, Open Space Conservancy, Theodore Roosevelt Conservation Partnership, Trust for Public Land, Wildlife Conservation Society, and the Woodrow Wilson National Fellowship Foundation. With the Foundation's support, these grantees are generating significant momentum behind the state wildlife action plans. They are providing capital, coordination, education, research and leadership in implementing the action plans on multiple fronts across the country.

Recently, the Duke Foundation sponsored a $2-million-grant opportunity through the Wildlife Conservation Society (WCS) called the Wildlife Action Plan Opportunities Grant. Proposals were solicited from nongovernmental organizations for the implementation of the states' wildlife action plans over a 2-week period. The WCS received 550 proposals totaling $45 million. This indicates a great deal of interest and the need to implement state wildlife action plans.

Collectively, the state wildlife action plans are a national blueprint for conservation that make the needs of fish and wildlife more transparent. The current federal administration has shifted more responsibility for conservation to the states and has encouraged cooperative partnerships with the private sector. This model has proven to be effective and is likely to stimulate greater opportunities for funding from the philanthropic community. Thus, these plans will serve as a focus or rallying point for ongoing efforts at several scales and will promote multiple partnerships at the federal, state and local levels of government as well as nongovernmental organizations and Native American tribes.

Finally, development and implementation of the wildlife action plans provides a legacy for the future of fish and wildlife agencies and other conservation organizations across the country. This may be an undervalued benefit. In a recent survey, Steve McMullen of Virginia Tech found that 77 percent of state fish and wildlife agency leadership will leave their agencies in the next decade, and only 7 percent of surveyed fish and wildlife agencies have employees under the age of 30, compared to about 25 percent in other sectors. Also, about 48 percent of the surveyed state fish and wildlife agency workforce is expected to retire within in the same 10-year period. Within Washington's agency, 4 of 7 of our senior executive managers are beyond the 30-year minimum required to retire. All those in executive management will be able to retire within 5 years. Additionally, an informal poll taken of wildlife biologists and managers within Washington's Wildlife Program found that 34 (45 percent) were between 50 and 60 years of age, 27 (36 percent) were between 40 and 50 years of age, 12 (16 percent) were between 30 and 40 years of age, and one person was under 30 (see Figure 3). The take-home message is that completion of the wildlife action plans could not have come at a more fortuitous time, when fish and wildlife agencies will probably be losing their institutional knowledge faster than they recruit the next generation of biologists and managers. This should provide further motivation for implementing the wildlife action plans before we lose the Baby Boomer generation.

Figure 3. Estimated demographics of biologists and managers of Washington Department of Fish and Wildlife Program



Collaborative Implementation of Nebraska's Wildlife Action Plan: The Nebraska Natural Legacy Project

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Introduction

In November 2005, the U.S. Fish and Wildlife Service (USFWS) approved Nebraska's state wildlife action plan—the Nebraska Natural Legacy Project (NNLP)—the first comprehensive wildlife-conservation strategy for the state. Approval of the plan was the culmination of a 3-year effort to build broad collaboration between conservation, agriculture and tribal interests in the state. Key to the development of the plan was the assembly of the 21-member NNLP Partnership Team representing diverse stakeholders that had collaborated little in the past (Table 1). The self-appointed roles of the partnership team were: (1) to serve as communication conduit to stakeholders, (2) to develop and participate in an extensive public input process, (3) to develop guiding principles and (4) to serve as principal reviewers of the draft plan.

One of the primary themes of the plan that resulted from public comments and input from the partnership team was the need to improve communication and collaboration between private and public conservation organizations and the agricultural community. The NNLP identified 11 statewide and 4 ecoregion-specific actions intended to address barriers to communication and collaboration. At the core was a desire by citizens (particularly those involved in agriculture) to become more involved in local decision making relating to wildlife conservation. Since Nebraska has a history of stepping down decision making for natural resource management to local governmental units, this desire for increased local control of wildlife-conservation actions was not entirely unanticipated.

Table 1. Members of Nebraska Natural Legacy Program Partnership Team during planning and implementation.

Organization	Planning	Implementation
Audubon Nebraska	X	X
Ducks Unlimited, Inc.	X	X
Grassland Foundation	X	
Farmers Union	X	X
Natural Resource Conservation Service	X	X
Nebraska Alliance for Conservation and Environment Education	X	X
Nebraska Association of Resources Districts	X	X
Nebraska Cattlemen (two members)	X	X
Nebraska Department of Agriculture	X	X
Nebraska Farm Bureau (two members)	X	X
Nebraska Forest Service/University of Nebraska	X	X
Nebraska Game & Parks Commission	X	X
Nebraska Land Trust		X
Nebraska Partnership for All-Bird Conservation	X	X
Nebraska Wildlife Federation	X	X
Pheasants Forever, Inc.	X	X
Ponca Tribe of Nebraska	X	X
Rainwater Basin Joint Venture of Nebraska	X	X
Running Water Ranching Coalition		X
The Nature Conservancy	X	X
U.S. Fish and Wildlife Service, DeSoto National Wildlife Refuge	X	X
U.S. Fish and Wildlife Service, Partners for Fish and Wildlife	X	X
U.S. Forest Service	X	X

Plan Development

The NNLP was spatially explicit and identified 40 biologically unique landscapes (BULs, Figure 1). The landscapes were selected based on known occurrences of ecological communities and at-risk species, and they offer the best opportunities for conserving the full array of biological diversity in the state. Threats and conservation actions were identified by biologists attending a facilitated practitioner workshop and through regional meetings and expert workshops. The public provided input to the plan through 20—mostly partner-facilitated—public-input meetings and via the Internet. Over 500 animal and plant species were identified as Tier 1 and Tier 2 at-risk during the planning process. Since approximately 97 percent of Nebraska is under private ownership, voluntary, incentive-based, conservation action on private land is a centerpiece of the plan. The complete NNLP is available for review at http://ngpc.state.ne.us/wildlife/programs/legacy/review.asp.

Figure 1. Biologically unique landscapes in Nebraska.

Planning for Implementation

Following submission of the plan to the USFWS, a meeting of the NNLP Partnership Team was held to discuss if there was a need and desire to continue working together as a team. Nineteen of the original 20 partnership-team members, including all of the original agricultural partners, agreed to remain on the team to guide implementation of the plan. Two organizations were subsequently added. The implementation roles of the partnership team were defined as: (1) to lead prioritization of landscapes for implementation, (2) to review, endorse and provide support for local landscape-level implementation initiatives, (3) to serve as a communication conduit to stakeholders, (4) to monitor and evaluate performance and (5) to assist with outreach.

The phrase “flagship initiative” was coined to describe local, landscape-level, implementation initiatives under the NNLP banner, and the partnership team developed criteria to aid in the selection of initiatives (Table 2). The 40 BULs were prioritized for implementation based on partner interest, potential for community support and the absence of an existing conservation partnership. Public input meetings were held to inform community leaders of the NNLP, to seek input and to gauge support for starting a community-led flagship initiative.

When sufficient community and partner support was evident, then a small workgroup was formed to develop a flagship initiative proposal. Proposals were reviewed by the NNLP Partnership Team, and a group decision was made whether or not to endorse an initiative. Endorsement meant that funding and other resources would be allocated to the initiative. Principal federal funding sources included the Nebraska Wildlife Grants Program and the Landowner Incentive Program, and state funding was provided through a grant from the Nebraska

Table 2. Criteria used in the selection of Nebraska Natural Legacy Plan flagship initiatives.

Criteria
Initiative will occur within a biologically unique landscape
Initiative has definable, long-term benefits
Initiative will give priority to conservation of remaining high-quality habitats
High likelihood for success
Initiative is biologically and economically sound
Initiative is value-added to current conservation efforts
Initiative will address multiple conservation actions identified in the NNLP
Initiative has potential to serve as a demonstration project
Initiative will provide opportunities to conserve habitat for multiple species
Initiative will seek to maximize local public participation
Initiative will include education and outreach components
Timeline is acceptable
Scale and scope of initiative is appropriate
Budget is realistic and justifiable
Opportunity to maintain or restore habitat for many species

Environmental Trust and the Nongame Tax Check-off programs. The initial budget included $75,000 in federal monies matched by $75,000 in state funds to hire a coordinating biologist, to provide seed money for conservation projects, to conduct outreach and for partnership-building activities.

The NNLP Partnership Team developed a conceptual model for a flagship initiative. The model includes the coordination of private-land and public-land conservation actions, the integration, monitoring and adaptive management of the actions, and educational program delivery and outreach. Leadership for the initiative is provided by a coordinating wildlife biologist hired through a partner organization and cosupervised by the principal funding agency and the sponsoring organization. The coordinating wildlife biologist serves a diverse local steering committee made of local representatives from private and public conservation organizations, from agricultural and community leaders, from economic development interests, etc.

During the initial phase of the flagship initiative, the coordinating wildlife biologist is instructed to conduct outreach to raise awareness about it, to develop a network of potential collaborators and to implement conservation actions on private and public land that can demonstrate the projects. The use and leveraging of conservation-program dollars from the U.S. Department of Agriculture's Conservation Title of the Farm Bill, USFWS Partners for Fish and Wildlife Program and Private Stewardship Program, and from other sources is critical to the success of a flagship initiative.

Implementation

Implementation of the NNLP started in January 2006. Since that time, five other flagship initiatives spanning six BULs have been started. Three or more flagship initiatives will likely be started by December 2007. Four coordinating wildlife biologists were hired in 2006, and the remaining will likely be hired in 2007. In several cases, existing partner positions in various BULs that predate NNLP will be redescribed to conform to the duties associated with the implementation of a flagship initiative. These positions were born out of existing partnerships that may also elect to migrate into the flagship initiative model; this effort is being done under the scrutiny of the NNLP Partnership Team.

To date, all coordinating wildlife biologist positions have been hired through partner organizations rather than through the state wildlife agency for several reasons. Like many state agencies, it has been difficult for the Nebraska Game and Parks Commission (NGPC) to hire new, full-time, permanent employees, even when funding sources have been available. This is mostly attributable to the Executive Branch's desire to keep state governments from growing. NGPC is also seeking to grow the capacity of partner conservation organizations in order to more evenly distribute the workload of wildlife conservation in the state and to raise the profile of these organizations. Lastly, through cooptation, the agency can absorb new and diverse elements into its operating and policy-making structure by collaborating with outside organizations.

The identification of win-win opportunities between agencies and private landowners has lead to the success of flagship initiatives. Although controversial conservation actions, such as acquiring in-stream flow rights and acquiring conservation easements, were identified in the NNLP, we initially are focusing on the delivery of conservation actions that are more readily acceptable to private landowners. Incentives to control invasive species (e.g., eastern red cedar [*Juniperus virginiana*], honey locust [*Gleditsia triacanthas*], smooth brome [*Bromus inermis*]), to improve grazing conditions and to develop and deliver educational programs have been well received by private landowners.

In cases where there is an established partnership working in a biologically unique landscape that predates the NNLP, meetings have been (or will be) held to determine what, if any, role NNLP should play in implementing conservation actions in the landscape. The availability of funding and general support for NNLP implementation has resulted in interest by several existing partnerships to become flagship initiatives. During the expected life of the NNLP (10 years), it's anticipated that new flagship initiatives will start or that existing partnerships will expand in nearly all of Nebraska's BULs. The principal limiting factors that are anticipated are a lack of sustainable funding, partner cooperation or landowner and community support. Currently, sustainable funding appears to be the only barrier for full implementation of the plan.

Discussion

Nebraska's wildlife action plan created a solid foundation of science and partnerships on which to carry out conservation. We believe that the Nebraska model is what was imagined when the idea of state wildlife action plans was conceived. We know that we went beyond the minimum requirements, but we believe that this approach must serve as a means for delivering meaningful conservation on the landscape while providing a basis for future iterations of plan. Even though this plan has received praise, we understand that it is only a beginning.

A key to the development of this plan was that we would actually implement it upon its completion. The flagship initiatives in the BULs are the beginnings of implementation. Some of our pre-existing partnerships, which embodied many of the ideals of the NNLP before it was conceived, were even earlier beginnings that are now being incorporated.

Finally, our work in the flagship projects will conserve species and habitats. Those conservation efforts will, in turn, be studied and monitored, and the results will be fed back into planning iterations and into fine-tuned implementation techniques. They also serve as a foundation for locally led conservation education and information exchange. The impact of such grassroots interactions will help to change the way people think and act when taking conservation action at the local level.

Integrating Wildlife Action Plans with Transportation Planning and Projects: A First Look

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Introduction and Methodology

Many state wildlife action plans provide detailed blueprints for addressing prioritized threats to species of concern and their habitats. Several plans rank the direct and indirect impacts of surface transportation projects among the most significant threats at state or regional scales and demonstrate geospatial capabilities to identify specific transportation projects of potential concern. However, even these plans do not include meaningful strategies for participating in transportation planning processes to assure favorable outcomes for wildlife and to access federal transportation funding for plan implementation. Passage of new federal transportation legislation and federal administrative changes created significant opportunities for spending federal transportation funds to enhance wildlife conservation and to implement relevant portions of wildlife action plans while achieving worthwhile transportation goals.

This paper provides a preliminary report on an ongoing project to identify immediate opportunities for pilot projects to implement relevant portions of state wildlife action plans through federal-state transportation planning and through projects using transportation funding. First, we evaluated authorized federal transportation funding allocations to states over the period 2005 to 2009 for the potential to implement state wildlife action plans and to produce favorable outcomes for wildlife conservation. We analyzed factors such as: (1) total level of federal transportation funding by state, (2) increases in federal funding per state over historical trends, (3) historical state transportation expenditures on programs benefitting wildlife and (4) amount of project-specific funding (earmarks) designated by Congress for projects likely to involve significant wildlife impacts. Based on this analysis, we selected 15 state wildlife action plans for review.

Second, we evaluated these 15 state action plans to determine: (1) whether or not they ranked highly direct and indirect threats posed by surface transportation activities, (2) whether or not they demonstrated geospatial capabilities for identifying specific transportation projects of potential concern, (3) the degree to which leaders of the state's wildlife agency and of its transportation agency may be open to incorporating its wildlife action plan into transportation planning and projects and (4) the existence of a competent and committed constituency for wildlife conservation with knowledge of and support for the state's wildlife action plan.

Third, we analyzed current, federal, transportation-funding programs to identify those programs most likely to be available for expenditure on wildlife-related outcomes. Federal transportation funding is not allocated to states in a lump sum. Rather, it is allocated to states through several distinct programs, with specific amounts of federal funding allocated for distribution to states through each program. We identified eight distinct federal transportation funding programs that could potentially help fund implementation of relevant portions of a state wildlife action plan.

Finally, we evaluated the allocation of funds from each of these programs for use in the 15 selected states to identify 10 transportation initiatives—representative of this array of funding programs—that could serve as pilot projects. Each project may present a significant opportunity for a state wildlife agency and its constituents to work with state and federal transportation agencies in the relevant planning process to implement components of the wildlife action plan (while also achieving appropriate transportation goals) with transportation funding. These projects are currently being evaluated intensively to determine their appropriateness as pilot projects.

Benefits to Federal and State Transportation Agencies of Using Wildlife Action Plans

Transportation practice is gradually migrating to a context-based approach to both program and project planning (see http://www.contextsensitivesolutions.org). Increased sensitivity to wildlife and natural resource protection is a natural result of this trend. However, mission-critical goals, such as improved network efficiency and safety, also support greater attention to wildlife protection. These goals include the following.

Expediting Planning and Project Completion

As tools and techniques for integrating wildlife and natural resource outcomes become available, agencies that incorporate these outcomes into their project development process achieve accelerated approvals as promoting environmental stewardship. Early consideration of wildlife outcomes adds little (about 1 percent) to project costs, a trivial figure when compared to the cost of delay and the benefits of acceleration with highway construction costs increasing by 27 percent from 2001 to 2005 (http://www.fhwa.dot.gov/pricetrends.htm).

Safety Considerations

Transportation cost-benefit analysis focuses on private benefits (reduced delay, more reliable freight delivery, improved safety) to allocate scarce public transportation dollars. The cost of wildlife-vehicle collisions in terms of human injuries and fatalities, vehicle damage and wildlife-related costs (carcass removal and disposal, etc.) is rapidly growing as the actual costs, including run-off-the-road accidents by drivers veering to avoid collisions, are more accurately documented. In rural states, wildlife-vehicle collisions account for more than 50 percent of all reported accidents. As these costs become better known, the safety benefits of making the road network more permeable to wildlife through construction of overpasses and underpasses and through better planning to avoid habitat-road conflicts in the first place become more obvious.

Federal Legislation and Administrative Actions Have Created Significant New Opportunities for Using Wildlife Action Plans to Influence Transportation Planning and Projects

Completion by all states of wildlife action plans and approval by the U.S. Fish and Wildlife Service (USFWS) has shifted attention to implementation. In addition to directing traditional funding streams for fish and wildlife conservation, wildlife action plans have the potential to significantly influence planning and projects by federal and state transportation agencies. Enactment in 2005 of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) and a variety of federal administrative actions have created new and significant opportunities. SAFETEA-LU included a significant new requirement that federally funded surface transportation planning reflect certain considerations, such as wildlife-conservation needs identified in state wildlife action plans. These planning requirements could influence the spending of significant amounts of federal money. Federal authorizations under SAFETEA-LU amount to $284.6 billion over 5 years (fiscal years 2005 to 2009). Since federal transportation grants must be matched by state or local project sponsors between 20 and 50 percent of total project costs, these grants leverage an even higher amount of transportation spending.

Federal funds are disbursed to states through a variety of programs, each of which has distinctive requirements and attributes. These funding programs include the Interstate Maintenance Program, the National Highway System (NHS, corridors of national significance), the bridge program and the Surface Transportation Program (STP, general support for roads of state significance). The federal law also carves out certain expenditures for distribution to states to achieve specific outcomes, such as highway safety, congestion relief, air-quality improvement and community enhancement. Funds provided under each of these programs are eligible, under certain circumstances, for expenditure on projects that benefit wildlife. However, such expenditures are not mandated; wildlife agencies and constituent groups must work closely with state transportation agencies to identify opportunities for achieving mutual objectives.

Recent administrative actions by federal and state governments also encourage integration of wildlife conservation and environmental considerations into surface transportation planning and projects and provide new tools to achieve this objective. Federal administrative actions and programs include: (1) context-sensitive solutions, which seek to calibrate project planning and design to the surrounding community and natural context, (2) exemplary ecosystems, which recognize projects and programs that support healthy ecosystems as a defined project outcome, (3) Eco-Logical, a new tool to assist transportation planners when adopting an ecosystem-based approach to project planning and development, (4) "green" highways, an interagency initiative in the Mid-Atlantic region to promote watershed protection, storm-water management and recycling in transportation project development and system management, (5) transportation enhancements, which is a separately funded program to achieve community and environmental goals, including efforts to reduce vehicle-caused wildlife mortality while maintaining habitat connectivity, and (6) new requirements that state transportation agencies incorporate conservation maps and plans, as well as natural and historic resource inventories, into transportation plans.

Federal Transportation Funding Available for Achieving Wildlife Conservation Priorities

While wildlife mitigation is an eligible project cost in almost all federal-aid, transportation-program categories, we identified several initiatives where intervention by wildlife agencies to affect transportation planning can be of greatest benefit.

Reconstruction of Interstate System

The 44,800-mile (72,098-km) Interstate System, the backbone of the NHS network, reached its 50-year anniversary in 2006. Long segments of the system, built before enactment in 1970 of the National Environmental Policy Act (NEPA), are now reaching their design life and require significant reconstruction. At the same time, other elements of the NHS are being brought up to Interstate System standards, and new high-priority corridors (HPCs) are periodically added to the NHS by Congress. Near-term opportunities for achieving wildlife conservation outcomes and for implementing relevant portions of state wildlife action plans in planning for reconstruction and construction include I-90 in Washington; I-95 in New Jersey, Maryland, Virginia, North Carolina and Florida; I-69 from Texas to Michigan; I-94 across Michigan; and I-73 and I-74 in North Carolina, Virginia and West Virginia.

Transportation Enhancement Program

Created in 1991, the Transportation Enhancement Program (TE) sets aside 10 percent of all funding under the STP for 12 specific categories of nonhighway, community-improvement programs, including improved wildlife habitat connectivity. However, in the 15 years of its existence, only $70 million (1 percent) of more than $7 billion in TE expenditures has been spent on environmental mitigation and much less for specific wildlife-conservation activities. Since the STP is funded at more than $6 billion annually under SAFETEA-LU, more that $600 million is available annually for TE, including wildlife conservation. Aggressive marketing of wildlife action plans to state departments of transportation (DOTs) could free much more TE money in support of these plans. Arizona, in particular, has mapped out wildlife-highway "choke points" throughout the state and is in a good position to take advantage of this opportunity.

Mitigation Banking Programs

All state DOTs are obligated under various federal statutes (NEPA, Clean Water Act, Endangered Species Act, etc.) to minimize the adverse environmental impacts of their projects and to mitigate damage that cannot be avoided. Mitigation costs are paid out of transportation project budgets. Rather than mitigate on a project-by-project basis, DOTs in Minnesota and North Carolina have entered into interagency agreements with their natural resource agencies, soil conservation agencies, U.S. Army Corps of Engineers (Corps), etc. to restore habitats on an ecosystemwide basis. North Carolina has restored between 30,000 and 40,000 acres (12,140 to 16,187 ha) of wetland and coastal habitat under this program, while Minnesota is focusing on restoring its Prairie Pothole Region. Minnesota has also committed to mitigating habitat loses caused by local road construction activities, even though such local road programs are not covered by federal law. DOT dollars are the major source of funding for these restoration efforts.

Federal Land Highway Program

Federal land management agencies (U.S. Forest Service [USFS], National Park Service, USFWS and U.S. Bureau of Land Management) have separate authorizations or, in the case of USFWS, have separate appropriations, for road funding. These funds are used to build and maintain roads within these federal lands. However, they can also be used to pay the nonfederal share (usually about 20 percent) of costs for projects that weave through or that are outside federal land boundaries if they provide access to these areas. Thus, federal NHS or STP funds could be matched with Federal Land Highway Program (FLHP) funds to build projects that protect or enhance these areas with 100 percent federal funding. A potential use of this approach could be funding improvements to SR 41 in Florida (the Tamiami Trail)—an at-grade road that impedes water flow from Lake Okeechobee south to the Everglades—to create an elevated structure (the Tamiami Skyway) to restore historic sheet flows.

Project Funding Generally

While mitigation banking can provide off-site mitigation for project-related habitat impacts, wildlife benefits most if habitat damage is avoided during project development and construction. Increasingly, state DOTs are avoiding habitat damage by adopting context-sensitive approaches to project planning and design. For example Maryland DOT, in partnership with the U.S. Environmental Protection Agency (EPA), is testing a green infrastructure approach to the reconstruction and upgrading of Route 301. It includes an early ecosystem-assessment process that goes far beyond traditional project-study boundaries to assess and mitigate damage to affected watersheds. Similarly, Florida, California, New Jersey, Arizona and Montana are focusing on making projects more permeable for both wildlife and stream flows by designing and constructing overpasses (for wildlife) and underpasses (for both wildlife and waterfowl). Planning, design and construction of these project-related habitat features are paid for out of general federal transportation assistance under the relevant federal program (NHS, STP, etc.).

Highway Safety Improvement Program

Section 1401(a)(3)(B) of SAFETEA-LU added language to the federal Highway Safety Improvement Program (HSIP), making the addition or retrofitting of structures or other measures to eliminate or reduce accidents involving vehicles and wildlife eligible for federal transportation assistance. Since such expenditures are newly eligible under this program, it is not clear if, and to what extent, state DOTs are programming safety money for these purposes. However, states are required to develop strategic highway-safety plans as a condition of receiving this assistance. This provides an opportunity for wildlife agencies and advocates to work with state DOT safety officials to study the magnitude of the safety problem resulting from wildlife-vehicle crashes (or run-off-the-road crashes related to wildlife avoidance) and to allocate HSIP funds to reduce wildlife-vehicle conflicts.

High Priority Projects

High Priority Projects (HPPs), also known as earmarks, are projects specifically funded by Congress as a set-aside from formula grants to states. These projects do not have to compete for funding; the funding is guaranteed. Earmarks can be for any element of project development (planning, design, construction, etc.), and multiple earmarks can fund different elements of the same project (roads, bridges, mitigation, etc.). SAFETEA-LU included more than 6,200 earmarks totaling more than $24 billion. California and Alaska each received more than $1 billion in earmarks. (A list of all earmarks by state can be found at http://www.taxpayer.net/transportation/safetealu/states.htm.) Given the amount of earmark spending in SAFETEA-LU (almost 5 percent of total authorized expenditures), HPPs should be regarded as a separate program with guaranteed, project-specific funding. Since the projects are specifically identified, wildlife agencies and advocates can work with state DOTs to identify potential conflicts between earmarked projects and wildlife action plans and to resolve these conflicts favorably for wildlife conservation through use of earmarked federal funds for wildlife mitigation.

Private-Public Partnerships

In addition to federal grant funding, SAFETEA-LU provided states with a valuable asset to finance transportation projects—the built highway system itself. The existing highway system was financed on a pay-as-you-go basis; highways and bridges were built with funds raised from federal and state gas taxes. Until recently, tolls were prohibited from being collected on the federal-aid system. Consequently, the public owns the system largely debt free. However, federal and state gas tax revenues have not kept pace with system needs, and Congress has gradually allowed states to: (1) borrow money from private equity markets to build projects now and pay for them with future gas-tax revenues, (2) collect tolls on the existing federal-aid system, including the Interstate System, (3) build new NHS highways using toll financing and (4) enter into long-term leases of segments of the federal-aid system to private equity partners who typically make a negotiated payment (up front or over time) for the right to collect and retain toll revenues over the period of the lease. Private payments are then (usually) reinvested in the transportation system to meet immediate funding needs. These public-private partnerships (PPPs) are encouraged by the federal government both on and off the federal-aid system (http://www.fhwa.dot.gov/ppp.htm). Although a new feature of federally financed surface transportation, PPPs are likely to become a major source of future funding for both system reconstruction and new project financing.

State wildlife agencies and advocates should move quickly and aggressively to work with state DOTs to integrate wildlife action plan objectives into state PPP initiatives. State wildlife agencies and advocates should work with state DOTs to include wildlife protection provisions in all leases of highway assets, including requirements that private partners increase corridor permeability for wildlife in the course of reconstruction of the leased asset. A portion of revenues realized from such leases should also be used to mitigate for past wildlife damage. If an asset is retained in public ownership but tolled, a portion of the toll revenues should be set aside for wildlife mitigation. Finally, if new tolled highways are being built, toll revenues should be used to incorporate wildlife mitigation features in highway design and construction and to acquire and protect wildlife habitat adjacent to, or off-site, as part of a mitigation banking program.

Potential Pilot Projects for Using Transportation Program Funding to Implement State Wildlife Action Plans

We reviewed these 8 transportation funding programs as applied to 10 targeted states to identify potential opportunities for using SAFETEA-LU funds—or private funds made available under SAFETEA-LU tolling provisions—to achieve wildlife conservation goals and to implement relevant provisions of state wildlife action plans. Our goal was to identify a potential pilot project in each targeted state that presented a significant opportunity to use one or more of these eight funding streams for wildlife benefits. We also identified a set of potential pilot projects that, together, represented opportunities to explore a diverse array of federal funding programs. Specific opportunities for pilot projects include the following.

Arizona

The Arizona Department of Fish and Game has developed the Vision for Protecting and Restoring Wildlife Connectivity and has identified 152 "linkage zones," where transportation infrastructure (highways, canals, rails) intersects wildlife habitat. It has also identified and mapped the most promising linkage zones along these corridors. This detailed research program (which won a Federal Highway Administration 2007 Environmental Excellence Award) provides an excellent basis for working with state and local transportation agencies to design wildlife crossings (overpasses and underpasses) into corridor reconstruction projects. In particular, U.S. Route 60 between Superior and Miami has been identified as a prime corridor for restoring wildlife connectivity. Arizona ranks third among all states in percentage increase in overall transportation funding (40.7 percent) under SAFETEA-LU, and U.S. 60 is part of the NHS. Since Arizona DOT is in the process of upgrading U.S. 60 in Pinal County, there is an immediate opportunity to incorporate wildlife protection elements into project design under the NHS or STPs.

California

The California wildlife action plan identifies the South Coast Region from southern Los Angeles County to the Mexican border as, "the most-threatened biologically diverse area in the continental U.S." (http://www.dfg.ca.gov/habitats/wdp/region-coast_south/overview.html). Among other things, this plan calls for protection of priority wildlands linkages identified in the South Coast Missing Linkages Project. California was the first state to authorize PPPs to attract private capital to new highway construction. There are several PPPs underway in the South Coast Region, with the most ambitious and the most habitat intensive being SR 125 through the Otay Mesa, an outer-ring-road around San Diego to the border. The project has already committed $20 million to wildlife-protection programs, including the purchase of 1,000 acres (404 ha) of habitat as permanent open space. This project is well into construction, but significant opportunities still exist to leverage this commitment to develop and implement a comprehensive wildlife-protection plan for the area.

Colorado

Transportation and infrastructure are identified in Colorado's wildlife action plan as "key issues affecting the future of wildlife in Colorado for all taxonomic groupings" (*CO CSWS*, Table 13, at 46). Colorado's plan identifies the conservation actions required for, "[m]aintaining and reestablishing habitat and landscape connectivity," to include, "[r]emoving or modifying barriers, protecting corridors (and approaches), riparian areas, using wildlife-friendly roadway crossings, improving planning for wildlife needs in transportation projects, etc." (*CO CSWS*, Table 15, at 57). Colorado received the highest percentage increase in total federal funding under SAFETEA-LU (46.7 percent). I-70, from the top of Vail Pass to East Vail, has experienced significant wildlife-vehicle crashes and high mortality rates for moose, elk and lynx. Parts of the road are scheduled for reconstruction, with Interstate Reconstruction and Maintenance funds available to fund wildlife crossings. Also, the danger to both humans and wildlife is sufficiently significant to consider use of HSIP funds for this corridor. Two new HPC highways are in advanced planning through the eastern prairie region: the Heartland Expressway from Denver to Rapid City, South Dakota, and the Ports-to-Plains Expressway from Laredo, Texas, to Denver. With a former director of Colorado's natural resource agency leading the state DOT, prospects appear good for establishing a productive collaboration between these agencies to address wildlife conflicts.

Florida

According to Florida's wildlife action plan, the highest ranking endangered ecosystem in the United States is the southern Florida landscape (*FL CSWS* at 30). "Roads, bridges and causeways" were identified in Florida's plan as one of the most important, "multiple habitat threats" (*FL CSWS* at 459). Florida has won two Federal Highway Administration Exemplary Ecosystem awards for its geographic-information-system-based tool for integrating transportation, wetland and wildlife planning. At $1.7 billion in average annual apportionments, Florida ranks third in total federal assistance under SAFETEA-LU. Florida is considering over 1,000 miles (1,609 km) of new, tolled highways to support a projected 8 million more residents in the next 25 years. One particular problem is S.R. 41, the Tamiami Trail, an at-grade road across southern Florida that impedes sheet water flow from Lake Okeechobee south to the Everglades. Wildlife advocates have proposed reconstructing an 11-mile (17-km) stretch of S.R. 41, as an elevated skyway that would dramatically improve water flow and wildlife permeability along the corridor. Funding for the estimated $300 million required may be available from three federal programs: the federal STPs, Corps funding under the Everglades Restoration Program and National Park Road (NPR) funding. Since NPR funds can be used as the local match for STP funds for roads through or near national parks, a skyway could be built with 100 percent federal funds.

Maryland

Maryland spends the highest percentage of any state of its TE funds on environmental mitigation, especially habitat restoration (14 percent). It is also cooperating with EPA for a new ecosystem-based, green-highway assessment process in the reconstruction of U.S. 301 through the Chesapeake Bay Watershed. Maryland also leads the nation in promoting a context-sensitive approach to project planning, design and construction. By combining U.S. EPA green-highway assistance with state and federal funding under the STP and TEs, Maryland DOT could collaborate with Maryland Department of Natural

Resources to integrate the goals of the state wildlife action plan into design and development of the U.S. 301 project.

Minnesota

Minnesota requires all roads that destroy wetlands to provide mitigation, even nonstate (local) roads that are not part of the state road system. Minnesota DOT (MinnDOT) will receive an FHWA 2007 Environmental Excellence award for its comprehensive approach to wetland mitigation. The state has identified a series of drained wetlands in the Prairie Pothole Region of the state, especially around and in the Wingard Wildlife Habitat Area in the Red River Valley, as the focus of mitigation efforts. MinnDOT teams up with the state's Bureau of Water and Soil Restoration (BWSR) to do the actual restoration work, and with the Minnesota Department of Natural Resources to manage the restored habitat. In this manner MinnDOT mitigation funding leverages restoration and management services from sister state agencies. Funding comes from federal funds on federally assisted projects and state gas-tax revenues for state and local projects. Minnesota's commitment to provide mitigation funding for virtually all highway projects provides a unique opportunity for wildlife advocates to guide this mitigation funding program to more directly support remediation efforts recommended under the wildlife action plan.

New Jersey

New Jersey, a highly built-out state with one of the lowest state gas taxes in the nation (10 cents per gallon), has limited transportation resources. Expenditures for wildlife must, therefore, closely support core state transportation goals. New Jersey DOT has responded to its funding challenge by closely coordinating transportation with land-use planning to reduce growth in travel demand. For example, New Jersey's wildlife action plan specifically recommends setting up joint working group with the state DOT (*NJ CSWS Summary* at 3). The plan recognizes that New Jersey's, "extensive road network fragments habitat, causes significant wildlife mortality and can present significant barriers to wildlife movement" (*NJ CSWS* at 21). New Jersey presents an important opportunity in one of the nation's most urbanized regions to advance dual transportation and habitat protection goals, especially in parts of the New York Metropolitan Watershed, such as the New Jersey Highlands. In addition, the New Jersey Turnpike (I-95) is a pre-NEPA Interstate Highway with severe habitat impacts, especially on the New Jersey Meadowlands. The turnpike is a prime candidate for an asset lease through a PPP that could contribute up to $22 billion to state coffers. Lease terms or lease revenues could be leveraged to retrofit this asset to restore hydrologic flows and to improve wildlife permeability as a condition of any such lease.

North Carolina

North Carolina DOT (NCDOT) has taken a proactive role in habitat mitigation by collaborating with the Department of Environment and Natural Resources (DENR) and the Corps to establish and fund an Ecological Enhancement Program (EEP). The NCDOT and the Corps place mitigation funds into the EEP based on projected wetland losses through implementation of the 10-year State Transportation Improvement Program (STIP). The EEP, located within DENR, manages these funds to identify, protect and restore degraded wetland habitat on an ecosystemwide basis. Over the last 10 years, more than 30,000 acres (52,609 ha) of wetland has been protected and restored in this manner. North Carolina is in the process of building I-73 and I-74, an HPP through its western region, and of reconstructing I-95 through its eastern region. Both projects could benefit from on-site wildlife mitigation through permeability improvements (overpasses and underpasses) and off-site mitigation through the innovative EEP.

Pennsylvania

Pennsylvania, a state of hills and valleys, has more than 5,900 substandard bridges. The cost of reconstruction to bring them up to state standards is estimated at $8 billion. With few funds left for system improvement, Pennsylvania is considering leasing or mortgaging the Pennsylvania Turnpike to raise approximately $14 billion to meet these needs. This presents an opportunity both to: (1) overlay maps of defective bridges with wildlife-habitat maps to determine if some defective bridges could be decommissioned and converted to wildlife overpasses as a wildlife action plan initiative and (2) embed wildlife permeability as an objective of any lease agreement concerning the Pennsylvania Turnpike. Funding could be provided through: (1) an up-front royalty payment, (2) making permeability retrofits a condition of the lease itself, (3) the federally assisted bridge program or (4) use of NHS funds to achieve this objective since the Pennsylvania Turnpike is part of the NHS.

Washington

Washington's wildlife action plan identifies the transportation system as a significant conservation problem for the North Cascades Ecosystem, observing, "[w]hen highways fragment landscapes, they divide wildlife populations into smaller, isolated units that are more susceptible to extirpation" (*WA CSWS* at 360). With respect to, "incompatible transportation development," the plan states, "[l]arge highway corridors (including Highways 20, 2, and I-90) and associated development fragment suitable habitat and create barriers or impediments to movement for gray wolf, wolverine and lynx" (*WA CSWS* at 362). Conservation actions recommended by the plan for this ecosystem include: "Work with the Washington Department of Transportation to locate highways away from important wildlife habitats and biodiversity areas. If impacts are unavoidable, design adequate mitigation such as underpasses, overpasses and fencing to accommodate wildlife that need passage, such as elk. . .and western toad" (*WA CSWS* at 369). Washington's DOT has a history of collaboration with conservation and environmental groups, including cooperative action to increase the wildlife permeability of the I-90 Corridor through the Cascade Mountains down to Puget Sound. This area, which is bounded in long stretches by national forest lands, has high habitat value. In addition, the Cascade Land Conservancy (CLC) has adopted the goal of preserving 1.26 million acres (509,903 ha) of land along the western slope of the Cascades, including 7 watersheds, as working farms, forests and natural areas (http://www.cascadeagenda.com). The Sierra Club is working with Washington DOT and the USFS to map wildlife routes, to identify appropriate I-90 crossing sites and to plan for wildlife and water passageways as a component of ongoing I-90 reconstruction. Protection of the western slope of the Cascade Range from sprawl development will also reduce demand for new infrastructure in this area and will allow Washington DOT to focus its capital funds on bridge reconstruction and transportation improvements in the Tacoma-Seattle-Everett Urbanized Area. Implementation of these conservation activities could be funded through the USFS Roads Program, Washington DOT's Interstate Reconstruction and Maintenance Funds, STP funds and private donations through collaboration with CLC and private philanthropists.

Conclusion

State fish and wildlife agencies must take the initiative when working with their constituent groups to engage in the various transportation-planning programs in order to implement wildlife action plans for species and habitats where plans indicate significant direct and indirect impacts of surface transportation projects. While state and federal transportation agencies may have enhanced flexibility—and resources—they lack related information and expertise, are focused on transportation-related outcomes, follow complex decision-making processes and use a vocabulary that is alien and arcane to outsiders. Implementing state wildlife action plans will require more than willing transportation agencies. It will require proactive engagement by wildlife agencies and their constituents to understand transportation planning and funding approaches, to master the relevant vocabulary, and to offer relevant expertise in a timely fashion. Most important, it will require that wildlife agencies and their constituencies acknowledge appropriate and worthwhile transportation needs and goals. Wildlife advocates must lead in finding ways to meet these goals that simultaneously advance wildlife outcomes and implement relevant features of state wildlife action plans.

Session Four.
Communicating Effectively about Aquatic Nuisance Species: Compilation of Aquatic Nuisance Species Workshop Abstracts and Presentations

Phil Seng
D. J. Case and Associates
Mishawaka, Indiana

Introduction

A full-day workshop, Communicating Effectively about Aquatic Nuisance Species, was held on March 19, 2007, in conjunction with the 72nd North American Wildlife and Natural Resources Conference. The workshop was a forum for state, federal and tribal agency administrators—along with technical staff, university researchers, nongovernmental organizations (NGOs) and corporate representatives—to discuss communication strategies to consolidate and coordinate issue-related information. The workshop focused on determining how to communicate most effectively to counter the spread of known and potential aquatic nuisance species (ANS).

The workshop was based on ANS communication efforts in four pilot states. In 2003, the Association of Fish and Wildlife Agencies (AFWA) received a multistate conservation grant to support a comprehensive, 3-year project to help address ANS communications issues. This project addressed the need to increase state agencies' effectiveness to manage ANS challenges. AFWA partnered with all four regional associations, four state fish and wildlife agencies, respective in-state and regional partners, and the U.S. Fish and Wildlife Service (USFWS) to test communication efforts. The completed project offers recommendations and resources that states and other partners can use to communicate on ANS issues. An interactive portable document format (PDF) file provides a wealth of information about ANS communications strategies and about how to address ANS regulation and enforcement issues. It is available at the USFWS Protect Your Waters Website at http://www.protectyourwaters.net/ansreport/mainmenu.pdf.

The workshop focused on highlighting states' pilot-program efforts and on engaging an even larger audience in this challenge. The event allowed participants to share information about and to discuss the successes and challenges in developing and implementing communication strategies about ANS. The workshop focused on:

- case histories of pilot project communication efforts
- communication strategies, using information developed by others as a template to address similar ANS issues elsewhere in consideration of personnel and funding constraints
- regional coordination mechanisms
- ANS materials that reduce development time, money and redundancy
- effective partnerships, including corporations, businesses and organizations
- scientific information and databases.

This paper is composed of abstracts and presentation excerpts, following the workshop agenda. The workshop was sponsored by the American Fly Fishing Trade Association, AFWA, Bass Pro Shops, D. J. Case and Associates, the Sport Fish and Boating Partnership Council, U.S. Geological Survey, USFWS, Wildlife Forever and the Wildlife Management Institute.

Workshop Presentations

Opening Remarks

Phil Seng
D. J. Case and Associates
Mishawaka, Indiana

Description of Association of Fish and Wildlife Agencies Communications Project and Tool Kit

Challenges for agencies and organizations that desire to improve ANS communications efforts include: (1) a lack of a unified policy approach, (2) a limited capacity for marketing natural resource issues and (3) conflicts in how the issue is viewed from state and federal perspectives.

Based on this knowledge, AFWA developed an ANS communications project to address and overcome these issues. AFWA selected four states (Arizona, Missouri, New Hampshire and South Carolina) to develop pilot programs targeting ANS communications strategies. AFWA also convened four regional workshops, where state agencies and partners identified key ANS regulation and enforcement issues at regional and national levels.

State Pilot Projects

The goal of the state pilot projects was to increase states' capacities to address ANS issues through comprehensive communications strategies. A representative state was selected from each of the four AFWA regions. States were chosen that had not completed an ANS management plan and were experiencing invasive species issues typical of the region. States represented coastal, marine and freshwater aquatic resources from northern to southern climates. States varied fairly widely in the level of fiscal and staff resources that they could contribute to the project, which provided an indication of the range of tasks that could be accomplished by agencies within a range of budgets.

The four states each generated a state-specific ANS communication plan. An in-state team identified a subset of high-priority and then feasible actions for immediate implementation. Actions were evaluated for success wherever possible.

As part of the communications pilot project, AFWA encouraged states: (1) to identify communications tactics to affect change, (2) to emphasize value-added outcomes and partnerships, (3) to create ownership at all levels of involvement, (4) to target key audiences with education and outreach activities that promote action and (5) to link education and outreach activities with policy processes and capacity building.

Pilot teams met to identify species-of-concern and target audiences. They assessed existing outreach mechanisms to develop marketing plans as well as to implement and evaluate strategies as part of overall ANS communications plans in each state.

Regional Workshops

Regional workshops and recommendations were: (1) to unite diverse stakeholders, including agencies, NGOs, universities and industry, (2) to identify priority ANS issues, actions and partners and (3) to strengthen regional association efforts for ANS management. ANS regional committees developed position statements and identified high-priority coordination actions. More information on regional workshops is provided in Joe Starinchak's presentation "Regional Workshops and Recommendations."

Results

Pilot ANS communications projects and regional workshops encourage other states to develop their own ANS communications efforts and management plans, providing a step-by-step process for doing so.

As part of the pilot communications strategies, the four states accomplished five key things. They (1) applied Stop Aquatic Hitchhikers! campaigns as an overarching communications vehicle, (2) developed state-specific ANS Webpages, (3) identified target audiences, (4) promoted prevention messages and (5) enhanced state capacity to handle ANS issues. All tools and materials developed through pilot program efforts and regional workshops are available at http://www.protectyourwaters.net/resources/iafwa-ans-comm-pilot.pdf.

The ANS communications project demonstrated that no single agency or organization has enough resources or authority to address ANS alone. It is clear that partnerships are effective to get beyond so-called standard government outreach to find real solutions to really difficult issues.

The communications project was developed by AFWA, D. J. Case and Associates, Southwick Associates, SR Enterprises and USFWS.

State Pilot Presentation—The New Hampshire Experience: Communicating with the Public about Aquatic Nuisance Species

Stephen G. Perry
New Hampshire Fish and Game Department
Concord, New Hampshire

Focus on aquatic nuisance species was a lower priority within the New Hampshire Fish and Game Department (NHFGD) prior to its involvement in the pilot project to develop a comprehensive ANS communications plan. The New Hampshire ANS communications efforts consisted primarily of partnering with a sister state agency to produce brochures jointly that provided information about dangers of zebra mussels and exotic plants and about how boaters could prevent their introduction and spread into New Hampshire waters.

The goal of the New Hampshire ANS Communication Plan is to, increase the level of awareness and action (i. e., public, media, legislative, etc.) to address aquatic invasive species problems in New Hampshire by communicating the significance of the aquatic nuisance species problem, current and potential dangers, and potential solutions—including prevention—in order to mitigate negative impacts on New Hampshire's natural resources and its economic environment.

During the planning process, three principal outcomes were identified for the New Hampshire ANS Communication Plan: (1) enhance New Hampshire ANS policies, (2) induce measurable changes in targeted audience behavior to reduce ANS infestations and (3) develop long-term partnerships to effectively address ANS issues.

The actions taken as a result of the New Hampshire ANS Communications Plan include: (1) forming a planning team to develop a New Hampshire ANS Management Plan that will establish ANS priorities and will enhance the coordination of multiple state agencies in addressing ANS issues, (2) establishing a New Hampshire-specific ANS Webpage that is hosted on the Protect Your Waters Website (http://www.protectyourwaters.net), which contains a variety of educational and outreach materials that can be used to communicate with various audiences about ANS issues, (3) incorporating of the Stop Aquatic Hitchhikers! logo along with New Hampshire's Protect Your Waters Webpage address into all New Hampshire-related ANS material to build brand recognition of the national ANS public awareness campaign, and (4) reaching out to targeted audiences in an effort to get individuals to take preventive actions against spreading ANS.

The New Hampshire ANS communications planning process served as a catalyst to bring partners together to address common ANS issues in a more coordinated and effective way. It also identified key audiences, along with specific obstacles and opportunities to consider when developing strategies and tactics. Since funding is a primary factor that drives most programs, it's critical for cost efficiency to be an integral component. Developing New Hampshire ANS partnerships provided the opportunity for partners to review outreach efforts associated with each ANS-related program area. As a result, they could determine whether there were more cost-effective ways to do things, as well as to identify cost-sharing possibilities.

State Pilot Presentation—The Arizona Experience: Aquatic Nuisance (Invasive) Species Communications

Lawrence Riley
Arizona Game and Fish Department
Phoenix, Arizona

ANS is a topical and challenging issue for Arizona, although by no means a new one. As wildlife managers in the Southwest, we find the definitions adopted and interpreted by many to be challenging, recognizing that not all introduced species should be considered invasive. Arizona's participation in AFWA's ANS pilot communications project was slow to start, but it took an unusual, productive turn. Working through the project, we identified key audiences and messages to meet our desired outcomes to:

- increase public awareness of ways to reduce the spread or impact of existing species and to prevent the introduction of new ones
- increase the number of public users who take the initiative to monitor and report ANS observations
- change behaviors so that the public is proactive in responding to messages, in asking questions and in taking actions to prevent spread and introductions
- improve partnerships among cooperating agencies and organizations
- increase the level of participation by Arizona local, state and federal organizations in the Stop Aquatic Hitchhikers! campaign
- influence Arizona policy to address ANS issues and to ensure that the state remains current in regulating them.

Aquatic Nuisance Species and Their Impacts

Arizona's full implementation of a communication strategy was compelled by an opportunity to influence a key audience—Arizona policy and decision makers. In 2005, Governor Janet Napolitano signed Invasive Species Executive Order 2005-09 that afforded us the opportunity to lead development of recommendations for a broader, coordinated state approach. Arizona deployed resources into that undertaking. In that regard, we met many of our desired outcomes with that audience and with the broader public, though less measurably than initially planned.

In January 2007, Governor Napolitano signed a second invasive species executive order directing establishment of the Arizona Invasive Species Advisory Committee as a standing body led by Arizona's Game and Fish Department and the U.S. Department of Agriculture (USDA). The executive order also mandated development of a state invasive species management plan. Arizona's communications strategy will be an underpinning for elements of that effort.

State Pilot Presentation—The Missouri Experience: ANS Communication Pilot Project

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Missouri Department of Conservation
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Norman P. Stucky
Bass Pro Shops
Jefferson City, Missouri

This paper highlights lessons learned from this ANS communications pilot project in Missouri, representing Midwestern states.

Prior to the pilot project, the Missouri Department of Conservation (MDC) did not have a comprehensive approach or a clear, consistent message for ANS outreach efforts among all resource divisions. Staff dealt with ANS as a hot topic or as opportunities and issues arose. Materials were developed as needed or as time allowed with no specific plan for marketing. A key reason ANS was addressed in a fragmented manner was that MDC had no one person coordinating or documenting past or current efforts.

The ANS pilot project provided the opportunity to have dialogue and to brainstorm ideas in a forum that involved all divisions and that included input from other states and agencies. The resulting ANS communication strategy was a multidiscipline document that helped MDC to set goals and objectives, to establish priorities, and to meet milestones in a timely manner. The strategy was incorporated into the Missouri Aquatic Nuisance Species Plan required by USFWS.

Key to successfully tackling the ANS issue is solicitation of partners to reach target audiences. Missouri partnered with bait shops, anglers and corporate sponsors, such as Bass Pro Shops. Bass Pro Shops has been a solid MDC partner and is nationally recognized for working with state and federal agencies on diverse conservation efforts.

Involvement in the pilot project allowed us to leverage funds to produce products outside of our normal scope; we wouldn't have been able to develop them otherwise. The pilot project reaffirmed MDC's commitment to be more active in regional and national ANS meetings and workshops. It was a reminder that more financial and staff resources must be directed to the issue. Finally, it helped MDC to identify the greatest threats, to examine the various pathways for these threats, to identify partners and to set realistic goals and time lines.

Accomplishments

Missouri's ANS plan:

1. formed the ANS Outreach Subcommittee to work on a variety of outreach materials, including those already developed by other agencies that could easily be modified to fit Missouri's needs
2. identified a person in MDC Outreach and Education to coordinate development of additional outreach materials
3. secured an invasive species coordinator position within MDC, using the communication strategy as a supporting document.

Recommendations

Upon review of the situation, Missouri's ANS plan recommends the MDC to:

1. pursue opportunities to partner more with the tackle industry, particularly Bass Pro Shops, to help with outreach efforts to anglers
2. encourage other states to develop ANS management and communication plans (Since our aquatic resources are potentially impacted by anglers and boaters coming from neighboring states, it is appropriate that we offer assistance to other states in helping them develop a marketing strategy.)
3. conduct a regional or national survey of boaters to determine boater awareness of ANS issues to document user patterns on various waters

and to identify marketing strategies to further develop prevention efforts, particularly on zebra mussels

4. encourage USFWS, the American Sportfishing Association, and the American Boating Association to work with manufacturers, especially the bait bucket industry, to include ANS messages on products.

Regional Workshops and Recommendations

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Regional workshops have been a critical part of the building formula for addressing ANS issues nationwide. As part of the ANS communications project for pilot states, AFWA hosted a series of workshops to identify and prioritize issues on a regional basis throughout the United States. A workshop was held in each of the four AFWA regions and involved state fish and wildlife agencies, state and federal law enforcement, regional entities, and federal agencies responsible for regulating ANS through development of region-specific plans. The goal of the regional coordination workshops was to help AFWA and regional associations of fish and wildlife agencies develop a stronger voice and greater capabilities when addressing regional and national ANS regulation and enforcement issues.

In the past, states have lacked ownership of the ANS issue and have had diverse learning curves to become knowledgeable about it. As a result, states have not been strong in addressing ANS independently or with their neighbors. By uniting in regional workshops, states could form a team to learn and share data and resources, to identify regulatory and policy needs, and to clearly understand their strengths and weaknesses in addressing ANS issues. In addition, states could present a united front to the public by developing and sharing effective public outreach strategies.

Results

Regional ANS coordination action plans were developed during the workshop for all regions. These action plans represent the best thinking in the country on what needs to be done to elevate ANS at regional and national levels. The workshops were successful in generating diverse participation and in identifying priority issues and actions on a regional level.

Recommendations

Top recommendations for action across all regions are to:

1. generate additional funding at state, regional and national levels for regulation, enforcement, planning, education and control, including reauthorization of the National Aquatic Invasive Species Act (NAISA) and similar federal and state legislation
2. continue support for development and implementation of state ANS management plans. This is particularly critical for enhancing and establishing local and regional infrastructure to combat invasives
3. develop proactive early-detection and rapid-response procedures with adequate funding and regulatory authority for identification and control of newly established populations
4. increase resources for enforcement of importation laws, including training for species identification, investigation into Internet sales and inspection of shipments
5. develop and use economic-impact information to promote prevention strategies among traditional fish and wildlife agency constituent groups and nontraditional audiences.

Next Steps

Next steps include continuing to encourage regional associations of fish and wildlife agencies to enhance their capacity by: (1) formalizing invasive species standing committees, (2) elevating ANS to a priority within regional associations and within the national AFWA, and (3) using and updating action plans as guidance.

Status

Following are ANS activities by the four regional associations.

Western Association of Fish and Wildlife Agencies. The Western Association of Fish and Wildlife Associations (WAFWA) published the resolution "State Wildlife Agency Leadership for Aquatic Nuisance Species," in July 2004. The resolution was coordinated with a resolution from the Western Governors Association (05-11). Both resolutions call for building regional capacity through collaborative work among the two associations and with the Western States Water Council.

WAFWA also improved its relationship with the Western Regional Panel of the ANS Task Force by identifying a WAFWA representative to participate on the panel. WAFWA is involved in several ongoing activities.

1. The region's fisheries chiefs address ANS annually at their annual meeting, and action items are elevated to western states' directors through the Inland and Marine Fisheries Committee.
2. Since the workshop, fisheries and law enforcement chiefs have coordinated annually by sharing an agenda item for training and discussion at the annual WAFWA meeting.
3. Collaboration between WAFWA and members of the Western States Boating Law Administrators (WSLBA) has increased, with training sessions provided at their annual meeting.
4. Training was developed for enforcement officers regarding zebra mussels, boat inspections and boat decontamination. William Zook of the Pacific States Marine Fisheries Commission led the effort by seeking financing and by developing the training module. This effort involved collaboration among WAFWA, WSBLA, National Association of Boating Law Administrators (NASBLA), and the Western Regional Panel of the ANS Task Force. NASBLA has accredited training as a continuing education unit.
5. Worthy of note is collaboration between WAFWA and the U.S. National Park Service (NPS), which activated the Incident Command Team to develop plans for park units that might become affected by zebra or quagga mussels. A WAFWA representative is working with the team to provide input from states' perspective to include in the planning effort.

Midwestern Association of Fish and Wildlife Agencies. The Midwestern Association of Fish and Wildlife Agencies (MAFWA) has yet to form an invasive species committee. State wildlife action plans are directing considerable attention to invasive species. Recommendations are to develop a wildlife action plan working group, which will be voted on during MAFWA's next annual business meeting in July 2007.

Northeastern Association of Fish and Wildlife Agencies. In 2005, the Northeastern Association of Fish and Wildlife Agencies (NAFWA) leveraged involvement with American Fisheries Society's Northeast fishery administrators to develop a technical advisory group. The advisory group members created the document, "Statement on Transgenic Fishes," recommending steps for protecting native and naturalized fish species from the potential threat posed by transgenic fish.

In 2006, NAFWA sponsored a half-day Aquatic Nuisance Species Rapid Response Workshop. It compiled a master list for the Northeast of prohibited ANS in each state to facilitate communication and coordination.

Southeastern Association of Fish and Wildlife Agencies. The Southeastern Association of Fish and Wildlife Agencies (SEAFWA) has established regional priorities and has created the ANS Committee. It has elevated the ANS issue by sponsoring a regional session at its annual meeting. SEAFWA is uniting efforts among the Southeast Aquatic Resources Partnership, AFWA Invasive Species Committee and ANS Task Force regional panels.

Communicating ANS Issues Using Partnerships: The Stop Aquatic Hitchhikers! Yellowstone Case Study

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This paper highlights the lessons learned from this pilot ANS communications effort in the Greater Yellowstone Area.

Prior to AFWA's pilot project in the Greater Yellowstone Area, ANS issues were addressed in a piecemeal fashion. However, under the leadership of the Western Regional Panel on Aquatic Nuisance Species, interagency coordination, networking and information sharing has helped to build government capacity for addressing this issue. This has only been possible through the support of the Pacific States Marine Fishery Commission and USFWS. Through USFWS regional ANS coordinators, the 100th Meridian Initiative has served as the primary communications vehicle to addressing western ANS issues.

While these efforts are vital for addressing aquatic nuisance species issues in the West, Stop Aquatic Hitchhikers! Yellowstone has added some additional value. By providing a model for driving government coordination and for collaboration at the ground level, Stop Aquatic Hitchhikers! Yellowstone also serves as a catalyst to create significant partnerships in the region to promote aquatic nuisance species awareness and prevention behaviors and to leverage additional communication capabilities.

Within the Greater Yellowstone Area, efforts to address ANS invasions have been compartmentalized, confined and limited by the efforts and scarce resources of individual federal and state resource agencies or of nonprofit organizations. Also, they primarily have been focused on the issue's resource components. Montana Department of Fish, Wildlife and Parks has led the way through the implementation of its statewide ANS management plan. Wyoming and Idaho have addressed the issue as part of their resource management responsibilities.

While the three states have done a good job in recognizing the issue's outreach component, they have acknowledged their limitations and the value of synergy through partnerships. This is where Stop Aquatic Hitchhikers! Yellowstone comes into play. By relying upon collaboration and by focusing on the human dimension of the ANS issue, Stop Aquatic Hitchhikers! Yellowstone is the foundation for a unique, public-private partnership to conserve a unique area. While the ANS pilot communication strategies served as a guide, they were not explicitly used due to the unique regional nature of this effort. As a result, a different set of strategies was pursued. The primary drivers of this collaborative response were threefold. The goal was to:

1. create a lasting, public-private partnership focusing on promoting aquatic invasive species awareness and behavior change (i. e., cleaning equipment to prevent the spread of aquatic invasive species)
2. communicate the same message in the gateway communities surrounding Yellowstone National Park
3. leverage considerably greater communication capabilities than what is available to the government.

Regarding these strategies and extensive consensus building efforts to secure support among government agencies, a variety of them worked while others did not. However, the key has been to focus on common ground, to recognize public-private synergies, to demonstrate public unity and to provide a value-added mechanism to communicate about ANS and how audiences can become part of the solution. Involvement in the regional pilot effort allowed partners to build and leverage relationships and funds to facilitate a different way of thinking.

Accomplishments

This program has:

1. formed the core ANS Outreach Working Group comprised of representatives from the USFWS, USDA Forest Service, Yellowstone National Park, Federation of Fly Fishers, Montana Fish, Wildlife and Parks, Wyoming and Fish Department, Idaho Fish and Game Department, Patagonia, and Simms Fishing Products
2. emphasized promoting simple, consistent messages and built on existing information and experience, instead of reinventing the wheel
3. identified specific funding sources to support on-the-ground efforts to raise aquatic nuisance species awareness
4. sponsored a regional, marketing workshop to engage public, private and nonprofit interests and to encourage regionwide thinking.

Recommendations

The Stop Aquatic Hitchhikers Yellowstone must:

1. pursue strategic opportunities within Greater Yellowstone Area gateway communities to better understand the business community's needs when it comes to marketing conservation
2. educate potential funding sources about this complex conservation issue, particularly stressing human dimensions
3. pursue innovative partnerships with affected interests to leverage their unique skills and abilities.

Closing Remarks—Where Do We Go From Here?

William W. Taylor
Sport Fishing and Boating Partnership Council
Michigan State University, East Lansing

During this workshop, we've heard a lot about the shared leadership roles that AFWA and USFWS have assumed regarding ANS. Collaboration needs to become the standard for addressing this issue.

The pilot projects are instructive of new approaches to communications and partnerships related to aquatic nuisance species. The tools that these pilot programs highlight are available now.

Whether through state pilot efforts, regional workshops or public-private activities in the Greater Yellowstone Area, these projects focus on collaboration and building capacity. That is an appropriate focus given the complexity of our efforts to control and manage aquatic nuisance species.

My charge is to assimilate all this great work and to offer direction. I think we can get the biggest bang for our buck by enhancing the conservation community's capacity for addressing invasive species. There are several ways to do this.

Work across Boundaries

No one organization has the resources or authority to undertake or maintain an effective ANS management regime. We need to work across the jurisdictional boundaries that often define how we work.

One way to work across organizational boundaries is to form partnerships among agencies, conservation organizations and industry. Industry has an interest in this fight and can be a formidable ally. This workshop is a good example. We wouldn't be meeting today if industry hadn't recognized the critical need for communications and hadn't tried to move this agenda. As has happened in the case of the Greater Yellowstone Area, industry and conservation organizations can be a powerful force in on-the-ground efforts in critical local areas.

See the Bigger Picture

We need to look at the bigger picture. Coming from the Great Lakes, I have an intimate understanding about existing bureaucratic, funding and legislative challenges our community faces. I suggest that we explore many different ways to enhance our community's capacity.

The U.S. Congress is critical in granting authority to address ANS issues. The houses of Congress are at different places when it comes to aquatic nuisance species. The House of Representatives will address this issue only on a species-by-species basis; the Senate will address the issue in a more comprehensive fashion. Given this gap, I suggest that the conservation community seize the opportunities and come up with several alternatives to address the capacity issue.

By seeking legislative sponsors who are willing to put forth bills that address various challenges, like funding obstacles, bureaucratic challenges and legislative disincentives, I think we have a better shot at getting what we want.

AFWA can play a critical role by elevating this issue on its legislative agenda, by finding sponsors willing to address various issues and by building the community's capacity wherever possible.

Speak to Target Audiences

Probably most important when speaking about ANS issues, we need to make sure we speak in a direct way to the various audiences with which we seek to communicate. As biologists, we often have a level of understanding that the public may not have. If we are going to be effective in speaking about these critical issues, we must speak about nuisance species in using language that is easily understood.

Poster Session

Opening Remarks—Wildlife Forever: Marketing Reaches Sportsmen and Women to Battle Aquatic Nuisance Species

Brett Richardson
Wildlife Forever
Brooklyn Center, Minnesota

It is a pleasure to share Wildlife Forever's experiences as an NGO working with partners to promote the control of invasive plants and organisms. We are in the second year of enlisting anglers, hunters and recreational users of our lakes, streams and wetlands in a collective effort to combat ANS.

Wildlife Forever is the nonprofit conservation arm of the North American Hunting Club and of the North American Fishing Club, with a combined membership of 1.3 million hunters and anglers nationwide. We work with a broad spectrum of agencies and organizations to conserve fish and wildlife. In short, partnerships are at the core of how we operate.

What if North America's sportsmen and sportswomen were fully engaged on the invasives issue? What benefits would be created if 50 million new partners understood the need to inspect, clean and drain their equipment to remove invasive species after a day on their favorite lake or stream?

Wildlife Forever believes the solution lies in education and cost-effective marketing to raise awareness of the challenge that invasives pose to North America's outdoor heritage. By collaborating with federal and state agencies, local partners and private media corporations to promote ANS messages, Wildlife Forever serves as a bridge linking diverse partners in the public and private sectors. We call this growing effort the Threat Campaign, and this year we will reach out to fellow nongovernmental sporting organizations and to local conservation clubs to partner on outreach to hunters and anglers.

Wildlife Forever understands the threat that invasive species pose, and we can act fast to secure media buys (buying advertising space from companies operating media properties). However, we look to scientists and invasive-species professionals to recommend best management practices to halt the invasion. We don't have staff biologists, so we rely on you. Our hope is that, by working together, we can make your message resonate within our community. On national and regional levels, we are working closely with invasive species experts, such as Mike Ielmini and Nick Schmal (of USDA Forest Service), Mike Hoff (of USFWS), and other invasives specialists from Minnesota, Wisconsin and Iowa departments of natural resources. We also work with Sea Grant, the National Fish and Wildlife Foundation, and the Center for Invasive Plant Management.

Wildlife Forever has used proven strategies of professional marketers to disseminate ANS messages. Private corporations must generate a return on investment when spending marketing dollars, and we are following that example. The Threat Campaign is a multimedia outreach campaign that includes television, radio, lake-country billboards, airport dioramas and magazine and newspaper public-service announcements. All messages are crafted to gain quick attention and to take advantage of current thought trends and concerns of the U.S. public. Headlines include "Stop Aquatic Hitchhikers!," "America's Most Wanted," "Warning," "Fugitives" and "Invaders." Using proven marketing tactics, we target the message to the means of delivery.

In 2006, our pilot Threat Champaign reached more than 125 million people in the United States, promoting best management practices for fighting the invasion of exotic species. Our group pooled more than $100,000 for the effort. And, through discounts and partnerships, we received a $250,000 media buy. Using the power of television, we teamed up with Babe Winkelman to support our effort.

An independent industry poll named Babe as the most recognized sportsman in the United States. According to Jarrett Babinscak of Miller Beer, Miller drinkers like legends, and when we get Babe involved in a promotion or sweepstakes, the results are incredible. Babe knows his audience. With input from invasive species specialists from USDA Forest Service and USFWS, the public-service announcement we produced conveys a scientifically sound message in a way that resonates with viewers. Through Wildlife Forever's relationship with Winkelman Productions, this media buy was obtained at only 41 percent of Babe's regular rate. That's cost-effective marketing, and we make it available to our partners.

Our 2007 public-service announcement features Steve Pennaz from the North American Fishing Club. Steve is lucky enough to spend 60 days a year on premier fisheries throughout the United States. Having seen the adverse affects of unchecked invasive species firsthand, he and the North American Fishing Club have collaborated with Wildlife Forever to become dedicated advocates on this issue. The 30-second, public-service announcement will air on North American Fisherman Television for 20 weeks. Networks carrying the announcement include Fox Sports, Comcast West, Sports South and the Sportsman Channel. The total number of possible impressions is 20.3 million. We also teamed up with Steve in North American Fisherman magazine with full-page ads, reaching a targeted audience of 12 million anglers and boaters.

In 2006, a unique partnership was formed with Clear Channel and Lamar Advertising, the nation's largest billboard companies. In partnership with Minnesota DNR and Sea Grant, along with the USDA Forest Service and USFWS, Stop Aquatic Hitchhikers! signs were strategically placed on northbound arteries from Minnesota's Twin Cities with heavy lake travel. During peak fishing and boating months, we reached out to 9.3 million travelers with the message. This success can be duplicated in your state.

Another effective project is use of airport diorama—the illuminated light boxes in airports. We selected Minneapolis-St. Paul International Airport for the pilot program. We worked with invasive-species professionals to target scientifically sound messages to the means of delivery. During 6 months, we reached out to 51.4 million people traveling to the Land of 10,000 Lakes at 25 percent of the media buy's retail value.

All told, the Threat Campaign pilot project reached out to 1,200 people with every $1 invested. This year, we're working to do better. There is much work to do. Know that you have an ally in Wildlife Forever and that we will help carry your message forward to hunters and anglers.

Invasive Species in Stream Ecosystems

Bruce Rieman, Daniel Isaak, Charlie Luce, Russ Thurow and Kerry Overton
U.S. Department of Agriculture, Forest Service,
Boise Aquatic Sciences Laboratory
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Invasive fishes are a primary threat to the integrity of stream ecosystems. Although widely distributed, invasions and disruptions of native communities are not universal. Understanding locations for major invasion risks will be key to prioritizing limited management resources. Accordingly, our research has three major elements *detection*, *prediction* and *management.*

Detection is focused on development of unbiased and more efficient sampling tools to understand the distribution and dynamics of species across river basins.

Even with better sampling, inventory and monitoring will still be expensive; new models are needed to predict existing distributions and to identify vulnerable habitats. We are adapting newer statistical tools for landscape-scale analyses to identify important processes. We also are developing new models to predict distribution and dynamics of critical environmental characteristics, such as stream temperature.

Management of nonnative invasions often is a trade off. Intentional isolation of native species to preempt invasion, for example, can increase the risk of local extinction through habitat fragmentation. We are working in collaboration with the USDA Forest Service's Region 1 and with other agency biologists to develop framework and decision tools for evaluating these competing issues.

Nab the Aquatic Invader: A National Partnership to Use Free-choice Learning to Reduce Introduction and Spread of Aquatic Invasive Species

Terri Kirby Hathaway
North Carolina Sea Grant
Manteo, North Carolina

Samuel S. Chan
Oregon Sea Grant
Oregon City, Oregon

Nab the Aquatic Invader (NAI) is the result of a partnership of national, regional, state and private agencies involved in aquatic invasive species research, outreach and education. Funded through the National Sea Grant College Program, the tool kit was tested at institutions accredited through the Association of Zoos and Aquariums (AZA) nationwide. The final version will be distributed to over 200 AZA sites.

Educators at these facilities have the potential to reach millions of visitors annually; however, they need interactive and entertaining programs for diverse audiences. NAI engages an audience for about 20 minutes. By illustrating common behaviors, the program arms them with knowledge to help them to avoid contributing to the introduction and spread of invasive species.

The kit contains props and background material for educators to present the short program, with additional information to develop longer programs. The national message focuses on (1) invasive species as a threat to natural ecosystems and (2) identification of distinct pathways by which the general public may unknowingly introduce invasive species or may encourage their spread. The program is flexible; thus, it facilitates creating regionally relevant messages about pathways or species.

The project included evaluation processes throughout, including input from regional ANS Task Force panels, demonstrations at appropriate national meetings, and beta testing.

Stop Aquatic Invaders on Our Coast!: ¡Detanga el Transporte de Especies Invasoras Acuáticas en Nuestras Costas!

Leigh Johnson and Jamie Gonzalez
University of California Cooperative Extension,
Sea Grant Extension Program
San Diego, California

The University of California Cooperative Extension, Sea Grant Extension Program, in San Diego County, has been working on issues of coastal water quality protection and invasive species prevention. Recent studies suggest that fouling growth on boat hulls is a significant vector for aquatic invasive species, especially for boats traveling along the coast. Aquatic invasive species can consume or out-compete native species, can foul vessels and coastal structures, and can damage shorelines.

We published a bilingual poster which explains problems caused by hull-borne invasive species and how to reduce the risk of transporting them on recreational boat hulls. Colorful photos of invasive species will help boaters to identify them and report them to the appropriate agencies. We have also published a bilingual fact sheet based on the poster.

Controlling Nutria

Edmond Mouton
Louisiana Department of Wildlife and Fisheries
Baton Rouge, Louisiana

Nutria (*Myocastor coypus*), native to South America, is an introduced, invasive semiaquatic rodent. Populations in coastal Louisiana result from escapes and possible releases from nutria farms in the 1930s. The decline in fur trapping since the mid-1980s has resulted in an overpopulation of nutria. Annual surveys have revealed that approximately 80,000 acres (32,375 ha) of Louisiana coastal wetlands can be impacted at any one point in time. Nutria herbivory damage is ongoing, and many damaged sites are not likely to recover naturally.

Without comprehensive management of nutria herbivory damage, the stability of the Louisiana coastal ecosystem is threatened. Since the introduction of the Coastwide Nutria Control Program, the estimate of impacted acres has been reduced to approximately 46,000 acres (18,616 ha). The project is funded by the Coastal Wetlands Planning, Protection and Restoration Act through the Natural Resources Conservation Service and the Louisiana Department of Natural Resources with the Louisiana Department of Wildlife and Fisheries as the lead implementing agency.

The project goal is to significantly reduce damage to coastal wetlands resulting from nutria herbivory by removing 400,000 nutria annually. The method chosen for the program is an incentive payment to registered trappers and hunters for each nutria tail delivered to established collection centers.

Eradicating Knotweed in Riparian Corridors

April Johnson
The Nature Conservancy
Olympia, Washington

Infestations of Japanese knotweed (*Polygonum cuspidatum*), giant knotweed (*P. sachalinense*) and bohemian knotweed (*P. bohemicum*) are widespread throughout the Chehalis River Basin in Washington. They likely will significantly alter riparian habitat on this river if their spread continues unchecked.

In 2004, The Nature Conservancy initiated a project to eradicate knotweed in riparian corridors throughout the basin. We expect to accomplish this goal over several years through a headwaters-down control strategy, beginning with the most upstream knotweed infestations. This approach reduces chances of reinfestation lower in the watershed via stream transport of stem or root fragments or seed.

The majority of private landowners have been cooperative, while some have liability concerns limiting our treatments. Two methods of application are employed: (1) injection of 100 percent glyphosate or (2) targeted foliar spray of 2 percent glyphosate and 1 percent imazapyr. This has resulted in kill rates of 80 to 100 percent following a single treatment.

The West Coast Ballast Outreach Project: Coordinating Ballast Water Information Exchange for the West Coast

Holly Crosson
University of California, Sea Grant Extension Program
Oakland, California

California Sea Grant Extension Program's West Coast Ballast Outreach Project (WCBOP) coordinates information exchange about ballast water, vessel fouling and associated aquatic nuisance species along the West Coast of North America.

Initiated in 1999 with National Sea Grant College Program funding, WCBOP began its second phase in 2005 with funding from the CALFED Bay-Delta Program.

A primary goal of WCBOP is facilitating communication among stakeholders in the maritime industry, state and federal government, universities, environmental organizations and the public. Outreach about ballast-water management and treatment technologies, about vessel fouling and about ANS are guided by an advisory committee with more than 50 members. It has representation from California, Oregon, Washington, Alaska and Canada.

Outreach materials include our award-winning Stop Ballast Water Invasions poster, its companion brochure, our biannual newsletter—*Ballast Exchange*—and a Website. WCBOP also organizes meetings and educational seminars for various audiences.

At this communication workshop, we will display and distribute our poster, brochure and newsletter.

100th Meridian Initiative

Paul Heimowitz
U.S. Fish and Wildlife Service, Pacific Region
Portland, Oregon

Stephen Phillips
Pacific States Marine Fisheries Commission
Gladstone, Oregon

The 100th Meridian Initiative is a national campaign to prevent the westward spread of zebra mussels and other aquatic nuisance species. Its Columbia Basin Team represents a diverse partnership of federal and state agencies, tribes, NGOs, academia and others—all cooperating to reduce ANS impacts in the Pacific Northwest.

This team has carried out a number of communication projects to enhance prevention and early detection efforts. Those projects include a variety of boater education activities (written materials, boat shows, etc.), outreach to private marinas, training of law-enforcement personnel regarding identification and decontamination of contaminated watercraft (classroom and video), media communications, Websites and low-power radio broadcasts.

Most recently, driven in part by the discovery of quagga mussels in the Colorado River Basin, this team has developed an interagency zebra and quagga mussel rapid-response plan, of which external communications is a major component.

Outreach Tradeshow Exhibits for Control of ANS

Paul Heimowitz
U.S. Fish and Wildlife Service, Pacific Region
Portland, Oregon

Stephen Phillips
Pacific States Marine Fisheries Commission
Gladstone, Oregon

USFWS Pacific Region works with a variety of partners to promote prevention of, detection of, rapid response to and control of aquatic nuisance species. Outreach of the public and specific user groups is an essential tool for each of those objectives. A tradeshow-style exhibit has been developed and displayed in a number of venues to raise awareness about ANS with these target audiences. The exhibit was recently on display at the Museum of Idaho for 6 months, and a second version of the display is now permanently featured at the Bonneville Dam Visitor Center, which is a major tourist destination in the Pacific Northwest.

Schools and Science Curricula as Potential Pathways for Aquatic Invasive Species

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Robyn Draheim
Portland State University, Center for Lakes and Reservoirs
Portland, Oregon

Classroom teachers often use live specimens ordered from biological supply houses to illustrate concepts in their science classes. However, live organisms used in school can become nuisance species if they are released outside of the classroom. Live organisms commonly used in classrooms highlight a potential ANS problem involving both technical and social issues. This issue first came to our attention in spring of 2005 when a colleague attended a parent-teacher conference and was invited to help release lab species into a local creek. In examining the curriculum, we discovered that little or no information was provided about specific species used or about their disposal.

We began researching these pathways which included schools, curriculum, supply houses, suppliers, teachers and students. As a short-term goal, we developed an awareness and prevention brochure distributed to schools and teachers to provide schools with the information and resources about ANS, to encourage instream studies and to learn through the use of native organisms, their proper care and disposal and ways to prevent their spread.

Medium-term goals include providing ANS information built on science and social knowledge, informing students and teachers about more ecologically benign options for dealing with organisms, and working with supply houses to supply more benign species and ANS prevention information. In the long-term, goals could include stopping use of invasive species (at the risk of ignoring an important teaching opportunity), incorporating concepts of biological invasions and invasive species awareness and prevention into existing lesson plans, and using native species or instream learning.

Inventory of Aquatic Invasive Species Outreach Materials

Robyn Draheim
Portland State University, Center for Lakes and Reservoirs
Portland, Oregon

Education on invasive species impacts and management is critical to effective prevention efforts. While outreach materials come in many forms, the most common products are brochures, signs, handouts and other printed materials aimed at specific audiences advancing specific messages. A regional inventory is vital to avoid duplication of effort, to enhance exchange of readily available information and to help educators evaluate gaps in existing outreach efforts.

With seed money from the Western Regional Panel on Aquatic Nuisance Species, the Center for Lakes and Reservoirs began to develop such an inventory of information in 2003. Approximately 200 outreach and education materials focused on aquatic invasive species in the West have been catalogued and an online database interface has been created.

As a result of a pilot database and beta testing, additional database features have been requested by potential users including:

- a dynamic Website-database interface, allowing authors and publishers to input their own records while maintaining a high standard for submissions
- a peer review and ratings system for material evaluation
- expansion of the geographic scope of the inventory beyond the western United States
- more powerful search algorithms
- storage space for PDFs and joint photographic experts group (JPEG) files of materials available online.

West Coast Ballast Outreach Project Website: A Tool for Communication, Outreach and Information Exchange

Alisha Dahlstrom
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The updated West Coast Ballast Outreach Project's (WCBOP) Website (http://ballast-outreach-ucsgep.ucdavis.edu) serves as a medium for increasing awareness of ANS and ballast water issues, contains WCBOP outreach materials—including the Stop Ballast Water Invasions poster and brochure, issues of *Ballast Exchange* and a calendar of upcoming events.

Biosecurity for Natural Resource Pathways

Bob Pitman
U.S. Fish and Wildlife Service, Southwest Region
Albuquerque, New Mexico

David K. Britton
U.S. Fish and Wildlife Service, Southwest Region
Arlington, Texas

Without appropriate planning, natural resource management work may provide pathways to unintentionally spread hitchhiking nontarget species. Introduced biologic contaminates often impact native species and their habitats. In the 1960s, NASA and Pillsbury Foods refined the Hazard Analysis and Critical Control Point (HACCP) planning process as a straightforward method to prevent contamination in food processed for the moon missions.

Today, as a common-sense planning method, HACCP is used around the world to identify, analyze and manage contamination risks in all kinds of activities, including natural resource work. Hitchhiking species of plants, animals, diseases, pathogens and parasites are pathway concerns to agencies across the country. Adopting HACCP as a common language used by all states to manage natural resource pathways could help reduce the spread of hitchhiking species or biologics. Improved biosecurity barriers developed through strategic planning protects species and habitats.

HACCP gained worldwide support and use because it works! Its five linked forms help planners strategically evaluate risks (hazards) and develop prevention actions, which are focused on key locations (critical control points) in an operation or pathway where they are most effective. Prevention strategies are easily reviewed in transparent plans allowing quick evaluation to block high-risk pathways. Records assist agencies in consistently improving efficiency through time. HACCP plans its document by asking: who, what, why, where, when and how.

USFWS sponsors a support Website, http://www.haccp-nrm.org, providing forms, guides, training announcements, links and a searchable database of plans. A computer-based planning wizard, developed by David K. Britton, is available to help with planning.

The Global Invasive Species Information Network

Elizabeth Sellers
U.S. Geological Survey
Reston, Virginia

Annie Simpson
National Biological Information Infrastructure, U.S. Geological Survey
Reston, Virginia

The transport, translocation and introduction of invasive alien species are issues of global concern. Successful early detection, prevention and management of invasive species and their impacts on the environment require cooperation on information exchange at local, national and global levels. In 2002, the Global Invasive Species Information Network (GISIN) was proposed at the sixth meeting of the Conference of the Parties to the Convention on Biological Diversity, held in The Hague, Netherlands. It is a network of invasive species experts, information managers, scientists, researchers, land managers and computer scientists sharing knowledge and experience, adopting standards and protocols for information exchange, and facilitating the dispersal and increased availability of invasive species information at the local, national, regional and global level.

In 2004, experts from 26 countries attended the first GISIN meeting to establish goals and an interim steering committee to move the network forward. In 2005 a Website was established for the GISIN (http://www.gisinetwork.org), and an extensible markup language (XML) schema for invasive species profiles was developed, with support from the Convention on Biological Diversity secretariat. The schema will establish a standard method for global invasive species information exchange.

Work has continued through workshops held in 2006 and 2007 to develop a prototype implementation of the GISIN Invasive Species Profile Schema that may eventually be adopted by invasive species data owners worldwide. The number and complexity of invasive species information systems, databases, clearinghouse mechanisms and networks in the United States and the world will continue to grow. The GISIN will grow with them to promote Internet application server (IAS) information sharing.

Session Five.
Predators and Prey: Integrating Predator and Prey Management to Achieve Conservation Objectives

Opening Remarks

Robert L. Byrne
Workshop Chairman
Safari Club International Foundation
Washington, DC

Welcome. For those who do not know me I am Bob Byrne, the former Conservation Program Manager for the Safari Club International Foundation. I am now a Project Manager for D J Case and Associates, a Conservation Communications Consulting firm in Indiana.

I appreciate you all taking time out of your busy schedules to attend this workshop. This is a timely topic, and an exciting time for the issues we are covering.

Before we get started, I'd like to talk briefly about the history of this workshop and SCIF's role in its development.

SCIF is a relatively new 501(c)(3) conservation, education and humanitarian services organization affiliated with the better known Safari Club International. SCI is an international hunting organization and its members are avid eco-tourists who are motivated by hunting to embark on world–wide adventures. Throughout its history, SCI members have contributed to conservation projects in both the US and in far-off lands. The formation of SCIF was a logical step so that SCI members could focus their conservation efforts in a more effective manner.

However, since SCIF *formally* entered the "conservation game" rather late, it was far easier to develop a conservation program that is "brand-able" in foreign countries than it is in the US. Quite simply, the US is blessed with a plethora of species- and equipment-driven sportsmen/conservation organizations that cover the conservation waterfront quite well, and there was little left of SCIF to "own."

After some internal reviews it was determined that one area that was not fully covered is the interaction between large predators and their prey, particularly large ungulates. This focus fits very well with our member's interest in having well managed populations of both. As a result, we have been strategically investing in research on this issue for several years and will likely to continue investing in this research for some time. The results of some of that research will be presented here today.

Saying that we have "well managed populations of both predators and their prey" is much easier than doing it! As we all know managing a single species of wildlife in today's economic, social and political (ESP) climate is far from easy. Doing so, with multiple species, each species with a complex array of ESP issues, which in turn are often matched with conflicting human values and diverse stakeholders, is *nearly* impossible.

The operative word in that sentence is "nearly," because the agencies involved are doing a remarkable job in spite of the difficulties.

You will note that while the planning committee strove to obtain a diverse mix of speakers; the agenda is weighed toward agency personnel. That was a conscious decision, because they have the vested legal authority to make decisions. *How* they make the decisions is a participatory process that anyone can join. However, ultimately, the agencies (even if aided by court rulings) will have to make the decisions.

Decision making is difficult at best. In spite of its difficulties, generally, you can expect better outcomes if you make *informed* decisions. And that is why we are here, to share information so that our collective wisdom can be applied to the decision making process.

However we should not stop here. We hope that this is meeting will help set the stage for future discussions on *achieving conservation objectives.* As we all know, decision making without knowing your outcomes and how to measure those outcomes can be fraught with danger. Again, that is why we are here, so that we can begin to crystallize achieving these conservation objectives in an integrated manner.

SCIF is certainly committed to that process, which is why we elected to host this meeting in conjunction with the Wildlife Management Institute.

In closing, I also want to thank our presenters and moderators for assisting SCIF and WMI in putting this program together. They have a lot of information to share. In fact if you look at the agenda we could be accused of having too much information to share.

Again, thank you all for attending. I am confident that it will be worth you time and effort to be here.

Culling Mountain Lions to Protect Ungulate Populations—Some Lives Are More Sacred Than Others

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Introduction

Long ago, I heard someone note that hardly ever has there been a group of placard-waving, animal-rights protestors present when a lake or reservoir is treated with piscicide, also known as fish toxicant, to remove carp (*Cyprinus carpio*) and other "trash" fish. Compare this to the national, and even international, outcry that results from a state wildlife-management agency's decision to conduct lethal removal of top carnivores, such as wolves (*Canis lupus*) or mountain lions (*Puma concolor*), despite a body of scientific literature to support such management efforts (Gassaway et al. 1983, Ballard et al. 1987, Sinclair et al. 1998, Ernest et al. 2002, Hayes et al. 2003). To paraphrase George Orwell, indeed, "some lives are more sacred than others," (Orwell 1945) Reiter et al. (1999) noted that the sociopolitical ramifications of culling top carnivores are substantially greater than those affecting trash fish or even mesocarnivores. How does society and science reconcile this management dilemma?

Societal perspectives on predator control are snapshots. If we were to record the societal perspective on culling top carnivores from the late-19th century until the mid-20th century, they would be very different than a recording made today in the early-21st century. Governmental and societal goals of extirpating top carnivores to protect drastically reduced wild-ungulate populations at the turn of the 20th century were in concert. Society and science subsequently recognized that the consequences of eliminating top carnivores cascaded throughout ecosystem processes. However, it might be argued that, if global-warming predictions come true and if massive crop failures result in a return to the bushmeat trade in North America, then, the culling of all top carnivores may become the dominant societal paradigm once again. In Africa, bushmeat trade increases in direct proportion with societal chaos, including armed conflict, crop failure and displaced refugees. Societal perspectives on culling top carnivores are inextricably tied to societal economic viabilities.

Bounties and Bounty Hunters

Historically, top carnivore removal was carried out to protect game species and livestock throughout the western states. In fact, most predator species were bountied, with higher bounties paid for culling females in a concerted effort to reduce or eliminate populations. For example, in New Mexico in the 1950s, the New Mexico Department of Game and Fish employed 23 full-time trappers; the federal government emplo yed full-time trappers in New Mexico as well (A. Ford, personal communication 2003). This intensive governmental effort occurred during an era when most private ranchers kept their "steel in the ground,"i. e., leghold traps, year-round in an effort to eliminate top carnivores. It is important to note that these government trappers were highly respected members of their communities and were considered members of an honored profession. However by the early 1970s, all but two western states had converted mountain lions to game-animal status and state-agency trapper positions were essentially eliminated. Despite the best effort of the government trappers and of their private-sector allies, mountain lions were never extirpated in the western United States. The conversion to game- animal status came too late for wolves in the western United States and Mexico and for grizzly bears (*Ursus arctos*) in Mexico and in much of the western United States. These two species went from varmint status to endangered-species status.

California versus Texas

California and Texas, bounding the western and eastern distribution of mountain lions, have equally dichotomous management strategies for mountain lions. Presumably, these divergent management strategies are based on differing societal values in these two states. Texas never elevated mountain lions to game-animal status, and year-round hunting and trapping of mountain lions continues throughout their range there. The management strategy in Texas contrasts sharply with that in California where a legislative moratorium passed in 1972 ceased sport harvest and public trapping of all mountain lions.

Intensive mountain lion harvest in Texas has not resulted in the extirpation of mountain lions, and mountain lion distribution is considered to be similar today to what it was 35 years ago (C. Brewer, personal communication 2007). Because of this fact, Texas Parks and Wildlife (TPW) was a principal complainant resulting in the Western Association of Fish and Wildlife Agencies (WAFWA) not endorsing, or otherwise sanctioning, the recently drafted *Cougar Management Guidelines—First Edition* (Schroufe 2006). Perceived differences on the needs for harvest quotas and sanctuaries, to maintain mountain lion populations, were central to this complaint.

The consequences of no-sport harvest of mountain lions are less understood in California. High levels of mountain lion predation on small isolated populations of bighorn sheep (Wehausen 1996, Ernest et al. 2002) has resulted in Peninsular bighorn sheep (*Ovis canadensis cremnobates*) and Sierra Nevada bighorn sheep (*O. v. sierre*) populations being listed as federally endangered populations.

Ballot Initiatives

There are important sociological and scientific lessons to be learned from the ballot initiatives regarding mountain lions passed in California, Washington and Oregon. In 1990, California's Proposition 117 made permanent the 1972 legislative moratorium on harvesting mountain lions. Although Proposition 117 barely passed—51 percent to 49 percent, and with the exception of Mono County, only passed in the major urban counties—California Department of Game and Fish lost management authority for this species. Some states prohibit wildlife management issues from becoming ballot initiatives, thereby leaving management authority for wildlife in the hands of professional wildlife managers.

It is interesting that prior to the elimination of sport hunting in California, annual harvest was approximately 150 mountain lions per year. Today, California and U. S. Department of Agriculture, Wildlife Services cull approximately 150 mountain lions per year because of depredation complaints on livestock and on pets and because of concerns for human safety. The historical number of 150 mountain lions per year more accurately reflects the actual number of mountain lions killed than does current estimates because a bounty was paid during much of the historical period. It has been suggested that frustration with restrictions imposed by Proposition 117 may result in mountain lions being killed illegally, resulting in an underestimate of mountain lion harvest. Total mountain lion harvest in California today, following the complete ban of sport harvest, probably exceeds mountain lion harvest prior to the ban.

The use of hounds to hunt mountain lions was eliminated in Oregon and Washington in the mid-1990s via ballot initiatives promoted by the animal-rights community. Prior to the ban on hound-hunting in Oregon, between 400 and 600 mountain lion licenses were sold, and 140 to 250 mountain lions were harvested statewide. In Washington, approximately 1,500 mountain lion licenses were sold annually and approximately 300 mountain lions were harvested annually. Currently, due to changes in license fees and seasons, Oregon and Washington sell about 35,000 and 50,000 mountain lion hunting licenses, respectively. As a result of the dramatic increase in the number of hunters afield with mountain lion licenses, harvest levels in Oregon have doubled and female harvest in the last 5 years has increased 242% compared to levels prior to the ban (from 1987 to 1994 it equaled 78 females per year versus 189 per year between 2001 and 2005). Harvest levels in Washington remain essentially the same, with an increase in the number of females lions harvested.

Hound-hunting generally allowed for bayed mountain lions to be sexed prior to harvest. Preference for larger males resulted in a male-dominated harvest with hound hunting. Because of the different hunting technique employed in the absence of hounds, the opportunity to identify sex of a mountain lion prior to harvest rarely occurs. The result has been a higher proportion of female mountain lions harvested in both Oregon and Washington than prior to the ballot initiative.

Endangered Ungulates versus Hunted Ungulates

Predator control of mesocarnivores, including raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*) and striped skunks (*Mephitis mephitis*), has been recommended to protect rare or endangered species (Hecht and Nickerson 1999). The same biological principle would apply to predator management of large carnivores, including mountain lions, wolves and bears (*Ursus* spp.), that prey on endangered ungulates, including Selkirk woodland caribou (*Rangifer* *tarandus caribou*) or Peninsular desert bighorn sheep. Four western states have endangered populations of ungulates (Table 1). Except Oregon, these states allow the removal of mountain lions to protect endangered ungulates; although, the action has rarely been employed (Table 1).

Table 1. Status of mountain lion control efforts for endangered ungulates and game ungulates by state. X represents where lion control can occur; O represents where lion control does not occur; n/a represents no endangered ungulates existing in that area.

	Endangered ungulates	Game ungulates
California	X	X
Idaho	X	X
Washington	X	X
New Mexico[a]	X	X
Oregon	O	X
Arizona	n/a	X
Utah	n/a	X
Nevada	n/a	X
Montana	n/a	O
Wyoming	n/a	O
Colorado	n/a	O

[a] In New Mexico, desert bighorn sheep are classified as a state-endangered species.

In part, the reluctance of state agencies to cull mountain lions, even to protect rare or endangered species, stems from fear of litigation from the animal-rights community. However, an interesting anecdote suggests that, if state agencies have adequate data distributed to the public, less litigation might transpire. The anecdote goes something like this. At a public meeting to address concerns about high levels of mountain lion predation on translocated radiocollared woodland caribou in the Selkirk Mountains, the topic of culling mountain lions to protect endangered woodland caribou was broached. A member of the animal rights public asked the biologists, "Let me get this straight. You can kill mountain lions for fun [i. e., for sport harvest], but you can't kill mountain lions to protect an endangered species?"

In New Mexico, state-endangered desert bighorn sheep declined to fewer than 170 individuals with mountain lion predation determined to be the principal mortality factor (Rominger and Weisenberger 1999, Rominger et al. 2004). New Mexico Department of Game and Fish radiocollars all desert bighorn sheep that are handled; generally more than 25 percent of the statewide population was radiocollared during the monitoring period. Research in Arizona on diets of mountain lions in desert habitat found 43 percent of dietary biomass was comprised of domestic beef calves (Cunningham et al.1999). Extensive use of exotic ungulates by mountain lions in the desert results in their being subsidized predators, *sensu* Soule et al. (1988). Mortality data (Rominger et al. 2004), combined with evidence in New Mexico of the subsidized predator prediction, resulted in near unanimity among concerned groups and agencies that culling mountain lions to mitigate the high level of mortality was required to avoid extinction of this state-endangered species. This was a case of an informed society being able to make a better decision than an uninformed, polarized society.

The effects of mountain lion predation on big-game populations are such that most western game agencies cull mountain lions, or have plans to cull mountain lions, to protect big-game populations (Table 1). Hunting and conservation groups and state wildlife agencies have recognized that in some circumstances, culling of top carnivores is beneficial for protection of newly translocated big-game populations, small and isolated big-game populations, or big-game populations held below carrying capacity by predation (Hayes et al. 2003, Rominger et al. 2004, McKinney et al. 2006). In the Yukon, most residents agree that the consumptive interest of people should be balanced with the needs of predators (Yukon Wolf Planning Team 1992).

Between 1985 and 1999, mountain lions were not culled to protect endangered desert bighorn sheep in New Mexico (New Mexico Department of Game and Fish, personal communication 2007). Between 1992 and 1999, approximately 85 percent of the known-cause mortality of radiocollared desert bighorn sheep was attributed to mountain lion predation (Rominger et al. 2004). Concern about the cascading effects of a subsidized mountain lion population on faunal biodiversity in the New Mexico portion of the Chihuahuan desert, particularly state-endangered desert bighorn sheep, resulted in an agency decision to reinstitute culling of mountain lions in five desert bighorn sheep ranges. A combination of translocation and significantly higher survival rates of radiocollared adults has resulted in the desert bighorn sheep population in New Mexico increasing from fewer than 170 in 2001 to more than 400 in 2007 (New Mexico Department of Game and Fish, personal communication 2007).

Conclusions

The geographic range of mountain lions is larger than any big-game mammal in North and South America (Logan and Sweanor 1999). It would be unreasonable to believe in a one-size-fits-all understanding for mountain lion populations. An example of this is the recent mountain lion research conducted in the Chihuahuan desert by Logan and Sweanor (2001) that diverged from findings documented from earlier, more northerly mountain lions studies (Hornocker 1970, Seidensticker et al. 1973). Research conducted early in the Logan and Sweanor (2001) study was contradicted by results derived later during drought conditions in the same study area. A better understanding of the cascading effects of subsidized mountain lion populations and the effects of harvest regimes on mountain lion populations, may change both societal perspectives and perspectives of management agencies responsible for these populations. It is important for society, and for scientists, to recognize that societal perspectives and scientific understanding change with time and with increased knowledge.

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Prey Specialization by Individual Cougars in Multiprey Systems

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Introduction

The cougar (*Puma concolor*) has made a remarkable recovery in North America over the last half century. This can be attributed primarily to the termination of predator-bounty programs and to a change in management status for cougar from vermin to big-game species. Most western states and provinces now boast healthy, harvestable populations of the big cats (Beausoleil and Martorello 2005), and the animals are even reoccupying parts of their historic range east of the Rocky Mountains (Neilsen et al. 2005). This is a rare success story in a world where most of our large carnivores are threatened, and many are even critically endangered through habitat loss and overharvest. A plethora of recent scientific work on predators (Ray et al. 2005) suggests that recovering and maintaining large carnivores in ecosystems can have benefits that go beyond their intrinsic value as wilderness icons, their recreational and economic value as big-game species and furbearers, or the inherent fascination that they hold for most people. Growing populations of wolves in North America, for example, have been shown to decrease populations of ungulate prey and, through what is known as a trophic cascade, to increase the biomass of plants that benefit numerous other species, from songbirds to beaver (Hebblewhite et al. 2005). Predators also may influence population dynamics and community structure by changing the behavior of their ungulate prey (Brown et al. 1999). Predation risk imposed by healthy populations of predators can cause ungulates to avoid certain areas, resulting in an alteration of ecosystem structure and increased biodiversity (Ripple and Beschta 2004). The predatory behavior of cougars, therefore, can have a substantial influence on ecosystems.

This same predatory behavior, however, can result in unwanted declines in populations of prey that are locally or regionally endangered or that have recreational and economic importance for hunters and other wildlife enthusiasts. While cougar predation may have compensatory effects on ungulate populations in some cases (Hornocker 1970, Laundre 2005), although detailed experimental evidence is often required to clearly implicate predation as a major limiting or regulatory factor for prey (Boutin 1992), there have been several documented cases where cougar predation is the primary cause of population decline (Wehausen 1996, Festa-Bianchet et al. 2006). Indeed in some cases, cougars have taken prey to the brink of local extinction (Sweitzer et al. 1997, Logan and Sweanor 2001), leaving little doubt about the potential for predation by cougars to negatively affect the population viability of prey.

Cougar predation, therefore, can be considered to have both positive and negative effects, depending on perspective and context. To optimize these effects through management, a firm understanding of cougar predatory behavior is required. This paper examines one important aspect of this behavior—prey specialization by individuals—which can have important implications for the extent that cougars influence populations of their prey. We begin by discussing cougar predation in multiprey systems because it is in these systems that the effects of cougar predation are most pronounced and because this is where strong individual preferences for a particular species of prey (specialization) is possible. Next, we review the literature as it pertains to cougar prey specialization and also provide some new data from the first year of an ongoing study of cougar predatory behavior along the eastern slopes of Alberta's Rocky Mountains. Finally, we discuss the management implications of prey specialization by cougars and the gaps in our knowledge that still need to be addressed by future research to improve the performance of management actions.

Cougar Impacts on Prey and the Importance of Multiprey Systems

The effect that large carnivores have on populations of their ungulate prey has been studied and hotly debated in North American wildlife management circles for decades. It is a topic that has predominantly centered on wolf-ungulate systems and has focused chiefly on interactions between wolves and their primary prey (Bergerud et al. 1983, Boutin 1992, Messier 1994, White and Garrott 2005). Until recently, other predators and types of systems had not received the same attention. In the case of cougars, this was no doubt due to preliminary data suggesting that their predatory behavior did not restrict the growth of prey populations (Hornocker 1970), perhaps because cougar populations were constrained by social factors to a level below that set by food supply (Seidensticker et al. 1973). In the 1990s, however, reports of cougars depressing populations of their prey began to emerge (Turner et al. 1992, Wehausen 1996, Ross et al. 1997, Sweitzer et al. 1997). These case studies, combined with research dispelling the idea that social factors kept cougar populations below what food availability would predict (Pierce et al. 2000, Logan and Sweanor 2001), catapulted cougars to the foreground of predator-prey debates.

In direct opposition to Hornocker's (1970) early belief, with respect to bighorn sheep (*Ovis canadensis*), that, "the numbers taken by lions are insignificant," (23), several of the reported examples of cougars depressing populations of prey involve bighorn. For small populations of these sheep, even a single cougar is capable of causing substantial mortality. In Alberta, for example, a lone female cougar was responsible for killing 9 percent of a sheep population, including 26 percent of the lambs, over the course of a few months during winter (Ross et al. 1997). In the peninsular ranges of California, cougars reportedly killed 26 percent of the sheep in one population and are thought to be capable of impeding the recovery of endangered populations. In the Sierra Nevada, cougar predation has been identified as the single most important factor in the precipitous decline of what had previously been a successful reintroduction of bighorn (Wehausen 1996), and cougar predation has recently been identified as a primary cause of four major declines in three populations of sheep in Alberta and Montana (Festa-Bianchet et al. 2006). Bighorn are not the only species to be affected, however. Populations of mule deer (*Odocoileus hemionus*), feral horses (*Equus caballus*), mountain caribou (*Rangifer tarandus*) and even porcupines (*Erethizon dorsatum*) have suffered declines as a direct result of cougar predation (Turner et al. 1992, Sweitzer et al. 1997, Kinley and Apps 2001, Robinson et al. 2002).

In nearly every case of prey depression reported for cougars, the species suffering a decline is a secondary prey item in a multiprey system. The critical feature of multiprey systems that exacerbates the ability of cougars to negatively affect prey is the ability of the cougar population to sustain itself on alternate prey. The impact this has on ungulate prey can take two forms. The first is known as apparent competition, which occurs when two or more prey species collectively contribute to the maintenance of a larger predator population than could be sustained on any one prey type alone, to the detriment of all types of prey (Holt 1977). The second is known as indirect amensalism, which occurs when the presence of one prey species negatively affects a second prey species, but the presence of the second has little or no effect on the first. Asymmetrical apparent competition (i.e., approaching indirect amensalism) may be common in vertebrate predator-prey systems (Chaneton and Bonsall 2000), and, if the smaller population of alternate prey is the more negatively affected, predation may rapidly become depensatory. This is especially true if the predator numerical response to population reductions of alternate prey is delayed or nonexistent because of a strong association of predator populations to those of their primary prey.

In many predator-prey systems, predation on small populations of alternate prey is rare and may be incidental to the search for primary prey (Schmidt et al. 2001). In such cases, small populations are less likely to be adversely affected by predation, especially if they are able to occupy habitats that are rarely frequented by the predator in its search for primary prey species (Schmidt 2004). In systems where selection of prey by predators occurs, however, the negative effects of asymmetrical apparent competition on populations of secondary prey are greatly exaggerated if the secondary prey species also happens to be the preferred prey (i.e., taken at a rate greater than available). Cougars often exhibit prey selection in multiprey systems (Hornocker 1970, Kunkel et al. 1999) and, thus, are capable of such exaggerated impacts. For example, in a cougar, white-tailed deer (*Odocoileus virginianus*) and mule deer system in southern British Columbia, white-tailed deer were the primary prey of cougars and, consequently, a primary determinant of cougar carrying capacity (Robinson et al. 2002). Cougars in this system, however, selected heavily for mule deer, which suffered a predation rate of nearly double that of white-tailed deer. White-tailed deer populations are stable and continue to support a relatively large cougar population that is capable of exerting sustained pressure on the dwindling population of preferred mule deer prey (Robinson et al. 2002). This has resulted in a steady predator-caused decline in mule deer numbers, which is ultimately a result of asymmetrical apparent competition with white-tailed deer. Similar situations have been suggested for cougar-caused declines in mountain caribou (Kinley and Apps 2001) and bighorn sheep (Rominger et al. 2005). Multiprey systems where cougar populations can be supported by large populations of one or more species of primary prey and where cougars demonstrate a preference for killing individuals from a smaller population of secondary prey, therefore, are the most highly prone to experiencing the negative effects of cougar predation.

Prey Specialization in Cougars

Cougars are normally considered to be a generalist predator. As a description of the species, this is certainly true. Cougars live in a broad variety of habitats and kill a full spectrum of prey. Cougars in North America kill primarily deer (*Odocoileus* spp.) but also prey upon elk (*Cervus elaphus*), moose (*Alces alces*), pronghorn (*Antilocapra americana*), bighorn sheep, mountain goats (*Oreamnos americanus*), caribou, coyotes (*Canis latrans*), black bear (*Ursus americanus*), porcupine, beaver (*Castor canadensis*), small rodents, fish, various birds and other cougars, to name a few (Ross et al. 1997, Murphy 1998, Kinley and Apps 2001, Logan and Sweanor 2001, Sunquist and Sunquist 2002). In Central and South America, they have been known to eat brocket deer (*Mazama* sp.), armadillos (*Dasypus* spp.), hare (*Lepus* spp.), guanacos (*Lama guanicoe*), white-tailed deer, mule deer, desert bighorn sheep, peccaries (*Tayassuidae* sp.), capybaras (*Hydrochoerus hydrochaeris*), rhea (*Rhea* sp.), vizcacha (*Lagostomus maximus*) and caiman (*Caiman* sp.) (Sunquist and Sunquist 2002, Rosas-Rosas et al. 2003). Indeed, cougars are the epitome of a generalist predator.

However, there is growing speculation and some evidence that, while the species is capable of preying on almost anything, an individual cougar may focus its predatory efforts and can even specialize on a particular type of prey. Specialization by individual cougars is simply an extreme form of the selection discussed in the previous section, but it takes place at the level of the individual instead of the level of the population. In the purest sense, an individual specialist would consume only a single type of prey. Cougar in single-prey systems are *de facto* specialists, but cougars in multiprey systems are extremely unlikely to ever meet this definition of specialization. How, then, can we define individual specialization for cougar in multiprey systems? We set forward three criteria that should be met if individual specialization exists. First, the species of prey being specialized on should comprise the primary component of the individual cougar's diet. Second, the species being specialized upon should be selected such that the focal species is consumed more often than would be expected on the basis of availability. Third, if specialization is an individual characteristic, then individuals should differ in their preference patterns, and some individuals might not specialize at all (i.e., individual-level specialization and population-level specialization are different things).

If cougars exhibit individual specialization in this way, it could have important implications for predator-prey dynamics and management. In a multiprey system, individual specialization focused on a smaller population of secondary prey can have effects similar to those produced when the population of predators selects for the secondary prey. These effects are likely to be more erratic than those caused by population-level preferences for prey, and they also may be more severe. When specialists are not present, the population of secondary prey does not suffer more than incidental predation and may do well even when there are large numbers of predators. When specialists are in the system, on the other hand, a small and isolated population of prey could be drastically reduced or even eliminated by the specialist over a short period of time, with no subsequent effect on the predator population.

Predation by individual cougar specialists has recently been suggested as a primary determinant of the population dynamics of bighorn sheep in three separate locations in western North America (Festa-Bianchet et al. 2006). Bighorn were monitored for over 80 population years and 4 separate declines driven by cougar predation occurred. In each case, the cougar predation episode had a clear and abrupt beginning and end. The authors point out that this pattern is consistent with predation by a specialist predator because the predation periods are sharply defined, which one would expect if it is caused by an individual specialist that enters and leaves the system. Unfortunately, they have only limited data to support this. Indeed, while information on cougar dietary habits is reasonably common (Ross et al. 1997, Murphy 1998, Logan and Sweanor 2001, Rosas-Rosas et al. 2003), detailed information on the killing rates and predatory patterns of individual cougars is scarce in the published literature.

The most comprehensive data currently available on individual prey specialization come from a study of cougar predation conducted at Sheep River in southwestern Alberta. Individual radio-collared females in this study varied greatly in their predation patterns. Of five females that had home ranges overlapping with bighorn range, three rarely or never killed sheep, one occasionally killed sheep and another focused almost exclusively on sheep during some years (Ross et al. 1997). The fact that mule deer were much more abundant than bighorn and that individual cougars differed so drastically in their predation patterns is strong evidence that the sheep-killing cougar exhibited specialization. Males at Sheep River killed moose almost exclusively despite much higher availability of deer in the study area (Ross and Jalkotzy 1996), but it is difficult to say if this was a result of population-level selection by males or because the single intensively monitored male in the study was an individual moose specialist.

Individual Cougar Predation Patterns in Westcentral Alberta

We have recently completed the first year of a study of cougar ecology in a multiprey ecosystem situated along the central eastern slopes of Alberta's Rocky Mountains. Our 5,791.-square-mile (15,000-km^2) study site (approximately centered at 52°16'0"N, -115°38'0"W) contains a wide variety of wild ungulate prey, including white-tailed deer, mule deer, elk, moose, bighorn sheep, feral horses, and very small numbers of mountain caribou and mountain goats. Our initial data on the predatory behavior of cougars in this environment helps to shed more light on individual-prey specialization. From December 2005 to March 2006 we deployed global positioning system (GPS) radio collars on 15 independent adult and subadult cougars. We monitored each cougar intensively by downloading GPS data from the collar monthly, or in some cases biweekly, for as long as the collar continued to collect data. We entered the data into a GIS program (ArcGIS 9.0), identified clusters of GPS locations and visited these locations to find kills. This technique was pioneered for cougars (Anderson and Lindzey 2003) and has since become a popular method for assessing prey composition and kill rate in large carnivores (e.g., Sand et al. 2005). Because we had downloadable GPS information (from Lotek model 4400S), we were able to visit location clusters soon after they were made, increasing our chance of finding kills. We visited 1,243 cluster locations, and we identified 510 cougar predation events and 24 cougar scavenging events at cluster sites.

Figures 1 and 2 represent the percentages of individual prey items and the biomass of cougar diet for our entire sample of kills. These are the kinds of population-level data that are normally presented in the literature and used by managers. Very different management strategies are required, however, for a population of cougars where all individuals tend to have similar prey composition and where a population that has a great deal of variation in predation patterns and may include specialist predators. Consequently, we use preliminary data

Figure 1. Percentage of individual prey items in the aggregate diet of all cougar monitored.

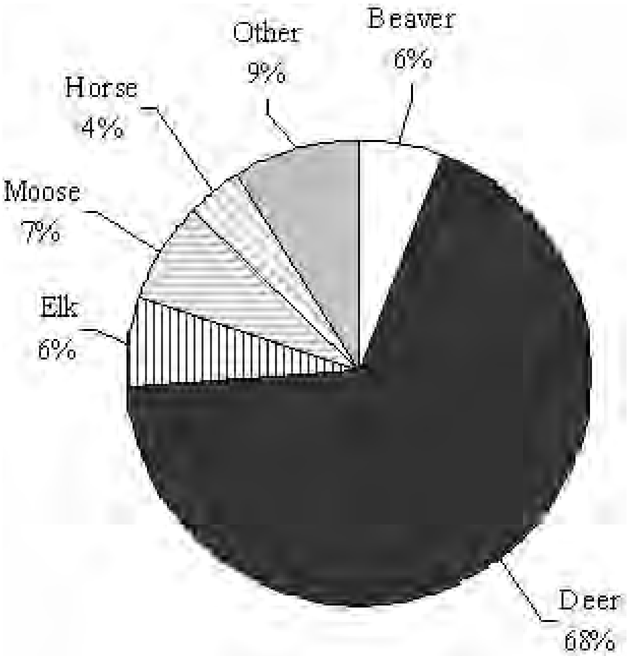
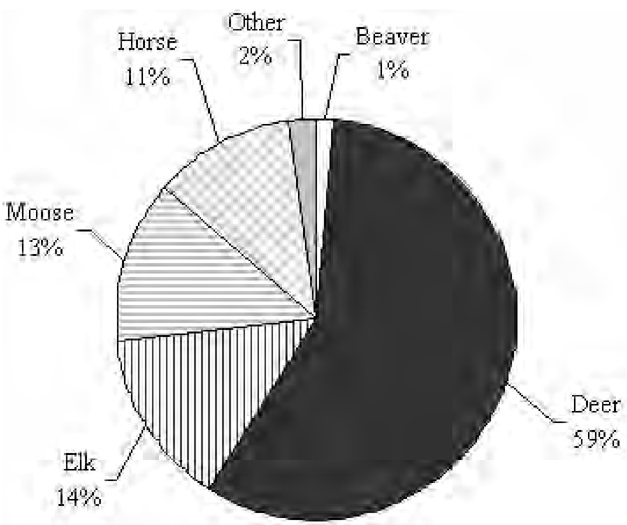


Figure 2. Percentage of prey biomass in the aggregate diet of all cougar monitored.



from 9 cougars for which we have continuous kill information for a period of at least 8 months (Tables 1 and 2) to look for evidence of individual prey preference and specialization. We examine only wild-ungulate kills when examining individual variation in predation because these are the most important component of cougar diet, making up over 85 percent of all kills and over 95 percent of the biomass consumed by cougars. We visited 375 ungulate kills for the 9 cougars over approximately 90 cougar-months of monitoring. We are fairly certain that we obtained a near census of large-ungulate kills for each cougar over the entire period it was monitored. We are somewhat concerned that our cluster visitation methods caused us to slightly underestimate neonate predation in spring, but it is unlikely that this would greatly affect our observed patterns of ungulate prey composition (Tables 1 and 2).

Table 1. Prey items killed for individual cougars monitored continuously for at least 8 months in westcentral Alberta.

Cougar ID	Number of kills	Percentage species composition				Species most commonly consumed
		Elk	Horse	Moose	Deer	
0003R	32	3.13	0.00	9.38	87.50	Deer
9823R	32	6.25	0.00	0.00	93.75	Deer
9825R	27	0.00	0.00	3.70	96.30	Deer
9827R	35	14.29	48.57	22.86	14.29	Horse
9871R	55	5.45	5.45	0.00	89.09	Deer
9873R	50	2.00	0.00	2.00	96.00	Deer
9876R	38	13.16	0.00	31.58	55.26	Deer
9878R	56	16.07	0.00	10.71	73.21	Deer
9879R	50	2.00	0.00	4.00	94.00	Deer

Table 2. Biomass of prey killed for individual cougars monitored continuously for at least 8 months in westcentral Alberta.

Cougar ID	Total biomass (kg)	Percentage species composition				Species comprising the majority of biomass
		Elk	Horse	Moose	Deer	
0003R	2015	3.97	0.00	14.89	81.14	Deer
9823R	1775	17.46	0.00	0.00	82.54	Deer
9825R	1605	0.00	0.00	21.81	78.19	Deer
9827R	5325	12.58	66.67	15.02	5.73	Horse
9871R	3635	9.90	8.25	0.00	81.84	Deer
9873R	3390	9.44	0.00	2.95	87.61	Deer
9876R	3890	25.71	0.00	41.13	33.16	Moose
9878R	3950	28.86	0.00	15.19	55.95	Deer
9879R	3195	2.50	0.00	10.95	86.54	Deer

Five species of wild ungulate (elk, mule deer, white-tailed deer, moose and feral horses) were killed by the nine cougars examined here. We did not differentiate between the two deer species in this analysis because species identification was impossible for a large number (39 percent) of the deer kills we visited. The inability to identify species was particularly common for fawns, which cougars often consume entirely. Availability of the various ungulate species differs across the study area, but deer are by far the most abundant prey in the home ranges of all of the cougars we examine here. It is, therefore, not surprising that deer were the most important prey item for most cougar (Tables 1 and 2). Cougar 9827R is the clear exception. Cougar 9827R meets all three of the criteria of an individual specialist outlined previously. Horses made up the majority of his diet (particularly in terms of biomass), and they were consumed at a rate much higher than availability would suggest. Moreover, there is substantial variation in individual predation patterns among cougars at the study site. Both 9873R and 9878R have home ranges that are subsumed within that of 9827R, for instance. And, there is a great deal of variation in prey composition in the diets of these three cats, despite similar availability of prey.

When looking at Table 1, however, it is apparent that none of the cougar we monitored were pure specialists. Each cougar exhibited at least some tendency to generalize. Some cougar may be specializing in the primary prey—deer—to the near exclusion of other ungulate prey (e.g. 9825R and 9873R). But, specialization on primary prey is more difficult to identify because we require better information on the relative abundance of each prey species in each cougar home range before it will be possible to determine whether deer are being selected. Similarly, we do not currently have sufficient details on ungulate-prey availability at the home-range scale to quantify selection for secondary prey when they do not dominate the diet. This kind of selection may be occurring, however, and also may vary greatly between individuals. Cougar 9876R, for instance, consumes substantially more moose and fewer deer than most other cougars. In terms of biomass (Table 2), 9876R might even be considered a moose specialist. In addition, 9878R and 9873R have overlapping home ranges with similar prey availability, yet 9878R consumes considerably more elk and moose than does 9873R, indicating that 9878R may be selecting for secondary elk and moose prey.

Individual cougars may also avoid certain types of prey. With the exception of 9827R, the cougars examined here do not often prey on horses, even though feral horses are available to most of them. Avoidance in the case of horses may be due to their lower vulnerability to cougar predation, but 9827R avoids deer, which are highly susceptible to cougar predation, indicating that the degree of vulnerability alone does not dictate selection. Hence, it would appear that individual identity is an important component of cougar predation patterns at our study site and that cougars may cover a gradient of preferences for species of secondary prey that ranges from specialization to avoidance.

Management Implications and Future Research

As we note above, specialization by individual cougars has the potential to produce erratic, and sometimes severe, impacts on populations of secondary ungulate prey in a multiprey system. We give examples of cougar specialization from the literature and from our recent work in westcentral Alberta. Cougar specialization may not be uncommon, and at least one of nine cougars we studied intensively meets all the criteria of an individual specialist. When cougars that specialize on small secondary prey populations that are of management concern (e.g., bighorn sheep, mountain caribou) are not present in a system, incidental predation by cougars might not be sufficient to cause population decline. When specialists are present, however, predation is focused instead of incidental and negative impacts are far more likely. In these cases, management action may be necessary to prevent unwanted population declines.

Our research shows that, while pure specialization is unlikely in cougars, individual cougars can develop tendencies to focus primarily on one or a few types of prey, sometimes selecting strongly for secondary prey even if that prey item does not dominate the diet. Such individual preference for secondary prey can result in management problems similar to those caused by specialization and can call for similar management responses.

Lethal control may be necessary to prevent the negative consequences of apparent competition and indirect amensalism on small populations of alternate prey in multiprey systems (Gibson 2006). Cougar populations are easily controlled by hunting, and increases in cougar population density have been reversed by liberal hunting regimes (Lambert et al. 2006). Where cougars are known to negatively impact ungulate population dynamics, general population reductions may be effective at curbing these impacts (Cougar Management Guidelines Working Group 2005), particularly in situations where the amount of incidental predation is directly related to predator-population size, where there is population-level selection for secondary prey or where primary-prey populations have declined, forcing cougars to switch to secondary prey (Logan and Sweanor 2001). In such situations, it can also be important to reduce populations of the primary prey that drive the cougar numerical response (Gibson 2006). However, if the negative impacts of cougar predation are driven by specialization or strong individual-level selection, general population reduction will be ineffective if the specialist is missed. And, reductions of predators through a reduction of primary prey might not translate into a reduction of the number of specialists. Identification and targeted removal of the specialist(s) may be the best management option in such cases because it can preserve the integrity of the population of secondary prey without compromising the cougar population or requiring the reduction of primary prey.

Ernest et al. (2002) found that, to preserve very small populations of bighorn sheep (less than 15 ewes) in imminent danger of extinction via cougar predation, total removal of cougars from sheep habitat would be necessary. Their models of cougar-sheep dynamics also suggest, however, that removal of only cougars that kill a sheep (putative specialists) reduces the risk of decline and extinction in larger populations of bighorn. Thus, selective removal can be an effective solution where the cougar population itself is a conservation concern or where there are political, economic or ecological reasons to avoid complete removal of cougars. Specialists must be identified before they are removed and this represents an important challenge. Cougars are secretive by nature and ubiquitously cache their kills by dragging them under trees or rocks and burying them or by otherwise concealing them from plain view. The potential to remove specialist cougar by catching them on a fresh kill of the species of interest is, therefore, limited unless the prey are wearing radio collars with mortality sensors. Even if a cougar is removed after killing a single sheep, there is no guarantee that a specialist has been removed. Our data show that small numbers of secondary species are killed by most cougar inhabiting multiprey systems.

Simply removing cougars that overlap spatially with the population of interest also may not have the desired effect. Our data suggest that cougar territory that overlaps various types of ungulate-prey territory can specialize in, select for, use as available, or even avoid preying upon a particular species. Ross et al. (1997) and Ernest et al. (2002) similarly show that some cougars with home ranges overlapping bighorn range appeared to avoid them, rarely or never killing sheep. Spatial overlap by itself, while an obvious requirement of a specialist is, therefore, an insufficient basis for their identification. Indeed, removing cougar that overlap spatially with the prey species of interest but that avoid them as prey has the potential to create a vacancy that might be filled by a specialist predator.

Because of the importance of increasing the probability of correctly identifying specialist cougar for management purposes, it is essential that we better understand what drives prey selection in this species. Is individual-cougar predation a purely idiosyncratic and stochastic (i.e., unpredictable) phenomenon as some suggest (Festa-Bianchet 2006), or does it have a mechanistic and predictable basis that can help managers identify and prevent problems? Unfortunately, little is known about the drivers of cougar predation. Even population-level prey selection in cougars remains poorly understood. At some study locations, deer are selected at a rate greater than their availability in the environment would suggest (Kunkel et al. 1999) while, at other sites cougars focus on elk, even when deer are more abundant (Hornocker 1970). What is the basis for these differences and for the differences observed at the level of the individual? And, how much do habitat, alternate prey densities, age-sex structure of the cougar population or individual idiosyncrasies weigh in? Through our continuing research efforts in westcentral Alberta, we hope to provide some of the answers to these questions.

If specialist cougars have been identified as a management concern, methods for improving the probability of correctly identifying specialists are available. And, removal of these specialist cougars is recommended by management agencies to reduce impacts on ungulate populations. A removal method must be chosen. Within an appropriate management framework, hunting with hounds can be very selective and precise, allowing for specific regions, age-sex classes, or even individuals to be targeted. Consequently, this might be the best method available for managing problematic prey specialization by individual cougar. Hunting with hounds has been advocated as a cougar-harvest method (Cougar Management Guidelines Working Group 2005), and it has several advantages over removal methods which are not selective (e.g., general hunting seasons, widespread snaring, poisoning) because using nonselective removal methods makes it less likely that the intended targets will be missed, preventing unnecessary and undesirable reduction of cougar populations. By using appropriate identification and selective removal techniques to manage specialist cougar predation, it might be possible to avoid undesirable declines in endangered and or economically valuable populations of secondary ungulates while simultaneously maintaining the ecological benefits associated with a healthy cougar population.

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Effects of White-tailed Deer Expansion and Cougar Hunting on Cougar, Deer and Human Interactions

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Introduction

Mule deer (*Odocoileus hemionus*) are declining in many western states and provinces, and the reasons are presently unclear. Within Washington, mule deer have declined, but white-tailed deer (*Odocoileus virginianus*) have increased. For example, white-tailed deer were historically rare in Washington, but now comprise 73 percent of deer in the Selkirk Mountains, 82 percent of deer in Kettle Falls, 56 percent of deer in Republic and, as yet, 0 percent in our Cle Elum study areas.

Cougar (*Puma concolor*) populations appear to have increased in Washington. Confirmed cougar complaints have increased from about 250 per year in 1995 to about 400 per year in 2005. Might these problems (white-tailed deer increase, mule-deer decrease, and increases in cougars and cougar complaints) be related?

To answer this question, we studied cougar, deer and human interactions in four Washington study areas (Selkirk Mountains, Kettle Falls, Republic, Cle Elum) from 1997 to 2007.

Effects of White-tailed Deer Expansion on Cougar Predation of Mule Deer

Selkirk Mountains

We captured and radio-monitored both white-tailed deer and mule deer in the Selkirk Mountains of British Columbia, Idaho and Washington from 1997 to 2000. We estimated deer survival, fecundity and population growth for both species using Leslie matrix models. We also estimated population growth by comparing annual aerial surveys. Our results indicated that cougars were responsible for the majority of deer deaths. Cougar predation rates were 17 percent on mule deer and 9 percent on white-tailed deer. As a result of this disparate predation, white-tailed deer were increasing at 2 percent per year, but mule deer were decreasing at 12 percent per year. Predation rates were directly density dependent (predation increased as deer density increased) for white-tailed deer but inversely density dependent (predation increased as deer density decreased) for mule deer. These results suggested that mule deer were declining because of apparent competition (Robinson et al. 2002), whereby increasing alternate primary prey (white-tailed deer) resulted in increased predators, increased predation and population decline for sympatric secondary prey (mule deer).

Kettle Falls and Republic

We tested the apparent competition hypothesis in two, new, independent study areas (Kettle Falls and Republic) by capturing and radio-monitoring cougars from 2002 to 2004. We determined white-tailed deer and mule deer prey availability by year-round ground counts and annual winter-aerial surveys. We determined prey selection by cougars by comparing deer use (kills) versus availability. Our results indicated that white-tailed deer were much more abundant than mule deer in both study areas; in Kettle Falls, white-tailed deer equaled 82 percent of deer, and, in Republic, white-tailed deer equaled 56 percent of deer. White-tailed deer comprised the primary prey (60 percent of kills) and mule deer the secondary prey (40 percent of kills) in both areas. However, cougars selected for mule deer (observed kills exceeded expected kills based on availability) in both study areas; selection ratios were 1.61 in Kettle Falls and 1.36 in Republic. Cougar selection for mule deer (of disproportionate predation) only occurred during the summer season when white-tailed deer moved into higher elevation, mule-deer ranges (Cooley et al. 2007). These results again suggested the presence of apparent competition in three of three separate study areas (Selkirk Mountains, Kettle Falls, Republic). Expansion by white-tailed deer into traditional mule-deer ranges appeared to result in increased numbers of cougars, increased cougar predation on mule deer and subsequent population declines for mule deer.

Effects of Cougar Hunting on Cougar-Human and Cougar-Mule Deer Conflicts

Selkirk Mountains

The increased numbers of white-tailed deer and cougars also resulted in increased cougar-human conflicts in the Selkirk Mountains. We tested for the effects of increased hunting of cougars to reduce such conflicts from 1998 to 2003. We captured and radio-monitored 52 cougars during this 5-year period. During that time complaints increased dramatically, suggesting that cougar numbers were increasing as well. We estimated cougar maternity rate (kittens per adult female per year), sex (male, female) and age-specific survival rates, and we entered those vital rates into a dual-sex Leslie matrix model to estimate cougar population growth. Annual survival rates of cougars were extremely low—only 33 percent for adult males and 77 percent for adult females. Contrary to popular belief, the cougar population was not increasing but was declining at about 15 to 20 percent per year. Trends of cougar density corroborated our Leslie matrix results, showing a cougar population decline of about 13 percent per year. There were very, very few adult males left in the population with virtually no males older than 4 years. Harvest statistics also corroborated our results with a peak in cougar harvest during 1998, followed by a steep decline. Increased cougar complaints did not correspond with increased cougar numbers but did appear to correspond with a decrease in the age of cougars in this heavily hunted population (Lambert et al. 2006). Our results suggested that heavy hunting resulted in a decrease in the age of resident cougars and could have resulted in increased cougar-human conflicts because subadults are believed to be the age class responsible for most such conflicts.

Did heavy hunting result in decreased predation on mule deer? Yes! Cougar-predation rates on mule deer in the Selkirk Mountains declined dramatically following the cougar population decline. However, predation on white-tailed deer declined as well, resulting in a white-tailed deer population increase of more than 30 percent per year (Wielgus, unpublished data 2007). It appears that very heavy hunting of cougars will result in decreased predation on mule deer, but it also results in dramatically increased white-tailed deer population growth and subsequent expansion into traditional mule-deer ranges. The expected long-term implications of a 30-percent increase per year in white-tailed deer numbers is troubling for mule deer due to resource competition, disease and, perhaps, genetic introgression. You can't win for losing!

Kettle Falls

Were our results in the Selkirk Mountains a fluke? A one-off? A bad analysis? How could increased cougar hunting with a younger age structure possibly result in increased human-cougar conflicts? Was our reduction in age hypothesis a plausible answer? We tested for effects of heavy hunting in a separate study area in Kettle Falls by radio-monitoring 34 cougars from 2002 to 2006. That area also saw an increase in cougar complaints attributed to increased numbers of cougars. We estimated cougar population growth by estimating the vital rates (fecundity, age and sex-specific survival) and by entering them into a dual-sex Leslie matrix. We also compared the Leslie matrix stable-age distribution (estimated from the vital rates) to the observed standing age distribution to test for deviations in age class. For example, were there more subadult males than expected?

Similar to the Selkirk Mountains, our Leslie matrix results indicated a population decline of about 10 percent per year, contrary to the increased number of cougar complaints. The female component of the population was declining; however, the standing-age distribution and observed growth rates showed a male population increase of about 10 percent per year. Overall (both sexes) the population was stable, but the numbers and proportions of young males were increasing. We estimated a cougar immigration rate (observed growth rate minus expected growth rate) of about 15 percent per year. Heavy hunting did not reduce the overall numbers of cougars but simply shifted the sex and age structure to younger immigrant males (Robinson et al. 2007). Now we were two for two (Selkirk Mountains and Kettle Falls); heavy hunting appeared to coincide with increased, not decreased, cougar-human conflicts, perhaps, because of increased numbers or proportions of subadult immigrant males. What happens in an area without white-tailed-deer expansion and very little cougar hunting (e.g., where prey densities are lower and lack of hunting or killing resident cougars discourages immigration)?

Cle Elum

The Cle Elum study area has not yet been exploited by white-tailed deer. Cougar complaints are few and far between, and cougar hunting is very low compared to our other study areas. We captured and radio-monitored over 33 cougars from 2002 to 2006. Similar to Selkirk Mountains, Kettle Falls and Republic, we estimated fecundity and sex and age-specific survival and entered these vital rates into a dual sex Leslie matrix to estimate expected population growth. We also estimated the standing age distribution and observed growth rate by documenting sex, age and number of cougars in the study area. Our preliminary data indicate that survival rates were much higher than in the Selkirk Mountains and Kettle Falls. The survival and fecundity growth rate appears to be about 10 percent per year and the observed growth rate to be about 0 percent per year (stable). Emigration rate is estimated at about 10 percent per year. Both the stable and standing age distributions show a much older population than in the Selkirk Mountains and Kettle Falls (Wielgus et al., unpublished data 2007). There were no problems here with declining mule deer or with increasing cougar complaints.

Conclusions

Our results suggest that increased numbers of white-tailed deer results in an increased number of cougars. The increased number of cougars results in increased cougar predation on mule deer and possibly increased cougar complaints. The increased cougar complaints result in increased cougar hunting. Increased cougar hunting results in increased subadult male immigrants. Increased immigrants results in increased cougar complaints. Repeat. . .until such time as the female component of the cougar population collapses and cougars are functionally extirpated. At that time, the white-tailed deer population really explodes. Mule deer are then susceptible to further decline due to resource competition or genetic introgression.

We recommend experimental reductions of invading white-tailed deer to forestall such a scenario.

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Role of State Wildlife Agencies in Managing Mountain Lions

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Introduction

Mountain lions (*Puma concolor*) are the most widely distributed obligate carnivore in North America. The species' range generally overlaps that of their primary prey, mule and white-tailed deer (*Odocoileus* sp.), yet they also rely on a wide range of large and small mammals as alternate prey. Historically, mountain lions occupied diverse habitats throughout much of the United States. Intensive predator-control programs, intended to protect livestock and to restore big-game populations during 1900 to 1965 significantly reduced populations over much of the range. And, mountain lions were extirpated from large areas of the Midwest and eastern regions of the country. In general, populations now appear to be stable to increasing throughout most of the western United States; although, densities are not uniform. There is evidence of mountain lions recently recolonizing areas in the Midwest and in eastern regions of the country.

The history of mountain lion management in the United States reflects extreme shifts in public policy and in state wildlife agency management programs over the last 100 years. Although reliable estimates of distribution and abundance are not available prior to the 1970s for most states, it is likely that both the distribution and abundance of mountain lions were reduced and suppressed between 1900 and 1965. This trend resulted primarily from intense efforts by state and federal agencies to protect livestock and to aid in the recovery of native ungulates based on their value to hunters. Liberal hunting seasons and methods of take, incentives to hunters in the form of bounties, and employment of government hunters were widely used to reduce mountain lion numbers in much of the western United States until the 1960s.

During the mid-1960s, increased interest by the public and concern among professional wildlife biologists about the status and trends of the species resulted in critical reviews of public policy regarding mountain lions and of state wildlife agency management programs in the western United States. The practice of employing government lion hunters generally ended in the 1950s, and state-sponsored bounty payments for killing lions, common in the West from 1910 to 1960, ended in the early 1970s. In response to increased public interest in the species and to basic questions regarding the status of mountain lions, a number of western state wildlife agencies initiated field studies and developed plans for long-term research to document the life history and status of mountain lions within their boundaries.

Science-based, mountain lion field studies have evolved dramatically since 1975. The availability of reliable radio telemetry in the late1970s and its refinement during the last 10 years, including integrating global positioning satellite (GPS) locating capabilities, has greatly enhanced the ability of wildlife scientists to document mountain lion life-history aspects and to intensively monitor the status of mountain lion populations throughout their range. During the last 20 years, a number of state wildlife agencies, in cooperation with research universities and nongovernment organizations, have used Federal Aid to Wildlife Restoration Program funds and other sources to develop and implement science-based, long-term mountain lion research projects.

A number of these projects tested and refined the use of a variety of powerful tools, including genetic techniques, to enhance knowledge of mountain lions and their ecological role in a number of complex, multispecies, predator-prey systems (Ernest et al 2003). This effort to apply new technology has greatly enhanced information upon which the species can be managed within each jurisdiction. However, there are practical limits on the extent to which enhanced scientific tools can be used to address practical questions regarding mountain lion management and conservation. One limitation is the inherently high financial costs of long-term research relying on state-of-the-art technology needed over large geographical areas. Intensive studies typically range in cost from $400,000 to $1 million annually and may not be representative of populations and habitats statewide. Another limitation is the fact that mountain lion management and state-agency policy challenges also involve politics and stakeholder values beyond the limits of most wildlife agencies' professional expertise and direct influence.

State Wildlife Agency Authority

Under the North American model of wildlife conservation and management, wildlife collectively belongs to the people, and it is held in trust by the government. In the case of mountain lions, the states have authority over their management, with the exception of the Florida panther (*Puma concolor coreyi*) which is listed under the Federal Endangered Species Act. As is the case with most native large carnivores, implementing public policy for mountain lions involves a wide range of values and expectations from diverse stakeholder groups within the general public. As proof of this interest and involvement in public policy, since 1990 ballot initiatives have been used to substantially influence state agency authority for mountain lion management in California, Oregon and Washington.

Mountain lions are an important component of the multispecies predator-prey systems in the western states. The species has coexisted and evolved with typical prey species, including mule and white-tailed deer, elk *(Cervus elaphus*) and bighorn sheep (*Ovis canadensis*). Since mountain lions are generally secretive, are often solitary and occur in relatively low densities, they present challenges to scientific study and to practical population monitoring by wildlife managers. In addition, their ecological role as obligate predators focuses public attention on managing them in conjunction with other wildlife, livestock and domestic pets. There are also public concerns related to threats mountain lions may pose to public safety. In California, where there have been 11 verified mountain lion attacks on humans since 1985, 3 of which resulted in death of the victims, the state wildlife agency has been forced to devote considerable staff time and funds to developing and implementing emergency response capabilities (S. Torres, personal communication 2006). The real and perceived threats to public safety cannot be ignored by state wildlife agencies, regardless of relative risk, since they directly influence mountain lion management policy and most agencies have a public safety related mandate.

Legal Status of Mountain Lions in the West

The individual states have responsibility for managing mountain lions on behalf of the people, and the wildlife agencies are generally the custodians for all wildlife within each state. However, the specific legal status of mountain lions is defined in the laws for each state. In addition, commissions or administrative wildlife agencies generally have authority to adopt management plans, policies and regulations to implement, interpret and make specific state laws, including hunting seasons, limits and methods of take. With the exception of California, the current legal status of mountain lions in the western states is either big-game or trophy-game species. In California, they are designated a specially protected mammal, the result of a 1990 ballot measure which prohibited hunting and placed additional restrictions on management.

Historically, public policy related to mountain lions in the western United States followed a similar pattern in most states; although, the timing varied considerably. In the early 1900s when most state wildlife agencies were being established or given authority to actually manage wildlife, including mountain lions, they were classified as either a predator, with bounties offered for killing them, or as an unprotected species, with little or no restriction on their take. By 1975, western states had terminated bounties and had designated mountain lions as either big-game or trophy-game species. In a number of states over the last 30 years, sociopolitical processes forced wildlife agencies to study the mountain lion populations, to report on findings and to recommend conservation and management methods to policy makers.

In California during 1972 to 1985, the state legislature enacted a series of laws, each in effect for periods of only 3 to 4 years, which prohibited hunting, established guidelines to address livestock damage and required the wildlife agency to survey the status of mountain lions. In 1986, the legislature failed to extend these provisions of law, and mountain lions reverted to the pre-1972 status of game mammal under which they could be hunted pursuant to commission regulations. Hunting seasons were approved by the California commission in 1987 and 1988, but the regulations were successfully challenged in court, based on failure of the wildlife agency to fully comply with the state's Environmental Quality Act requirement to disclose and mitigate, where practical, potential negative impacts of the hunting proposal. In 1990, the ballot measure that prohibited hunting of mountain lions was approved by voters with a margin of 52 to 48 percent.

In addition to the legal status of mountain lion hunting, a number of western state wildlife agencies also have specific statutory guidance regarding damage to livestock and pets as well as public safety. Some states pay for verified mountain lion damage to livestock while others focus on providing the owners of livestock and pets the ability to take lions that are causing or threatening to cause damage to their property. These are some specific issues which continually challenge state wildlife agencies in achieving their missions of science-based management of mountain lions.

Science-based Management to Achieve Goals and Objectives

Most of the wildlife agencies in western states have similar missions which charge them with meeting their public-trust responsibilities by, "protecting, perpetuating and managing wildlife while providing appropriate public uses, including hunting" (Section 1801, California Fish and Game, Code and Section 103, Title 36, ID Statutes). These missions have a clear intent to sustain and, where practical, to enhance wildlife populations for current and future generations of citizens. Some state-agency missions also have specific statutory or policy guidance related to addressing conflicts with humans and the economic costs of wildlife causing damage to private property.

So, what is the appropriate role of the state wildlife agency in managing mountain lions based on science? The answer depends on the combination of laws, policies, management goals and objectives as well as stakeholder values, which exist in the individual state. The role also depends on the status of the lion population and their prey, landscape-level habitat trends, and human influences. All these factors need to be placed in context with the state's goals and objectives for mountain lions. Most western states have management plans for mountain lions; although, the form and content varies. A number of plans tend to have similar goals and objectives related to populations, yet strategies for implementing the plans—including hunting, protecting livestock and responses to public safety incidents—differ substantially. States as different as California and Idaho have some similar goals related to maintaining healthy populations, to minimizing conflicts with humans and to monitoring populations.

In California, emphasis is placed on protecting important habitat, on responding to public safety incidents and on improving public awareness of mountain lions as the state wildlife agency tries to deal with the pressures caused by a human population of over 35 million. By contrast, in Idaho with a human population of less than 1.5 million, there is more emphasis placed on providing diverse hunting opportunities and on managing mountain lions in conjunction with prey species, including bighorn sheep, deer and elk. In Idaho, specific mountain lion harvest quotas are used to adaptively manage mountain lion hunting within large regions or smaller units of the state. Agency management actions in California are generally limited to reacting to lions causing damage to livestock or pets and to responding to public safety incidents. Another important difference between these management models is the fact that in California the wildlife agency's plan has not been formally adopted by the legislature or commission while in Idaho the plan was reviewed and approved by the commission through a public process. These examples tend to represent both ends of the spectrum of state-agency mountain lion management programs in the western states.

Public policy goals for mountain lion management can either assist or hinder the state wildlife agency in implementing science-based management of the species. If the policies provide a strong mission statement for the agency, if the agency has a well qualified professional staff and if adequate funding is provided, the environment for science-based adaptive management is enhanced. However, if a state's public-policy goals for mountain lion management are not clear, if it lacks well qualified professional staff or if it lacks adequate funding to implement a balanced program, effective science-based management of mountain lions cannot be expected.

Management in Response to State Holder Values

In general, state wildlife agencies respond to public input and stakeholder values regarding wildlife, including mountain lions. The most effective agencies have formal processes to regularly receive public input and to clearly establish their role as the experts responsible for managing mountain lions within the state on behalf of the public. Assessing stakeholder interests in management and developing clear goals and objectives consistent with that input are important elements of publicly supported agency programs. Stakeholder values are generally reflected in the state's laws and policies regarding mountain lion management, yet they may not represent the full range of current public values as human demographics are changing rapidly in the western states. There may also be lag time in public values translating to laws and policies through the normal legislative and commission processes. This delay can also result from the influence of special-interest stakeholders and political pressure to resist change.

During the 1990s, ballot initiatives were used to change state laws and policies related to hunting of mountain lions in California, Oregon and Washington. It is interesting that experience gained from implementing these public mandates in California and Washington resulted in these mandates subsequently being modified by the state legislatures. In 1999, the California legislature passed a measure requiring a four-fifths vote to authorize mountain lions to be taken if the wildlife agency determines they were a threat to bighorn sheep. In 2004, the Washington legislature passed a measure which modified the ban on the use of hounds for taking mountain lions to provide a 3-year pilot project in a 5-county area intended to reduce damage to livestock and threats to public safety.

Assessing stakeholder values is a complex and dynamic task. Few state wildlife agencies have the internal capacity and professional human-dimensions expertise to do the job consistently. However, there are well qualified experts available in universities and working as specialized consultants who can assist state wildlife agencies. As the human demographics in western states continue to change at a rapid rate, it is important that the state agencies develop and maintain effective programs for two-way communication with stakeholders regarding their mountain lion management programs.

Summary

The role of state wildlife agencies in managing mountain lions involves a combination of factors unique to each state, including laws, policies, an agency's mission and stakeholder values. Recently, a working group published *Cougar Management Guidelines* (Guidelines; Beck et al. 2005) in an effort to synthesize and organize available information on management of the species. Although the western state wildlife agencies recognize that these Guidelines contain useful information, the process used to develop them and the final product raised concerns related, primarily, to failure of the authors to incorporate agency recommendations for changes to the draft document they were asked to review. The Western Association of Fish and Wildlife Agencies (WAFWA) formally expressed its concerns regarding the Guidelines (Shroufe 2006). In general, they focused on the review process used by the Guidelines' authors, the failure to incorporate agency comments, some management prescriptions promoted in the document and the potential impacts of certain recommendations to ongoing mountain lion management programs. The directors of the member states asked their wildlife chiefs to thoroughly review the Guidelines and to analyze potential problems and conflicts with ongoing programs before taking a position on the document. Their original intent was to offer constructive comments and suggestions in an effort to make the Guidelines more consistent with the real world in which state wildlife agencies must operate and are required to integrate science with stakeholder values and with the legal mandates of the individual states (J. Unsworth, personal communication 2006).

In my opinion, it is not surprising that state-agency directors were concerned since the overall tone of the Guidelines suggests mountain lions are an at-risk species, yet the document lacks science-based support for that conclusion. In addition, the discussion of sustainable hunting fails to acknowledge the recreational value and tradition for a segment of stakeholders. The authors also speculate the agencies may mislead the public regarding justification for proposing hunting as a management tool. With respect to public safety, the Guidelines fail to put in perspective the risk of attacks on humans with the legal mandates and stakeholder expectations to minimize threats and to remove offending animals. These are but a few of the reasons the WAFWA directors elected to not only formally express their concerns regarding the Guidelines, but to establish an *ad hoc* Cougar Workgroup to develop another document by early 2009 that is related to the initial publication. This workgroup will consult with the authors of the 2005 Guidelines to focus more on integrating and applying relevant information to mountain lion management programs across the diverse spectrum of conditions in which western state agencies operate.

At the end of the day, the ultimate responsibility for managing mountain lions rests with the individual state wildlife agencies. The challenge facing each agency is how best to adaptively implement science-based management while maintaining viable populations in conjunction with prey species and responding to stakeholder demands for sustainable hunting opportunities and minimizing conflicts with humans involving livestock damage and public safety.

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Reducing Populations of Medium-size Mammalian Predators to Benefit Waterfowl Production in the Prairie Pothole Region

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Introduction

Wildlife management has become more difficult in recent decades due to the increased requests to manage entire communities and to maintain ecosystem processes. However, wildlife managers still place much emphasis on management of particular wildlife populations. Focusing on a population or a set of species greatly simplifies the manager's task by keeping the goals simple. In most cases, the management goal is to increase the population of the target species. In urgent cases, the goal is to get the population above a threshold needed to assure the long-term persistence. In many cases, the management goal is to increase the population size to allow greater recreational use by consumptive users. Most waterfowl management in North America falls into the last category. Waterfowl hunters have consistently called for larger populations of ducks that would allow greater opportunity for hunting. Waterfowl hunters have also been very active in promoting waterfowl-population management so that ducks remain at population levels that allow considerable hunting opportunities. One important aspect of that population management involves the monitoring of population size and the sometimes-contentious regulation of harvest.

A second, and arguably more important, aspect of waterfowl management involves actions that increase duck recruitment or that decrease nonhunting mortality to allow populations to expand (Environment Canada 1986, Williams et al. 1999). Unfortunately, our knowledge of population biology of some ducks, such as sea ducks and scaup (*Aythya* spp.), is still too sparse to allow us to know what life-stage processes are most influential in causing population change (Austin et al. 2000). For other species, especially the midcontinent mallards (*Anas platyrhynchos*) and some other dabbling ducks, we know enough about population processes to be able to target our management to particular areas and events. For instance, in midcontinent mallards, we have much evidence that the population is driven by events on the breeding grounds (Johnson and Grier 1988, Johnson et al. 1992, Hoekman et al. 2002). Moreover, we know that nest success is the most critical factor influencing population size but that brood survival and hen survival during the breeding season are also important drivers of populations (Johnson et al. 1992, Hoekman et al. 2002).

Drivers of Duck-population Size

Sophisticated quantification of the relative importance of duck-population processes is relatively recent, but managers have long believed that management aimed at increasing productivity was the best way to enhance duck populations. Much effort has been devoted to management on the most important breeding grounds, namely the Prairie Pothole Region (PPR). Initial management effort was focused on protection of large marshes, but analysis of habitat use soon showed that small wetlands were preferentially used by most dabbling ducks (Kantrud and Stewart 1977, Kadlec and Smith 1992). The vast majority of these wetlands occur on private agricultural land and are susceptible to drainage (Turner et al. 1987). In spite of decades of waterfowl-management effort that was accelerated by the North American Waterfowl Management Plan, the rate of wetland drainage appears to be unaltered in the all-important Canadian PPR (Watmough et al. 2002). Pair ponds are the first requirement for any breeding population of ducks; thus, it seems obvious that efforts to protect wetlands must be the primary objective of waterfowl managers (Turner et al. 1987). However, abundant wetlands do not assure good duck production; rather, these wetlands provide the potential for good duck production. Dabbling ducks are also reliant on upland habitat because it is where most species nest; nest success is a critical driver of production (Hoekman et al. 2002).

In the last decade, waterfowl biologists confirmed that the quantity of upland cover is a major factor in nest success (Greenwood et al. 1987, 1995; Reynolds et al. 2001). Unfortunately, these studies also showed that rather large acreages of cover, often greater than 40 percent of the landscape (Reynolds et al. 2001), were needed to assure that nest success is above the break-even nest success of 15 to 20 percent. It is difficult for managers to achieve that level of nesting cover in agricultural settings, other than those where cattle production requires much perennial cover for grazing or hay production. We do not believe that wildlife managers will be able to acquire, through purchase or easement, enough farmland to restore enough land to upland cover as would be needed to cross the threshold of cover that assures high duck nest success. In areas of the PPR, where annual crops are the predominant land use of the farm community, it is unlikely that much productive and would be idle cover. Moreover, the cost of that land acquisition and management would be well beyond any funding mechanism currently in place in the wildlife community. Fortunately, on the U.S. side of the PPR, the establishment of grassland cover under the Farm Bill has had a major positive impact on duck recruitment (Kantrud 1993, Reynolds et al. 2001). The ephemeral nature of such farm programs makes reliance on this very beneficial nesting cover a risky strategy for waterfowl management. The threat of a dramatic decrease in Conservation Reserve Program (CRP) acreage became apparent in spring 2007 when the George W. Bush Administration proposed changes that would reduce new enrollments and would allow farmers to opt out of their existing CRP contracts.

Over the vast PPR, there are many areas where abundant wetlands provide the potential for duck production, but nest success is below break-even levels (Klett et al. 1988, Greenwood et al. 1995, Drever et al. 2004). In such situations it may be impractical to elevate nest success by increasing perennial nesting cover because the land is too valuable for annual crop production. This dilemma is not new and managers have responded with a variety of techniques to enhance nest success. In most cases the primary reason for nest failure is predation by a suite of medium-sized mammals, most notably red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*) and striped skunk (*Mephitis mephitis*) (Sargeant and Raveling 1992, Sargeant et al. 1993). Thus, many management efforts aim to separate these predators from duck nests. Such techniques include nest structures that make nests inaccessible (Doty and Lee 1974, Eskowich et al. 1998), creation of predator-free patches of cover on islands (Giroux 1981) or on fenced peninsulas (Lokemoen and Woodward 1993), or exclusion of predators from fields of cover with predator-proof fences (Lokemoen et al. 1982). Each of these techniques can be effective at elevating nest success, but each also has logistical or practical concerns that may limit the application of the technique

(Pietz and Krapu 1994, Trottier et al. 1994, Rohwer et al. 2004). For instance, some ducks do not preferentially nest on islands or peninsulas and will not use nest structures.

One long-standing, alternative solution for nest predation is to take a more direct approach by reducing numbers of predators of duck nests. Such management was relatively common in the early decades of waterfowl management, and the limited evaluation suggested it was effective at elevating duck production (Balser et al. 1968, Lynch 1972, Duebbert and Kantrud 1974). An executive order by President Richard Nixon in 1972 banned the widespread use of toxicants and effectively halted the use of predator-population reduction to enhance duck nest success for several decades. By the late 1980s and early 1990s, the alarming decline of duck populations, the compelling evidence of the magnitude of duck nest predation (Greenwood et al. 1987, Beauchamp et al. 1996) and the disappointing results of alternative methods to enhance nest success probably provided the impetus to reconsider lethal predator reduction to improve duck nest success.

Does Predator Management Work?

The most pressing question concerning trapping as a means of reducing medium-sized mammal predators to enhance duck nest success was obvious: can trapping work? Many predator ecologists and waterfowl managers believed that trapping would not reduce predator populations or that there would be compensatory predation so that duck nest success would change very little. Thus, the initial research focus was on efficacy of trapping to enhance nest success.

Initial research by scientists at the Northern Prairie Wildlife Research Station suggested that trapping on relatively small units of land, typically quarter sections (160 acres [64.7 ha]) that were waterfowl production areas purchased using duck-stamp dollars, increased nest success relative to control sites (Sargeant et al. 1995). However, nest success on predator-reduction sites remained below levels that could maintain a stable local population (Cowardin et al. 1985). Subsequent research by several graduate students, funded primarily by the Delta Waterfowl Foundation (Delta), produced a very different result. Studies at differing sites, scales and years produced a surprising convergence of results—trapping elevated Mayfield duck (*Genus species*) nest success to between 40 and 50 percent success, well above nest success on control sites (Table 1).

Table 1. Mayfield duck nest success in the Prairie Pothole Region with and without lethal predator management of medium-sized mammalian nest predators from 1994 to 2006.

Type of nests	Percent nest success		Plot	Sample		
	Trapped	Control	size[a]	size[b]	Location	Source
Dabbling duck[c]	6	14	Small	947	North Datota and Minnesota	Sargeant et al. 1995
Dabbling duck[c]	42[d]	23[d]	Medium	2,706	North Dakota	Garrettson and Rohwer 2001
Dabbling duck[c]	36	15	Large	3,305	North Dakota	Hoff 1999
Dabbling duck[c]	53	29	Small	4,240	North Dakota	Chodachek and Chamberlain 2006
Dabbling duck[c]	48	19	Medium	2,376	Saskatchewan	Vance Lester, unpublished data 2000
Dabbling duck[c]	57	36	Large	5,124	North Dakota	M. Pieron, unpublished data 2006
Diving duck[d]	57	29	Medium	167	North Dakota	Mense 1996
American coot[e]	67	75	Medium	233	North Dakota	Mense 1996

[a] Large equals 36 square miles (93.2 km^2); medium equals 16 square miles (41.4 km^2); small is equal to or less than 1 square mile (2.6 km^2) or smaller.

[b] number of nests followed

[c] Species composition primarily was blue-winged teal (*Anas discors*), mallard, gadwall (*A. strepera*), northern shoveler and northern pintail (*A. acuta*)

[d] Species composition primarily was ruddy ducks and redheads

[e] *Fulica americana*

Biological Issues with Trapping

Biological evaluations about predator reduction as duck management logically started with tests of the impacts on nest success. However, the secondary questions soon followed. In the age of ecosystem thinking, some obvious follow-up questions involved impacts on other members of the community. One study questioned the impacts of predator trapping on grassland passerines. Specifically, Nancy Dion tested whether there was a trophic cascade whereby reduction of medium-sized mammals allowed an ecological release of small mammals, some of which might increase nest predation on nests of grassland songbirds. Examination of natural nests and experiments using artificial nests suggested that overall predation rates on trapped blocks did not change (Dion et al. 1999). In contrast, for the grassland nesting shorebirds, primarily upland sandpipers (*Bartramia longicauda*) and Wilson's phalarope

(*Phalaropus tricolor*), predator trapping elevated nest success, though the increase in success was less than for nesting ducks (Jackson 2003, Darren Wiens, unpublished data 2006). Another Delta-funded graduate student, Jeremy Adkins, quantified the increase of mice on the trapped blocks. Rodent-population growth from spring to fall was almost twice as great on the trapped blocks relative to control blocks, but populations on trapped blocks were back to control levels after the winter (Adkins 2003).

Waterfowl biologists also asked questions about how trapping might influence other duck species and other phases of reproduction. The initial emphasis of predator reduction was to elevate nest success of upland nesting ducks. However, Ben Mense did overwater nest searching and found that diving ducks, such as redheads (*Aythya americana*), canvasbacks (*A. valisineria*) and ruddy ducks (*Oxyura jamaicensis*), also had greatly improved nest success on trapped blocks (Garrettson et al. 1996, Mense 1996). Likewise, two examinations of ducklings showed that brood survival for both northern shovelers (*Anas clypeata*; Zimmer 1996) and mallards (Pearse and Ratti 2004) was elevated on blocks that were trapped. Initial work by Garrettson and Rohwer (2001) suggested that duck-breeding populations on trapped blocks were elevated in the year after trapping but that work was based on only 1 year and is the subject of ongoing research.

Social Issues with Predator Management

Almost any wildlife management in this century will involve compromises among parties with differing philosophies. We suspect that the social issues of trapping are probably more complex than the biological concerns about the efficacy of trapping and unintended effects on other members of the community. However, because social issues of predator trapping might not be necessary if trapping proved to have little efficacy at improving duck production, we addressed biological issues first.

Reducing one population using lethal means to benefit a second population is probably as controversial as any wildlife management. There are three somewhat different aspects of this management that have the potential to make it of concern. First, intensive management of any kind is a concern to some in the natural resources community that have adopted a philosophy that nature should not be managed but, instead, left alone so that nonhuman forces shape populations and communities (Nash 1968, Decker et al. 1991). This nonmanagement philosophy has become more popular among the public in recent decades. A second point of issue is that the lethal aspects of predator trapping would concern anyone with a value system that precludes killing animals, especially higher vertebrates like mammals. The third controversial aspect of predator management is the fact that it involves lethal management that benefits other, relatively common animals, even if they are in high demand by some members of the public.

Several factors probably ameliorate the importance of the first objection of predator management. The idea of leaving ecosystems alone and prescribing no management is probably most appropriate for pristine environments where the community is intact and where the full range of ecosystem functions are still in place. This scenario is a dramatic contrast to most of the PPR where the majority of the prairie has long been under cultivation, where much of the flora is exotic and where the predator community is vastly altered from pre-European settlement times (Cowardin et al. 1983, Sargeant et al. 1993). The elimination of top predators, the abundance of cultivated high-energy foods, such as sunflowers that are readily available in the winter, and the abundance of excellent winter den sites surely cause unnaturally large populations of medium-sized-mammal predators to exist in much of the PPR (Cowardin et al. 1983). Finally, the proponents of no-management are less likely to be actively concerned about areas where the majority of land is privately owned and under intensive management for agricultural production.

Lethal Management

Predator trapping, as it has been experimentally tested (Table 1), involves intensive trapping on blocks of habitat with the goal of substantially reducing the predator population and, thereby, of elevating duck recruitment. This is a form of management that obviously involves killing large numbers of animals (Garrettson and Rohwer 2001). Acceptance of predator management requires a philosophy that allows killing of animals. The visibility of the antihunting and anti-animal-use movement makes it clear that there are individuals that do not embrace any philosophy involving animal use, particularly when animals are killed (Gentile 1987, Rutberg 2001).

Proponents of predator management recognize that causing the death of animals can evoke a deep philosophical divide. Whether they are avid consumptive users or ardent antihunters, individuals firmly on one side of this divide, are not likely to be swayed by arguments from the other side of the divide (Shaw 1977, Bright et al. 2000). Much literature suggests that values concerning wildlife will influence how people perceive and react to various options for wildlife management (Fulton et al. 1996, Manfredo et al. 1999, Bright et al. 2000, Dougherty et al. 2003). However, it would surely be incorrect to assume that animal death is a clear philosophical divide that will lead to predictable and consistent beliefs and behaviors of most people in North America regarding specific wildlife issues. To the contrary, we suspect the acceptability of a proposed wildlife-management activity, even potentially controversial management involving death of wild animals, will depend on the situation. Human-dimension surveys covering a wide variety of wildlife issues suggest that acceptance of wildlife management is situation specific (Manfredo et al. 1998, Messmer et al. 1999, Decker et al. 2006).

Predictions Regarding Predator Management for Waterfowl

Predator reduction to enhance waterfowl production might be predicted to have relatively low social acceptability because of three independent concerns. First, it is lethal management of some wildlife, which is less acceptable than nonlethal management (Manfredo et al. 1998, Decker et al. 2006). We note, however, that many studies on the acceptability of lethal management deal with charismatic animals, like big cats, wolves and deer (Kellert 1985, Decker et al. 2006), which may not be relevant to medium-sized, mammalian predators. Acceptability of lethal management varies with the species considered (Messmer et al. 1999).

Second, the on-the-ground management relies heavily on trapping, which has long been controversial in North America (Gentile 1987, Proulx and Barret 1991). Although legislative attempts to ban trapping have been remarkably unsuccessful (Gentile 1987), in at least six states, ballot initiatives have limited the use of trapping in the wildlife arena (Deblinger et al. 1999). The fact that ballot initiatives have been a far more effective means of reducing trapping than direct legislation reflects broad public concerns about trapping that are suggested by human-dimensions studies of the topic (Kellert 1981, Manfredo et al. 1999). The success of ballot initiatives to limit trapping also shows that antitrapping advocates can be organized enough to get issues in front of a public that might then form an opinion about trapping, even if most members of the public had not been active stakeholders in the trapping issue (Shaw 1977, Deblinger et al. 1999).

The third component of predator management for waterfowl that is likely to compound social concerns is the management goal itself. In this case, the goal of management is to increase the population of a set of ducks as game animals that is relatively abundant where it would influence hunting opportunities. Opinion surveys of various segments of the public show that the same type of management will have a range of acceptance depending on the reasons for management. Human safety issues often can engender the greatest support for intensive or lethal wildlife management (Manfredo et al. 1998, 1999; Messmer et al. 1999). Management that preserves ecosystem function or that protects endangered species will often yield less support than if the management goal is to protect human welfare. But, it will yield greater acceptance than if the goal is to increase game species (Messmer et al. 1999, Decker et al. 2006). Acceptance of lethal predator management with the goal of game-animal production also can vary depending on who benefits and on economic impacts to local communities (Decker et al. 2006).

Contrasting Predictions and Survey Results on Predator Management for Waterfowl

We might expect that the social acceptance of lethal predator management to increase duck production would be low because it combines three aspects of wildlife management that tend to engender little support: lethal management, trapping and a goal of game-animal production. However, the existing survey data that directly apply to predator management for duck production suggest that lethal predator reduction is acceptable among much of the public (Messmer et al. 1999). A mail survey of 1,500 random U.S. households that asked about controlling skunks, raccoons and foxes to improve duck nest success found that almost 60 percent of respondents fell on the side of supporting or strongly supporting this management. Individuals that opposed or that strongly opposed such management comprised less than 13 percent of respondents (Messmer et al. 1999). The same survey also asked about controlling these medium-sized predators to aid ring-necked pheasant (*Phasianus colchicus*) and gray partridge (*Perdix perdix*) populations (both exotic species) or to increase songbird populations. Surprisingly, there was less support (55 percent) for predator management for songbirds (a rapidly declining set of birds) than for waterfowl or for pheasants and partridge (56 percent). As expected, there was greater support (67 percent) for protecting endangered piping plovers

(*Charadrius melodus*) by controlling foxes (Messmer et al. 1999). We caution that this rather unexpected level of support for predator management for game animals may reflect the respondent population. The respondents (39.7 percent) were overrepresented by midwestern and rural residents, by those with a history of consumptive resource use, and by older men (Messmer et al. 1999), all of which likely biased results toward a more accepting view of predator management (Deblinger et al. 1999, Dougherty et al. 2003).

The wording of the survey by Messmer et al. (1999) may have inflated the apparent public acceptance of predator management for waterfowl. The survey began with background information on predator management. That information may have been biologically correct, but the respondents only got one side of a story, which surely would not have happened if there was debate about a pending policy issue (Shaw 1977, Deblinger et al. 1999). For example, the preamble to questions about management for duck nests emphasized the importance of the PPR for ducks, made it clear that farming had increased the ability of predators to find and raid duck nests, and suggested that nest success has fallen to dangerously low levels (Messmer et al. 1999). The nonneutral wording and the information provided before the survey questions may have lead to the high support for predator management. However, such information dissemination would be relevant if there was a debate about management policy.

We believe that there is much need for more detailed information about social acceptance of predator management to increase duck production, especially given that this management appears to be one of the most effective methods available to increase duck production (Rohwer et al. 2004). In particular, the survey work should target different aspects of the public and stakeholders.

Acceptance in the Waterfowl Management Community

Social acceptance of a management technique is likely to play a major role in the implementation of that technique. In this era of diverse stakeholders, intense political pressure on management agencies and frequent litigation, it is reasonable to anticipate that some managers will avoid management techniques that are highly controversial and that will inflame some stakeholders. However, the opinions of managers about various management options will probably also have much influence on whether a particular technique is implemented. West and Messmer (2004) recognized the importance of managers' views and surveyed federal and state land managers in duck-production areas of the United States.

While managers appeared well aware of the extent that predation of nests, hens and ducklings inhibits duck recruitment, their scoring of the acceptability of predator management did not appear to be any greater than public opinion about predator reduction (Messmer et al. 1999). It is also interesting that managers ranked dense nesting cover, elevated nesting structures, nesting islands, fenced nesting cover and fences on nesting peninsulas as more effective than predator trapping. Our review of duck nest success and of brood survival literature suggests that managers are not well informed about the relative efficacy of these techniques for elevating duck recruitment (Rohwer et al. 2004). We note, however, that managers' scoring of the effectiveness of any technique may have integrated both biological efficacy of elevating nest success and some assessment of cost efficiency.

We are aware that many biologists and managers have two concerns about funding for predator reduction in waterfowl management. First, there is concern about the cost efficiency. Predator management is an annual expense, so many wildlife managers assume that, in the long run, habitat management is always more cost effective, especially when management permanently secures habitat through fee title or perpetual easements. However, this assumption is unlikely to be correct for two reasons. First, the biological impact of upland-habitat protection and of restoration to improve duck nest success is not as dramatic as predator management (McKinnon and Duncan 1999), and it is very dependent on the scale of implementation (Greenwood et al. 1987, Reynolds et al. 2001). Second, habitat maintenance with fee title lands or monitoring for easement violations are annual costs for habitat management that are far from trivial (Hollevoet and Dixon 2007) and can overshadow the annual management costs of predator reduction, which are less than $2.00 per acre.

To our knowledge, there have been only two cost-benefit analyses of wildlife techniques used for duck production in the prairies. The pioneering work by Lokemoen (1984) showed that predator reduction was probably the most cost-effective technique for waterfowl management. Unfortunately, the exact methodology used by Lokemoen was unclear. But, his work is widely cited, and he has a well established reputation for his knowledge of waterfowl breeding ecology and management. Recently, Rashford and Adams (2007) completed detailed economic analyses that used the mallard model (Johnson et al. 1987) to generate the recruitment estimates and coupled those with actual management costs. This analysis, based only on mallard production, shows that direct management activities, such as predator management, are typically more cost effective than habitat-conservation measures in almost any landscape and for any desired recruitment goal (Rashford and Adams 2007).

Perhaps a greater concern of managers is the diversion of resources that might occur if predator management was widely accepted as appropriate waterfowl management. As an example of this concern, the Mississippi Flyway Council passed a resolution that explicitly stated that they did not support the practice of predator removal to improve waterfowl recruitment. The justification suggests a lack of cost efficiency and concern that, in an era of limited resources, expending funds on predator removal necessarily competes with landscape habitat programs. We recognize that habitat protection is necessary to meet long-term goals for waterfowl management, but we also believe that, in the short term, it would be wise to invest some waterfowl-management dollars in intensive management, such as predator reduction, that can substantially improve duck production on existing habitat.

Consideration of Other Stakeholders

Predator management, as practiced in the experimental studies supported by the Delta, almost always involves private lands. That means some of the obvious and active stakeholders in this management are private landowners that control access to their land for trapping and for evaluations of duck production. In the process of funding and coordinating over a dozen graduate projects to evaluate predator reduction, we have interacted with, literally, hundreds of landowners in North Dakota, South Dakota and Saskatchewan. The overwhelming majority of landowners we contacted have allowed us free access to their land. Many landowners actively embrace the trapping effort because they view raccoons and skunks as pests that cause damage to crops or outbuildings. However, a segment of the landowners we contact deny access to their land. Landowner concerns about predator reduction that have been serious enough to deny permission to trap on their property have primarily fallen into two categories: (1) dislike of ducks and (2) dislike of duck-management agencies because of their actions to protect habitat.

In the PPR with the highest duck densities, the primary agricultural crops have historically been cereal grains—mainly spring wheat and barley. Until relatively recently, these crops were cut into a swath in late summer or early fall, and the swath remained in the field for days to several weeks for drying before it was combined. During this drying period, depredations on waterfowl, especially mallards, geese and sandhill cranes (*Grus canadensis*), could occur and could be severe in years of delayed harvest (Bossenmaier and Marshall 1958, Sugden et al. 1988, Clark et al. 1993). Such depredations appear to be declining in importance because of earlier maturing varieties of grain, reduced time in swaths and direct combining. However, many farmers, particularly older farmers, have experienced what they consider serious economic loss to waterfowl, and some of those farmers have no interest in having larger waterfowl populations as a result of predator reduction. This is likely less relevant in Canada (compared to the United States) because there is compensation paid for loss of crops from wildlife.

Unlike fall grain depredations, which are declining in most of the PPR, there is a growing concern in eastern North Dakota regarding breeding season populations of Canada geese (*Branta canadensis*). Populations of resident geese have greatly expanded in the last decade (U.S. Fish and Wildlife Service 2006) and are now abundant enough that many farmers perceive these geese are causing crop losses by their grazing in the spring on cereal grains. In several cases, farmers denied us permission to trap because they were concerned about increasing populations of resident Canada geese.

The more common reason that landowners refused access relates to prior habitat protection by wildlife agencies, particularly the U.S. Fish and Wildlife Service (USFWS) in the United States. In much of eastern North and South Dakota, especially in the Devils Lake Wetland Management District (in northeastern North Dakota) where much of our predator management research has been conducted, there has been active wetland protection that involves purchase of perpetual easements (Naugle et al. 2001). While this is a voluntary program, many landowners believe that the USFWS took advantage of farmers during an economic crisis. Easement violations have been common (Sidle 1981) and have resulted in negative perceptions of the USFWS for many farmers. A related land issue is the concern by some farmers that too much land is being purchased by the USFWS, which means land is not available for farmers, is not on the county tax roles and is not productive. When asking for permission to trap in North and South Dakota, we made it clear that we did not work for the USFWS. In most cases, that separation from the easement agency helped. But in some cases, farmers lumped all wildlife groups, be they state, federal or nongovernmental as “the Wildlife.”

All other concerns of farmers and landowners were far less important and were only voiced by a few individuals. Some landowners were concerned with liability issues associated with allowing the trapper onto their land. A few landowners appreciate seeing predators; some had a friend or relative that occasionally trapped furbearers in the fall for recreation or profit. And, some of these landowners did not want fox or raccoon populations suppressed. Very few landowners expressed concern about potential effects on the ecological community, specifically a trophic cascade that might cause increased rodent populations that might increase agricultural problems. Perhaps the third most common concern of landowners was that the trappers or the students evaluating the trapping would discover an endangered species and report the finding to the Wildlife, which would then disrupt farming activities. We should note that we have never heard a landowner show any concern about trapping based on a philosophical or on a moral concern about predators or on an ethical concern about lethal management.

Views of Hunters and Trappers

Some hunters have enthusiastically supported the idea of predator management. Most hunters are well aware that habitat is the basic requirement to sustain wildlife populations, but decades of reporting has also made hunters aware of issues with duck nest success on the prairies. Trappers and trapping organizations have also been staunch supporters of predator reduction. We have experienced a few individual fur trappers that are concerned about trapping—that it would reduce populations in areas where they trap. However, there has been strong support for our research on predator reduction, including support from the Minnesota Trapper Association, the Saskatchewan Trappers Association, the Fur Institute of Canada and Fur Takers of America, Incorporated, which has state chapters in both North and South Dakota.

Conclusions

A decade of research has suggested that reduction of medium-size mammalian predator populations can substantially improve duck production on a variety of scales (Table 1). Moreover, analyses of cost efficiencies suggest that predator management is probably one of the best ways to elevate duck recruitment with limited resources, especially in environments where significant conversion to planted cover is not feasible. Initial studies of effects of trapping on other members of the community, such as other nongame birds, provide no cause for concern.

More research is needed concerning the social acceptance of predator reduction aimed at increasing duck production. Managers express concern about lethal management of predators and about trapping (West and Messmer 2004), which probably reflects their perception that the public will be concerned with predator reduction. We look forward to being able to report in a few years on planned research that samples several segments of the public, land managers, landowners and waterfowl hunters to gauge their acceptance and their activism concerning predator management.

We would like to acknowledge the hard work of over a dozen graduate students that have done most of the evaluations of predator management. We also thank the countless landowners that have allowed access to their private land for both the student researchers and the trappers. The student research was primarily funded by the Delta and was published with the approval of the Director of the Louisiana Agricultural Experiment Station as manuscript number 07-04-028.

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Impacts of Predators on Northern Bobwhites in the Southeast

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Introduction

The northern bobwhite quail (*Colinus virginianus*) is an important game bird that is intensively managed for hunting recreation in the southeastern United States. Despite interest regionwide, populations have been declining for much of the last 40 years (Brennan 1999). Population declines in the Southeast have occurred as a result of widespread habitat loss associated with land-use changes (Brennan 1999). These land-use changes include both conversion from agricultural to forest landscapes and changes in forest management practices, which result in dense forest canopies that shade required ground vegetation (Brennan 1999, Rollins and Carroll 2001). In addition, low-quality habitats may predispose bobwhites to high rates of predation, resulting in accelerated rates of population decline (Rollins 1999, Rollins and Carroll 2001, Cook 2004).

Although both avian and mammalian predator populations have increased across the bobwhite's southern territory at the same time that bobwhite populations have declined, focus on mammalian predators appears to be greatest. This group of species, often called mesomammalian predators (medium-size carnivores) are known to be major predators of bobwhites and of their nests (Stoddard 1931, Rollins and Carroll 2001). In general, these predators include coyotes (*Canis latrans*), bobcats (*Felis rufus*), raccoons (*Procyon lotor*), opossums (*Didelphis marsupialis*), nine-banded armadillos (*Dasypus* *novemcinctus*), striped skunks (*Mephitis mephitis*), red foxes (*Vulpes vulpes*) and gray foxes (*Urocyon cinereoargenteus*). Decreases in hunting and trapping, due to declining fur markets, and beneficial land-use changes have resulted in increased predator abundance, with some species reaching historically high densities across the Southeast (Peoples et al. 1995).

Long-standing paradigms in quail management suggest that predation was rarely a concern and that predators could be controlled indirectly through habitat manipulation (Errington 1934). The response of predators to habitat manipulation is unknown, but bobwhite populations and predator communities may both benefit from intense habitat manipulation (Taylor and Burger 1997).

The use of predator removal as a tool in bobwhite management has become increasingly important. For example, since 2001, Georgia has issued permits to private landowners for nuisance-wildlife damage control. These permits allow trapping and removal of furbearers outside of traditional trapping seasons. Many plantations have been issued such permits to control mammalian predators during the bobwhite nesting season. This practice is controversial, and some professional biologists would suggest that it is contrary to modern wildlife management principles.

Although there is a long history of predator removal to increase populations of bobwhites and other game birds, empirical evidence of its efficacy is limited. In addition, predator-removal studies have produced contradictory results on the benefits for target species. In particular, it is not clear if predator removal can increase avian breeding populations (Cote and Sutherland 1997). Although there are studies on several species of game birds in North America and Europe, there is little quantitative data on bobwhite responses to predator removal (Rollins and Carroll 2001).

In this paper, we review some of the basic, biological issues relative to predator removal within game bird management, and we outline some paradigm shifts that might allow management to be undertaken within a modern social context.

Bobwhites and Predators

Bobwhites, like many other ground-nesting bird species, experience high annual mortality rates (Rollins and Carroll 2001, Yarrow and Yarrow 2005). Approximately 80 percent of annual mortality is observed in bobwhites from natural predation, hunting, disease, exposure and other factors (Yarrow and Yarrow 2005). Predation is the primary source of mortality for bobwhites at all life stages (Rollins and Carroll 2001). Bobwhites are vulnerable to predation since they spend most of their time on the ground, including when nesting. Game bird populations can be limited by predators, but the effects of predation on the population depend on the extent to which predation is counteracted by compensatory reductions or by increased reproduction (Newton 1998). Nest predation has been considered the primary cause for bobwhite nest failure (Staller et al. 2005), and the most common bobwhite nest predators are reported to be mammals (DeVos and Mueller 1993, Taylor and Burger 1997, Staller et al. 2005). Nest predation studies have reported that between 52 and 60 percent of bobwhite nest losses are due to mesomammals (DeVos and Mueller 1993, Staller et al. 2005). The most commonly reported mammalian nest predators of bobwhites are skunks, raccoons, armadillos, opossums, bobcats, foxes and coyotes (Hernandez et al. 1997, Fies and Puckett 2000, Staller et al. 2005). Other known nest predators include snakes (*Elaphe* spp.), several avian species and fire ants (*Solenopsis invicta*) (Fies and Puckett 2000, Staller et al. 2005). Recent studies in the Southeast have only just begun to tease out the role of nonmammalian predators on bobwhite nests. For example, the use of cameras at nests of a number of different bird species suggests that snakes may be one of the most important avian nest predators (Weatherhead and Bloun-Demers 2004). A camera study of bobwhite nest predators in northern Florida and southern Georgia showed 29 percent of nest depredations from 1999 to 2001 were caused by snakes (Staller et al. 2005).

Game Birds and Predator Removal

A wide range of outcomes have been reported for avian population responses to predator removal (Cote and Sutherland 1997, Newton 1998, Rollins and Carroll 2001). The effects of predator control upon game species can vary, depending on the kind and intensity of predation, on the degree of predator control, and on the prey species (Chesness et al. 1968). Most studies examined nest success or some other index of productivity, such as ratios of young to adults in the fall. Some studies observed fall abundance, and a few studied subsequent breeding populations to assess the effects of predator removal on a target bird species. Nesting success or hatching success is the most commonly reported response variable to predator control. It is most often defined as at least one egg in the clutch hatching, and many studies have observed higher hatching success for ground-nesting birds when predator control was conducted. For example, increased nest success was observed when predators were controlled for ring-necked pheasants (*Phasianus colchicus*) (Chesness et al. 1968, Trautman et al. 1974), ruffed grouse (*Bonasa umbellus*) (Edminster 1939), and ducks (*Anas* spp.) (Schranck 1972, Duebbert and Lokemoen 1980, Sargeant et al. 1995). An increase in wild turkey (*Meleagris gallopavo*) production was also observed when mammalian predator removal was conducted (Beasom 1974). It is important to note that there has been very little standardization of definitions of predator removal in research or management. The impact of predator removal on predator populations is often unmeasured, which lends uncertainty to inferences of the relationships among predator and prey populations. Further, important issues of cost effectiveness, scale and movement of predators back to study areas are more difficult to understand when predator populations are ignored in predator removal studies.

Limited empirical evidence of the impact of predator management on quail breeding success exists in the literature, and no study in the Southeast has ever examined mesomammal predator removal on bobwhites in high-quality habitat. No treatment effect was observed for bobwhite or scaled quail when a mammalian-predator removal study was conducted on only 6 square miles (15 km^2) in southern Texas (Guthery and Beasom 1977). On 12 farms in North Carolina, predator removals had no effect on bobwhite populations unless habitat improvements were incorporated. While predator removals increased the response of bobwhite populations to habitat improvements, habitat was the most limiting factor on the modern farmed landscape (Palmer et al. 2005).

Relatively few avian studies examined fall abundance in response to predation management. Again, variable results have been reported for postbreeding population responses to predator control. Increased postbreeding numbers were observed in studies of pheasants (Trautman et al. 1974), gray partridge (*Perdix perdix*) (Tapper et al. 1991), black grouse (*Tetrao tetris*) (Marcstrom et al. 1988), and turkey and bobwhite (Beasom 1974). Whereas in other studies, no increase in postbreeding abundance was observed in ruffed grouse (Bump et al. 1947), pheasant (Chesness et al. 1968) or black grouse (Parker 1984).

From a population ecology standpoint, recruitment into a population is based, in part, on the number of individuals available for breeding in the spring. Thus, breeding population size is an important component in maintaining or increasing population size. After predator removal, increased breeding numbers were observed for various ducks (Duebbert and Lokemoen 1980), black grouse (Marcstrom et al. 1988) and gray partridge (Tapper et al. 1991). However, other studies did not find increased breeding numbers after predators were removed for ruffed grouse (Bump et al. 1947), pheasant (Chesness et al. 1968) or black grouse (Parker 1984). These studies reported varied responses to predator control, even within the same species. This variation may be due to different intensities of predator removal, or it may be due to differences in geographic areas where factors other than predation may be limiting the population. No studies reported bobwhite breeding population responses to predator removal.

Factors That Influence Avian Responses to Predator Removal

Cote and Sutherland (1997) conducted a meta-analysis to examine responses to predator removal in hatching success, in postbreeding populations and in subsequent breeding populations across a wide range of avian species. This study generally showed increased hatching success and increased postbreeding populations, but no overall increase in subsequent breeding populations occurred when predators were removed (Cote and Sutherland 1997). Since this study looked at both migratory and nonmigratory game birds, some of these results are probably an artifact of the different life histories. Migratory birds, such as waterfowl, may respond differently to localized predator removals than nonmigratory gamebirds since they are subjected to predation pressure across a much a larger area than nonmigratory species are, and they likely have different population limitations throughout the year. The environment (weather), resources (water, food, nest sites, breeding grounds), inter- and intraspecific competition, parasites, disease, and predation are all possible limitations upon avian populations (Newton 1998).

Europe has a long history of predator removals as a means of game management that can be traced back to the early 19th century when predators were removed on large, privately owned sporting estates (Reynolds and Tapper 1996). Several studies of the gray partridge reported increased production as a result of predator removals (Potts 1986, Tapper et al. 1996). In particular, Tapper et al. (1996) found that predators play a key role in limiting both production and breeding density of partridges; they observed increases in nesting success, average brood sizes and subsequent breeding densities in areas that received predator control. In Great Britain, red grouse (*Lagopus lagopus*) shooting estates have observed sharp declines in their populations when no predator management was conducted, but estates with active predator control have not seen these same declines (Reynolds and Tapper 1996, Redpath and Thirgood 1999). In fact, estates with predator removal have maintained populations with consistently high grouse densities (Reynolds and Tapper 1996). Thus, European studies suggest predator removal is an effective management tool to increase a fall population and even to increase the subsequent breeding population.

Regional differences in bobwhite response to predator control may exist. Early studies of bobwhite populations in Georgia, Florida and other southeastern states suggest that predators may limit populations size, especially during the summer months (Stoddard 1931). However, predation on bobwhites during winter in Wisconsin and Iowa seems to demonstrate a density-dependent relationship where severe weather and food limitations might act in conjunction with predation to limit abundance (Errington and Stoddard 1938, Newton 1998).

Small-scale Bobwhite Demographic Shifts

Few studies have examined mechanisms for possible increases in avian production as a result of predator control. Among studies of the impacts of predator control on gamebirds, few have investigated finer demographic parameters. For example, grey partridge studies (Tapper et al. 1996) reported changes in parameters, such as average brood size, as a result of predator reduction. Demographic parameters, such as brood size and clutch size, can reflect changes in per capita productivity that may otherwise be overlooked when only examining components of reproductive effort, such as nest success. None of the studies on bobwhites report small-scale demographic shifts that may occur across the breeding season as a result of predator control.

Predation Risk

Most predator studies on bird populations do not examine the predators themselves or the factors that account for how they affect nesting birds

(Weatherhead and Bloun-Demers 2004). Changes in the predator community from predator control over the course of the breeding season could alter risk factors associated with nest survival. There are a large number of complex relationships that exist among predator communities. Removal of one species of predator could result in increased populations of other smaller predators; the cascade effect could contribute higher levels of mortality on the target species than these larger predators. Predation that occurs among predator guilds is important in the shaping of predator communities (Reynolds and Tapper 1996). For bobwhite populations, the role of other predators that also serve as prey for larger predators, such as snakes, could increase as a result of decreased predator pressure from mesomammals, such as bobcats (Sovada et al. 1995).

In addition, it is important to consider alternative prey sources. Population cycling of rodents could provide some reprieve for bobwhites, allowing them an opportunity for population gains. Recent studies demonstrate dramatic shifts in annual survival of bobwhites (Palmer and Wellendorf 2007), which are negatively related to alternative prey abundance. These studies suggest that regional and temporal shifts in the avian predator community may help explain dynamics of bobwhite populations but also indicate the complexity of predator-prey relationships in the southeastern United States.

Southeastern U.S. Ecosystems and Predator Management

When assessing the potential impacts of predator control on game bird abundance, there is an obvious bias in where and in what types of ecosystems most studies have been undertaken. For example, the studies by Marcstrom et al. (1988), Sovada et al. (1995), Tapper et al. (1996), and Redpath and Thirgood (1999), which represent some of the best research on game bird-predator interactions relative to predator control, were all conducted in northern, temperate ecosystems. All of these systems can be characterized as having relatively simple predator and prey communities. In addition, habitat wasn't very complex and, in most cases, was dominated by agriculture. Translations of these results to more complex ecosystems found in warmer climates might be limited. It should be noted that these ecosystems are far less complex than those in the southeastern United States. Only a few key predators are critical to understanding population behaviors in those areas and, thus, are capable of being controlled with minimal potential interaction with nontarget species. In contrast, the southeastern ecosystems have a large number of mammalian, avian, ant and snake species that are all known bobwhite predators (more than 20 species).

Predator Control versus Predation Management

Lethal means of predator reduction has led to much controversy about the objectives and process of predation management. There is a clear distinction between predator control and predator management. Control is simply reducing predator numbers while management is just that—management of the system to minimize the effects of predators on a prey species. It may involve lethal or nonlethal removal methods. Predator management, as it is now defined, may include removal, but it may also include other management options, such as improving habitat for predator avoidance or supplementally feeding bobwhites. Even removal of predators might be defined quite differently; control implies that the purpose is to eliminate or significantly reduce abundance of predators. Whereas, management suggests removal only to the extent that the target species is released during some crucial period.

Conclusion

Predator management as a tool to enhance wildlife populations and hunting opportunities for game birds has a long and controversial history. This management paradigm appears to have shifted from the early 20th century's when predators were viewed as competitors with humans for a shared resource and their impact was additive. During much of the latter 20th century, the contrasting view that predators were not important in driving game bird populations, that is, that predation was compensatory, was predominant. We believe, like much dogma in wildlife management, that both views were based on little science and mainly on anecdote. Scientific investigation has been key to understanding the impact of predation and predator management on game birds, and we see a trend in places with rather simple predator and prey communities. How this translates to more complex systems remains to be seen.

Recent authors have suggested that predator-prey relations are important and complex (Closs et al. 1999, Stouffer et al. 2005, Rockwood 2006). As a result, we see a shift in this paradigm to encompass predation management rather than predator control. Like all management systems, we should not think about predator removal and how it might impact prey and predator species. Instead, we should focus on the predation process. What managers of bobwhites and those interested in ecosystem integrity should desire is management of predation, not necessarily reduction of predators. This movement of interest and research toward understanding processes and how to manage those processes is important to allow us to manage our ecosystems in a way that provides opportunities for reasonably intense management of popular game species within the context of societal goals of maintaining biodiversity.

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Impacts of Predation on Greater Sage-grouse in Strawberry Valley, Utah

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Introduction

In March 1998, we began to study a population of greater sage-grouse in Strawberry Valley of northcentral Utah. This population decreased from between 3,000 and 4,000 birds in 1939 (Griner 1939) to an estimated 150 birds in 2000. The goal of our research was to identify factors limiting the population and to recommend measures to mitigate or eliminate those factors. Initial work with radio-collared sage-grouse showed predation by red fox (*Vulpes vulpes*), a nonnative predator, as one of the major limiting factors contributing to decreased survival and nest success.

Kamler and Ballard (2002) documented the expansion of native and nonnative red foxes across North America in the 1900s. Their estimates of the arrival of the nonnative red fox to Utah are consistent with information from on-the-ground wildlife professionals. Kendall Nelson and Alden Thomas, former Utah Division of Wildlife Resources (UDWR) employees, spent extensive time in Strawberry Valley between 1966 and 1980 and never encountered a red fox (K. D. Bunnell, personal communication 2000). During personal interviews, Blaine Dabb, a UDWR conservation officer (early 1980s to1999), and S. Dick Worthen, a retired UDWR biologist (1971 to 1987), who both worked extensively in the area, indicated that they began seeing red fox commonly in Strawberry Valley by the mid-1980s (K. D. Bunnell, personal communication 2000).

The negative impact that introduced foxes can have on many different species of bird populations is well documented (Petersen 1982, Bailey 1993, Sargeant et al. 1998). Only two published studies (Gregg 1991, Gregg et al. 1994) have implicated predators as a limiting factor to sage-grouse populations. In both instances, unusually high predation rates on nesting females were attributed to poor habitat conditions. In addition, a recent study in Wyoming failed to demonstrate an increase in nesting success following coyote (*Canis latrans*) control (Slater 2003), reinforcing the opinion that predation is not a widespread factor limiting sage-grouse populations. Although marginal habitat may be the leading cause of poor reproductive success and mortality, scale and habitat contiguity may be more important than values of canopy cover or grass height. In Europe, where habitats are isolated, small and fragmented (Andren and Angelstam 1988), predator control has been effective in increasing nest success, juvenile survival and population size (Parker 1984, Marcstrom et al. 1988, Moss 1994) of other tetraonids. The Strawberry Valley study area is highly fragmented with large amounts of edge for predators. Cote and Sutherland (1997) showed that removing predators from bird populations increased hatching success and postbreeding population size, but it did not increase overall breeding population size. In addition, Mezquida et al. (2006) warned that predator control has the potential for both positive and negative direct and indirect effects that must be analyzed prior to initiation of control. Although the impacts of red fox predation on sage-grouse rangewide are largely unknown, the site-specific effect on sage-grouse survival in Strawberry Valley will be reported.

Our objectives were to (1) compare survival estimates of adult and juvenile sage-grouse in Strawberry Valley, Utah before (1998 to 1999) and after (2000 to 2005) predator control was initiated, (2) compare brood counts pre- and postcontrol and (3) report values of horizontal obscurity cover associated with resident locations in summer habitat.

Study Area

The study area is centered in Strawberry Valley of northcentral Utah. The area is a high mountain valley 2,460.63 to 2,679.35 yards (2,250–2,450 m), and receives about 22.83 inches (58 cm) of precipitation annually. Strawberry Reservoir is the dominant feature of the valley covering up to 2,812.57 acres (6,950 surface ha). Within the valley, there are approximately 3,621.94 acres (8,950 ha) of sagebrush-grass habitat that primarily borders the reservoir (Utah Reclamation Mitigation and Conservation Commission and U.S. Forest Service 1997). Mountain big sagebrush (*Artemisia tridentata vaseyana*) is the dominant shrub, with silver sagebrush (*Artemisia cana)* found in wet meadows and riparian corridors.

Methods

We trapped sage-grouse during March, April and May of 1998 through 2005 using the spotlighting method (Wakkinen et al. 1992). A necklace style radio transmitter, with mortality signal, was attached to sage-grouse of both sexes (Marcstorm et al. 1989).

Radio-collared sage-grouse were located and flushed on a weekly basis throughout the spring and summer (April 1 through August 31) to monitor survival and to measure habitat parameters. Daily survival estimates were calculated using the Mayfield estimator (Mayfield 1975). The midpoint between the last date a bird was known to be alive and the date it was found dead was used to determine the number of exposure days for calculating daily survival. We limited daily survival estimates to spring and summer because, during the 7 years of the study, 75 percent of total sage-grouse mortality and 80 percent of predation mortality occurred between April 1 and August 31. Sage-grouse that could not be located or that had radio transmitters that malfunctioned were right censored and excluded from the sample.

When we found a dead sage-grouse, the condition of the remains was examined to determine the cause of death, specifically whether the death occurred from mammalian or avian predation or from other causes (e.g., power lines, human interaction, accidents, sickness, etc). If bones and feathers were broken or matted (i.e., chewed), death was attributed to mammalian predation. If it was determined that a mammalian predator was responsible for the death of a particular bird, the area was examined for hair, scat, tracks or evidence of a den in an attempt to determine the species responsible. If feathers were intact and appeared to have been plucked or if only the breast was eaten, then death was attributed to avian predation. If a substantial amount or the whole bird remained, we submitted them to the Utah State Diagnostic Laboratory in Nephi, Utah, for necropsy. If there was an insufficient amount of evidence or information at the mortality site, the cause of death was designated unknown.

Reproductive success was measured by the ratio of chicks to hens during July and August brood counts from 1999 to 2005 (Connelly et al. 2003). Brood counts were conducted using trained German shorthair pointers to locate and flush both collared and uncollared sage-grouse hens throughout the study area. During July and August, chicks were developed enough to flush with hens but were still easily identified.

Horizontal obscurity cover, the habitat characteristic that likely has the greatest influence on predation (Gregg 1991, Gregg et al. 1994, DeLong et al. 1995), was measured at adult flush sites using a 0.84-square-yard (1-m^2) cover board stratified into thirds (0.00 to 13.11 inches [0–33.3 cm], 13.11 to 26.22 inches [33.3 –66.6 cm] and 26.22 to 39.37 inches [66.6–100 cm]) along the vertical axis with each stratification separated into 12 equal squares. Horizontal obscurity cover measurements were taken from a height of 10 to 14 inches (25.40 to 35.56 cm) at 2.73, 5.47 and 10.94 yards (2.5, 5 and 10 m) from the cover board in four directions.

Predator control efforts in Strawberry Valley began in 1999 and continued through 2005. Initial control efforts in 1999, by personnel from the U.S. Department of Agriculture, Animal and Plant Health Inspection Services, Wildlife Services (WS), were limited to aerially gunning from one fixed-wing aircraft flight and limited ground searches on, near and around the sage-grouse lek. From 2001 to 2002, WS expanded their control efforts spatially, by covering most of the sage-grouse habitat in Strawberry Valley and, temporally by increasing the frequency and timing of fixed-wing aircraft and helicopter flights followed by multiple ground searches to locate foxes, fox dens and other mammalian predators (i.e., coyote, badgers [*Taxidea taxus*] and skunks [*Mephitis mephitis*]). Active fox dens were readily identified from these aircraft by the presence of soil on top of the snow. WS subsequently treated active fox dens at the request of the UDWR with a large gas cartridge (Environmental Protection Agency registration number 56228-21). Also, beginning in 2003, WS broadened their efforts again by using leg-hold traps for terrestrial predators and poison egg baits for avian predators (corvid species). During 2003 through 2005, the overall predator control effort reached its highest point as aerial gunning, gassing dens, site-specific shooting and trapping, and weekly poison egg baits were used to protect sage-grouse of all ages. In addition to the aforementioned control by WS personnel, ground hunting and gassing dens by volunteers was used to remove and disrupt breeding of resident red foxes throughout the study area. Control was timed to kill as many red foxes as possible prior to breeding and, thus, to reduce fox densities and predation on sage-grouse before and during the lekking, nesting and brood-rearing seasons because our data indicated that this was when the majority of sage-grouse mortality occurred.

We used a chi-square test for homogeneity of proportions in a two-by-two table for pre- and postcontrol mortality rates. We considered results significant at an alpha-level of 0.05.

Results

Over the 8-year duration of the study, 160 resident sage-grouse were monitored to determine spring-summer survival rates. Combined spring-summer survival of sage-grouse radio-collared in 1998 (no red fox control) and 1999 (limited red fox control) was 43.6 percent using a Mayfield estimator (Mayfield 1975). Comparatively, spring-summer survival of sage-grouse during and after red fox control was expanded (2000–2005) averaged 67.8 percent. A chi-square test showed a significant difference (Pearson's chi-square statistic 20.95, with d.f. 1, P is less than 0.00001) between pre- and postcontrol mortality rates. Percent of overall mortality due to predation by red fox decreased from 68 percent in precontrol years to 54 percent in postcontrol years (Table 1). Of predation-related mortality, 87 percent was attributed to canids (Table 1).

During brood counts in 1999, prior to expanded predator control, we counted 12 chicks with 44 hens for a chick to hen ratio of 0.27, compared to an average chick to hen ratio of 0.72 for 2000 to 2005, after predator control was implemented (Table 2). We also documented an increase in the overall numbers of chicks and hens flushed during the brood-rearing season.

Horizontal obscurity cover from ground level to a height of 13.11 inches (33.3 cm) at 2.73 yards (2.5 m) from the nest (n = 22, where n represents the number of nests) or the adult flush site (n = 126, where n represents the number of male or female summer locations) was 99.3 percent and 97.1 percent respectively. Horizontal cover from 5.47 and 10.94 yards (5 and 10 m) at both the nest and adult flush sites totaled 100 percent.

In 1999, 24 active fox dens were located and treated with gas cartridges, and 5 foxes were killed through air and ground hunting, primarily from the area around the sage-grouse lek. During 2000 to 2005 an average of 26 fox dens were

Table 1. Spring-summer sage-grouse survival, percent mortality due to predation and percent predation due to canids and avian predation in Strawberry Valley, Utah, 1998 to 2005.

	Sage-grouse		Percent mortality	Percent predation by species	
	Monitored	Survival	due to predation	Canid/Red fox	Avian
1998[a]	21	0.384	0.92	0.92	0.08
1999[b]	22	0.484	0.42	0.8	0.2
2000	12	0.836	0.00	0	0
2001	27	0.636	0.75	0.83	0.17
2002	18	0.751	0.50	0.5	0.5
2003	14	0.777	0.33	1	0
2004	17	0.814	0.67	1	0
2005	29	0.862	0.50	1	0
Average	20	0.679	0.61	0.87	0.13

[a] no predator control

[b] limited predator control

Table 2. Summary of sage-grouse reproductive success measured through summer brood counts in Strawberry Valley, Utah, from 1999 to 2005.

	Hens	Chicks	Chick to hen ratio
1999[a]	44	12	0.27
2000	19	29	1.53
2001	38	9	0.24
2002	48	39	0.81
2003	12	11	0.92
2004	60	78	1.30
2005	171	86	0.50
Total	392	264	0.67

[a] limited predator control

treated with gas cartridges and 20 foxes were killed through aerial gunning and ground hunting-trapping throughout Strawberry Valley (Table 3). Red foxes are still found throughout the Strawberry Valley, so control efforts that focus only on sage-grouse habitat will never be effective in eliminating them there. We do not know if the density of red fox outside of core sage-grouse habitat is the same as fox density within the sage-grouse use areas.

Discussion

In our opinion, the red fox was not a causative factor in the early decline of the sage-grouse population in Strawberry Valley. It is likely that habitat loss

Table 3. Summary of predator control efforts to protect sage-grouse in Strawberry Valley, Utah.

	Red fox dens treated[b]	Red foxes killed	Other mamalian predators removed[c]	Estimated number of ravens removed[d]
1999[a]	24	5.0	19.0	0.0
2000	34	1.0	25.0	0.0
2001	25	12.0	48.0	0.0
2002	18	6.0	19.0	13.0
2003	10	32.0	33.0	75.0
2004	52	31.0	63.0	137.0
2005	5	35.0	37.0	150.0
Average	24	17.4	34.9	53.6

[a] control limited to the area around the sage-grouse lek

[b] This represents the number of active dens treated with a gas cartridge, where tracks, scat, fresh dirt or other fresh sign demonstrated current activity.

[c] Other mammalian predators included coyotes, badgers, skunks and racoons.

[d] Values reflect limited aerial and ground shooting; a large percentage of data comes from a U.S. Department of Agriculture, Animal and Plant Health Services, Wildlife Services estimate of one raven killed per four poison egg baits administered.

was the major cause of the original population reduction. In Strawberry Valley, 10,007.77 to 14,999.30 acres (4,050–6,070 ha) of sage-grouse habitat were treated to reduce sagebrush cover and increase forage for livestock (Utah Reclamation Mitigation and Conservation Commission and U.S. Forest Service 1997). In addition, Strawberry Reservoir was expanded in 1985 from 8,673.40 acres (3,510 ha) to its current size of 17 ,173.82 acres (6,950 ha), flooding 8,500.43 acres (3,440 ha) of sage-grouse habitat. In spite of this loss, some available and apparently suitable habitat is currently unoccupied by sage-grouse (Bunnell et al. 2004). Although red foxes were likely not responsible for the initial reduction in the sage grouse population, our data suggest that red fox predation is a major factor limiting the recovery of the population and, if left uncontrolled, threatens extirpation of this sage-grouse population.

Sage-grouse survival rates in Strawberry Valley during 1998 and 1999 are below the levels reported in other studies (Connelly et al. 1994, Zablan 1993; Table 1), and reproduction-recruitment for 1999 was only a fraction of the recommended guideline for a stable or increasing population (Connelly et al. 2000) (Table 2). We know many breeding aged birds are being killed, and red foxes are the implicated predator in at least 30 of 37 cases, based on examination of bird carcasses and the abundance of red fox. In support of this conclusion, mortality rates of sage-grouse declined following red fox control during winter 1999 and the expansion of this effort in 2000 through 2005 (Figure 1).

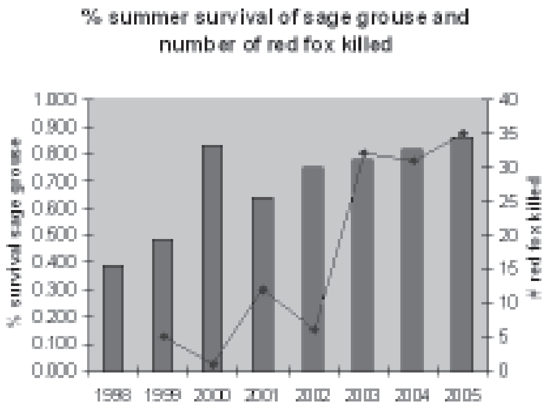

Figure 1. Percent survival of resident sage-grouse and the number of red fox taken by U.S. Department of Agriculture, Animal and Plant Health Inspection Servcies, Wildlife Services in Strawberry Valley, Utah, from 1998 to 2005.

Although we do not have conclusive evidence that predation is limiting recruitment (radio transmitters have not been placed on chicks), we feel strongly that, given the information available, predation on chicks is a major factor limiting recruitment. The fact that entire broods, rather than portions of broods, are lost is consistent with our hypothesis that predation, rather than habitat, is limiting chick survival. This hypothesis is also strengthened by the fact that brood counts prior to 2000 were only 66 percent of what they were during active control years (2000–2005) (Figure 2).

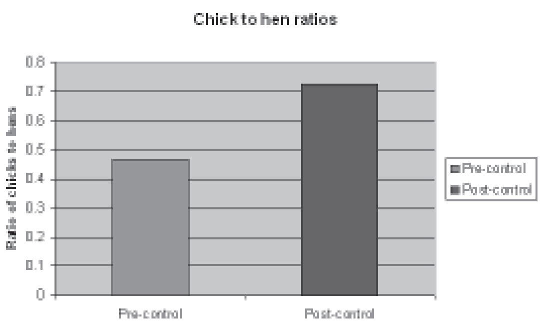

Figure 2. Chick to hen ratios of sage grouse from prepredator control years (1998–1999) and postcontrol years (2000–2005) in Strawberry Valley, Utah.

Horizontal obscurity cover, usually in the form of residual or current year growth of grass, is a major factor influencing predation on nesting sage-grouse (Gregg 1991, Gregg et al. 1994, DeLong et al. 1995). DeLong et al. (1995)

suggested that vegetative cover around nest sites, where birds are most vulnerable, provides scent, visual and physical barriers to potential predators. Based on these findings, the sage-grouse guidelines (Connelly et al. 2000) recommend maintaining herbaceous cover greater than 7.09 inches (18 cm) tall in nesting habitat. Because horizontal cover at both nest and adult sites approaches 100 percent at 13.11 inches (33.3 cm) above ground level, it does not seem to be a contributing factor to the high level of predation we found on sage-grouse.

Many factors likely contribute to the abundance of red fox in Strawberry Valley. The area is a popular recreation destination for camping and fishing, which results in large amounts of refuse and food products littered along the shoreline and at campsites. The productivity of Strawberry Reservoir as a fishery may contribute to the abundance of red fox by providing them with fish parts and entrails washed ashore or left on the banks by fishermen during the summer and found on the ice during the winter. In addition, the 11 tributaries that feed the reservoir boast large numbers of introduced Kokanee salmon (*Oncorhynchus nerka*) that spawn and die in the fall. Each of these events create a rich food supply, but Kokanee salmon consumed in September and October may bolster fat supplies going into the winter or may provide food for caches to be consumed later. Localized areas in Strawberry Valley also have large populations of Uinta ground squirrels (*Spermophilus armatus*) and sizeable breeding populations of waterfowl, both of which provide red fox with alternative prey. Strawberry Valley is also home to robust populations of mule deer (*Odocoileus hemionus*) and elk (*Cervus canadensis*). And, U.S. Highway 40 runs the entire length of the valley. This provides foxes and other scavengers with an almost year around supply of road kill.

Harding et al. (2001) documented a significant short-term (3 months) positive relationship between removal rates of red fox and population growth of a California clapper rail (*Rallus longirostris obsoletus*) population. Unfortunately, after only 3 months, red fox densities returned to pretreatment levels. The relationship between red fox and sage-grouse in Strawberry Valley is likely very similar. The major differences between our study and the Harding et al. (2001) study is that control efforts start in January and go through July and that WS and volunteers have been controlling all terrestrial predators (not just red fox) using various different techniques from 1999 to the present. In addition, control of avian predators began in 2003 and has intensified to place more than

600 poison egg baits during 2005. This sustained control has also increased in time and space since the inception of the control program. We expect that fox densities will increase after discontinuance of predator control; however, if fox densities in critical habitats can be reduced during breeding, nesting and brood-rearing seasons (early spring to early summer), it may have a significant positive influence on the sage-grouse population. Future research should focus on the feasibility of red fox control as a short-term management tool as part of a long-term conservation strategy and as the minimum viable population size or fecundity estimates necessary to withstand red fox predation.

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Integrating Science with On-the-ground Management: A Two-state Plan for Ground Nesting Birds

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History and Background

Wildlife Habitats of the Prairie Pothole Region

The once extensive and contiguous grasslands and wetlands that dominated North Dakota and South Dakota are now often dissected into islands of habitat buffered by cropland and urbanization. Grasslands lost in North Dakota since settlement are estimated at upwards of 70 percent and are estimated at 50 percent in South Dakota (Conner et al. 2001). More vividly stated, less than 1 percent of the original eastern tall-grass prairie, 30 percent of the mixed-grass prairie and 35 percent of the short-grass prairie remain in the Dakotas (Samson and Knopf 1994, Samson et al. 1998). Although the further western portions of these states incurred less dramatic losses than the eastern portions, natural processes that sustained the grasslands and wetlands were removed or replaced with less compatible management.

The formerly glaciated portions of North Dakota and South Dakota are located in what is known as the Prairie Pothole Region, and they possess some of the most critical habitat in North America for breeding waterfowl. This region occupies only about 10 percent of the waterfowl breeding range and produces approximately 50 percent of the birds (Kantrud 1983). The various wetland complexes that dot the landscape of this region attract breeding pairs, drive nesting intensity and renesting efforts, and provide brood habitat (Kantrud et al. 1989; R. Reynolds, personal communication 2005). According to Ron Reynolds, U.S. Fish and Wildlife Service, Bismarck, North Dakota, the small wetlands (e.g., temporary and seasonal basins) are the key to attracting duck pairs to the Prairie Pothole breeding areas. As an example, for every 10 1-acre (0.0469-ha) wetlands, there predictably will be 20 pairs. Whereas, for 1 10-acre (4.0469 ha) wetland there predictably will predictably be 7 pairs. The availability of wetlands in the Prairie Pothole Region is a primary factor driving duck breeding in this region (R. Reynolds, personal communication 2005).

According to Conner et al. (2001), the human impacts to the diversity of the biota of the North American grasslands are likely the most significant of all terrestrial ecosystems on the continent. When dramatic environmental changes occur, wildlife and plants may adapt and proliferate. Conversely, they may be reduced and even may become extinct in some cases. When immersed within grasslands, the wetland embedded landscape of the Prairie Pothole Region certainly provides more habitat for wetland-dependent wildlife than in landscapes where the uplands are entirely converted to crop production (Naugle et al. 2001). Several species of waterfowl and other wetland-dependent birds commonly nest in the grassed uplands surrounding wetland complexes; therefore, loss of grasslands results in the loss of productivity. Converting the native sod of this region to cropland directly impacted waterfowl by reducing and fragmenting the available breeding cover for grassland nesting species (Sugden and Beyersbergen 1984, Batt et al. 1989). According to Greenwood et al. (1995), duck nest success in the Prairie Pothole Region increases as the amount of perennial grassland on the landscape increases; further, Reynolds et al. (2001) determined that, with increased perennial cover, the daily survival rates of several duck species also increases. Specifically, for every 1-percent decline of priority grassland in the Prairie Pothole Region, there will be approximately 25,000 fewer ducks in the fall (R. Reynolds, personal communication 2005). Klett et al. (1988) also adds that nest success is usually lowest in cropland, hayland and right-of-ways, while more success is seen in grassland areas, such as planted cover (e.g., Conservation Reserve Program land).

Predator-Prey Dynamics

Across the prairie landscape, habitat conversions specifically changed the predator-prey relationships and actually bolstered the populations of several waterfowl predators. Issues related to waterfowl predation are highly connected to the changes in the landscape and, ultimately, to changes in the predator populations (Sovada et al. 2005). Prior to settlement, the highest ranking predators across the region were the gray wolf (*Canis lupus*) and an occasional grizzly bear (*Ursus arctos*). Less abundant across the landscape were coyotes (*Canis* *latrans*) and red foxes (*Vulpes vulpes*), while swift fox (*Vulpes velox*) populations were high. In a precipitous manner, gray wolves were nearly eliminated from the area, followed by a spike in coyote populations. The elimination of the gray wolf from the region had a profound impact on mesopredators, especially the other canids. Wolves are highly territorial and intolerant of other canids. Thus, fox and coyote abundance was limited and somewhat controlled by wolves. However, after the extermination of gray wolves from the prairies, fox and coyote populations grew. Subsequently, coyotes were targeted with a bounty and populations were driven down. This increased the abundance and distribution of the red fox, which adversely affected waterfowl populations because red foxes are a primary predator of nesting waterfowl and their eggs (Sargeant et al. 1993, Sovada et al. 1995). Populations of other species that were scarce and narrowly distributed expanded greatly as well, including raccoon (*Procyon lotor*) and American crow (*Corvus brachyrhynchos*). Predator species composition is noteworthy because of the impacts on waterfowl survival (Greenwood et al. 1995, Sovada et al.1995). Most waterfowl depredation is caused by Franklin's ground squirrels (*Spermophilus franklinii*) and six carnivores (raccoon, mink [*Mustela vison*], striped skunk [*Mephitis mephitis*], badger [*Taxidea taxus*], red fox and coyote) (Sargeant and Arnold 1984). Sargeant et al. (1993) determined that predation rates on waterfowl nests early in the nesting season increased simultaneously with the increase in the abundance of red foxes, badgers and American crows. Whereas, late in the nesting season, predation increased with the abundance of red fox and striped skunk.

Additionally, from a habitat perspective, fragmentation of the landscape caused by the wetland and grassland losses created edge effect, which negatively impacted many indigenous species and exacerbated predation. In theory, predators reside in areas that provide the necessary resources and, likely, will remain in or frequent that area as long as their needs are met at a more efficient level than what is provided by the surrounding landscape (Charnov 1976, Stephens and Krebs 1986). Relating this to the prairie, the patchy grassland habitats that are interspersed throughout the agricultural lands provide attractive food sources to predators, compared to sources from the surrounding croplands (Greenwood et al. 1999). Charnov (1976) indicates that predators will actually spend more time in these isolated grassland patches considering the increased efforts required to access these areas, i.e., they must traverse crop fields, roads and human dwellings to get to grasslands.

Science

Predation on Waterfowl and Other Ground Nesting Birds

Although predation is a natural component of population biology, analyses of waterfowl evidence suggests that it is a significant factor in reducing nesting success (Duebbert and Lokemoen 1980, Klett et al. 1988, Sargeant and Raveling 1992). The hatch rate of duck nests in U.S. Fish and Wildlife Service managed waterfowl production areas and national wildlife refuges on much of the Prairie Pothole Region, is often less than the 15 to 20 percent suggested for stability of populations of the 5 most common species of dabbling ducks (Cowardin et al. 1985, Greenwood 1986, Klett et al. 1988, Greenwood et al. 1990). Further, Sargeant and Raveling (1992) indicate that predation is the primary cause of nest loss of North American waterfowl during the breeding season.

Nesting waterfowl and predators are concentrated in islands of habitat, which further influences the unbalanced relationship between the two. It is likely that the decrease in the abundance of alternative prey increases predation on waterfowl (Sargeant and Raveling 1992). Also, it is well documented that ducks nesting in blocks of dense vegetation are less vulnerable to predation (Duebbert 1969, Duebbert and Kantrud 1974, Duebbert and Lokemoen 1976). Expanses of cover likely provide ducks and predators with increased nesting and foraging options, reducing the predation on waterfowl. Landscape level programs, such as the Conservation Reserve Program, provide more benefits than simply focusing on increasing grassland patch size (Reynolds et al. 2001). Converting cropland to grassland and reducing fragmentation on this level may be a viable solution in theory; however, practicality limits the progression of such activities. In order to improve waterfowl nesting success through cropland conversion, the relationship between patch size and composition must be considered (Clark and Nudds 1991). Reynolds et al. (2001) indicate that, on average and dependent on certain variables, 40 percent of the landscape must be in grassland cover for mallards (*Anas platyrhynchos*) to obtain a nest success of between 15 and 20 percent (population maintenance level).

The major source of mortality for North American waterfowl during the breeding season is predation (Sargeant and Raveling 1992), with greater than 70 percent of nest failures attributed to predation (Sovada et al. 2001). Managers are confronted with this problem because it causes a reduction in the annual production of waterfowl, and it decreases the effectiveness of habitat conservation activities (Sovada et al. 2001). In cropland-dominated landscapes where nesting habitat is limited and predation is high, restoration efforts on wetlands and uplands may be futile for increased waterfowl production. In these situations, improvements to the habitat alone do not effectively manage predation. Rather, management of predators is a necessary addition. Predation is symptomatic of habitat loss and deterioration (Sovada et al. 2001), and, specifically in the Prairie Pothole Region, nest success is negatively correlated with the percent of cropland (Greenwood et al. 1995, Reynolds et al. 2001). The interactions of a fragmented landscape and unbalanced predator community may limit attempts to increase waterfowl hatch rates (Sargeant et al. 1995). Recently, Devries et al. (2003) found that 50 percent of the mortality in nesting mallard females occurs while they are known to be nesting, despite the fact that they only spend 20 percent of the nesting season on the nest. Further, Hoekman et al. (2002) state that nest success, hen survival and duckling survival are the most critical and important factors in increasing mallard recruitment.

Managing Habitat and Predation for Ground Nesting Birds

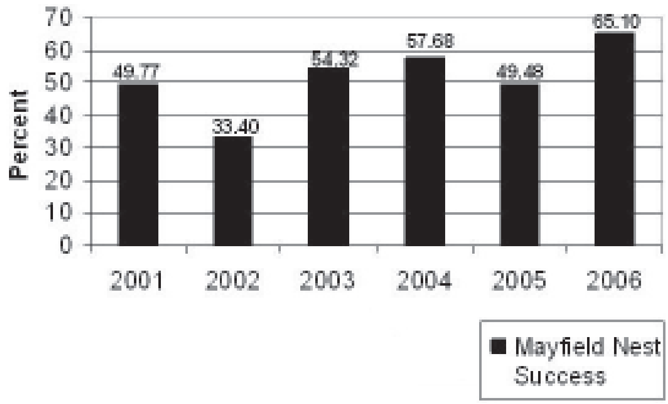
Prairie grasslands and wetlands evolved with natural disturbances, and changes or interruptions in these processes alter species composition by reducing native species and by increasing invasive species. Across North Dakota and South Dakota, these natural regimes are, by most accounts, absent due to human interventions that modified the physical and biotic conditions of the landscape (Hobbs and Huenneke 1992). Wildlife managers often use various tools to emulate the defoliation activities by which prairie plants evolved, including prescribed fire and herbivore grazing. These activities are necessary for maintaining the integrity and viability of habitats to support wildlife. Managing grasslands and wetlands for wildlife productivity is a labor-intensive and costly effort. Many organizations tasked with managing lands fail to meet habitat objectives because of limited funding and staff.

Managers are also tasked with attempting to balance predator-prey relationships of the current landscape. Waterfowl production is impacted differently by individual predators based on the behavior, food needs and abundance of a particular predator species (Sargeant et al. 1993). Raccoons, as an example, adapted to the monotypic grain crops that replaced the native sod, and found habitat in planted tree rows and buildings dotting the landscape. Raccoons substantially depredate waterfowl eggs and may partially or totally destroy a clutch (Sargeant and Arnold 1984). Additionally, Phillips et al. (2003) determined that, on landscapes with a low grassland composition, red fox gravitate to the isolated patches of planted cover. Striped skunks, on the other hand, are attracted to the edges of agricultural wetlands, meaning that ducks nesting closer to wetlands may be more vulnerable to skunk predation (Phillips et al. 2003). Unless predator populations change or agricultural practices change, the waterfowl and predator imbalance will remain unresolved (Sargeant and Arnold 1984). Adequate habitat management over the long term, integrated with predator management strategies, may increase the nest success of prairie nesting ducks (Duebbert 1969, Duebbert and Kantrud 1974, Sovada et al. 2001).

Other studies indicate that the removal of mammalian predators increases upland and overwater nest success, and it enhances duckling survival. Garrettson and Rohwer (2001) reported significant increases from the control to trap blocks (16-square-mile [41.44-km^2] blocks) in Mayfield nest success; the controls were 23 percent and the trapped blocks were 42 percent. This large and highly replicable study encompassed 9 pairs of trapped and untrapped blocks over a 3-year period. Mense (1996) evidenced that nest success of diving ducks increased significantly on trapped sites as well, going from 29 percent Mayfield nest success on the control sites to 57 percent on the trapped sites. Further, Zimmer (1996) assessed the impacts of predator reduction on duckling survival. Overall duckling survival in northern shovelers (*Anas clypeata*) increased from 50 percent to 71 percent on untrapped to trapped sites, respectively, and brood size was 70 percent higher on the trapped compared to the controls (Zimmer 1996). Hoff (1999) assessed the impact of predator removal on 36-square-mile (93.24-km^2) blocks and determined that the Mayfield on the trapped sites averaged 36 percent, compared to 15 percent on the untrapped sites. Also, trapping results from the intensively farmed prairies of Canada showed an increase in duckling survival with 33 percent on untrapped sites, compared to 54 percent on trapped sites (Pearse and Ratti 2004). Additionally, Chodachek and Chamberlain (2006) assessed small trap blocks (1-square-mile [2.59-km^2] blocks) and even saw an improvement in nest success in these areas. The nest success nearly doubled, even on these smaller blocks, resulting in an average of 53.4-percent Mayfield nest success on the trapped blocks and a 28.7-percent success on the control blocks (Chodachek and Chamberlain 2006).

In efforts to assess the effects of predator removal under typical management conditions, the U.S. Fish and Wildlife Service cooperated with partners in North Dakota to apply direct predator management on sites in the heavily cropped and fragmented Drift Prairie physiographic region. Simulating Hoff (1999), predators were removed from 36-square-mile (93.24-km^2) blocks, resulting in an average Mayfield nest success from 2001 to 2006 of 51.62 percent (Figure 1). Although studies show that nest success is the greatest contributor to variation in waterfowl production (Johnson et al. 1992, Hoekman et al. 2002), brood survival is the second major component in waterfowl recruitment (Hoekman et al. 2002). As described, predator reduction may enhance both of these variables.

Figure 1. This documents the average percent Mayfield nest success per year for 36-square-mile (93.24-km^2) trap blocks in North Dakota, between 2001 and 2006. The long-term average for these years is 51.62 percent.



In addition to waterfowl, predation on passerines, on other nongame birds and even on upland game birds is considered an important cause of nest failure (Martin 1988, 1995). Specifically, predator communities in fragmented landscapes, such as the Prairie Pothole Region, do not provide safe nesting sites for songbirds (Dion et al. 2000). An independent group of ornithologists indicated that the sedge wren (*Cistothorus platensis*), common yellowthroat (*Geothylpis trichas*), dickcissel (*Spiza americana*), clay-colored sparrow (*Spizella pallida*), lark bunting (*Calamospiza melanocorys*), savannah sparrow (*Passerculus sandwichensis*), song sparrow (*Melospiza melodia*), bobolink (*Dolichonyx oryzivorus*) and red-winged blackbird (*Agelaius phoeniceus*) would benefit from predator fence exclosures designed to reduce the impact of medium to large mammals. They also concluded that predator barriers, such as fences, are very beneficial to larger nongame migratory birds, including northern harriers

(*Circus cyaneus*), short-eared owls (*Asio flammeus*), and American bitterns (*Botaurus lentiginosus*) (Berkey et al. 1993). Additionally, Helmers and Gratto-Trevor (1996) determined that predation causes a significant impact to shorebird nest success, especially in southern areas of their breeding range. Finally, Witmer et al. (1996) indicate that two factors, protection or restoration of habitat and predator management, may curtail listing and extinction rates of avian species.

There is also evidence that predator management may provide benefits to upland nesting game birds, such as ring-necked pheasants (*Phasianus colchicus*). In a study by Trautman et al. (1973), the overall pheasant population on 3 study areas increased 338 percent after 5 years of reduced predation, due to intensively controlled predator populations (fox, raccoon, skunk, badger). In comparison, 3 associated nonpredator control areas increased only 53 percent (Trautman et al. 1973).

Concept

For the purpose of this manuscript, a cropland-dominated landscape is an area altered to such a degree that, even though habitat protection is implemented, it does not guarantee migratory bird recruitment above maintenance levels on a consistent basis. Likely, such areas consist of less than 40 percent grassland cover, generally indicative of the drift prairie physiographic region in eastern North Dakota and South Dakota where conventional cropland tillage dominates the landscape (Dixon and Hollevoet 2005). Current wildlife managers of such landscapes must, therefore, implement management that emulates the ecological process of more pristine times to sustain and increase ground nesting bird populations.

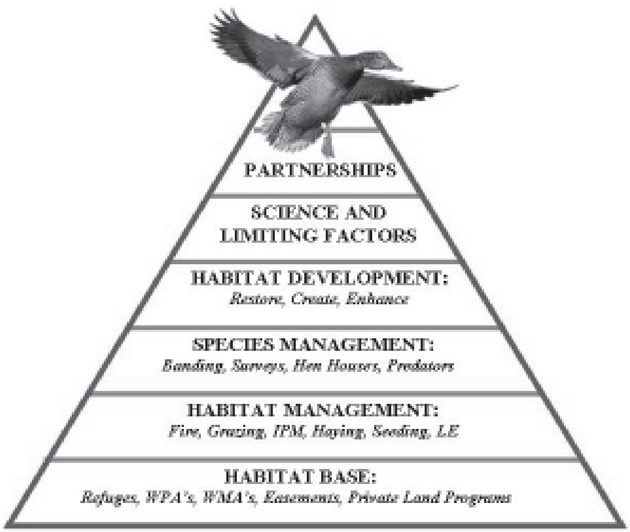
Adaptive management in cropland-dominated landscapes requires collaboration among partners to ensure science-based development and progression. The partners involved with various current management regimes in North Dakota and South Dakota developed *Ground Nesting Bird Management on Cropland Dominated Landscapes within the Prairie Pothole Region of North Dakota and South Dakota* (Dixon and Hollevoet 2005) to articulate their strategies for adaptive management. This document steps down the objectives stated in the Prairie Pothole Joint Venture Implementation Plan (PPJVIP) in a way that is locally applicable to wildlife managers and biologists. Working within the framework of the PPJVIP expands the partnership opportunities and collaboration that can occur from a local, state, regional, national and even a continental level to accomplish more for the resource. The prominent purposes of the Dixon and Hollevoet (2005) plan include:

1. to increase recruitment of ground nesting birds in cropland-dominated landscapes of North Dakota and South Dakota
2. to protect, restore and enhance habitat to address landscape level habitat needs
3. to synthesize the background and the research related to ground nesting bird management on cropland dominated landscapes
4. to serve as a management plan for federal and state agencies in North Dakota and South Dakota, specifically for field staff use
5. to manage risk by ensuring that optimal habitat will be available across physiographic regions when climatic variables provide for optimal conditions
6. to provide background documentation for potential partners and contributors.

These purposes echo visions of the designers of the North American Waterfowl Management Plan (NAWMP), which address the need to reverse the population declines of waterfowl caused by habitat fragmentation and degradation. The NAWMP focused much effort on habitat management, while recognizing that habitat improvements in heavily fragmented areas may not effectively manage predator populations (Sovada et al. 2001). The 2004 NAWMP strategic guidance document presents strategies to meet the challenges, and one of these strategies addresses the deficiencies in the breeding habitat in the midcontinent prairie region, including eastern North Dakota and South Dakota. Predator management is one tool that will address these deficiencies, and, as Sovada et al. (2001) indicate, the long-term conservation of waterfowl must incorporate strategies to limit predation impacts.

The Dixon and Hollevoet (2005) plan provides the long-term framework to increase waterfowl and other wetland-grassland bird production in cropland-dominated landscapes of the Prairie Pothole Region of North Dakota and South Dakota. The vision, goals and objectives provide the structure necessary to bring the intended purposes to fruition. As a vision statement, this plan states: "In a partnership effort, local individuals, private donors, grass roots groups, state and federal agencies, and nongovernment organizations will strive to ensure the long-term viability of breeding waterfowl and other birds throughout the cropland-dominated areas of North Dakota and South Dakota" (20). The development of the goals and objectives incorporates the findings of Hoekman et al. (2002), which suggest that variations in mallard-population growth are primarily dependent on nest success, on survival of adult females during the breeding season and on duckling survival. Further, as a visual approach to conceptualizing the necessary steps for effective bird conservation within the Prairie Pothole Region, the Hollevoet pyramid (Figure 2)—developed by Roger Hollevoet, U.S. Fish and Wildlife Service, Devils Lake, North Dakota—was also integrated in the development of goals and objectives. This approach provides a hierarchy for providing optimal management for grassland nesting birds in the cropland-dominated landscapes of the Prairie Pothole Region.

Figure 2. The Hollevoet-pyramid approach to ground nesting bird management in cropland-dominated landscapes of the Prairie Pothole Region of North Dakota and South Dakota. *(Developed by Roger Hollevoet, U.S. Fish and Wildlife Service, Devils Lake, North Dakota)*



Implementation—The Pyramid Approach

Habitat Securement and Management

The science reveals that landscape changes and the resulting predator population changes challenge modern managers and biologists. Striving to remediate the challenges associated with the losses of grasslands and wetlands in cropland-dominated landscapes requires a multifaceted approach. First, it is vital that habitat securement and protection be the major baseline effort, especially to ensure that current losses are not worsened or expanded. Strategies to carry out this foundational level of the Hollevoet pyramid (Figure 2) include fee-title and conservation-easement purchases, which are perpetually managed and protected by a government agency or nongovernment group. Additionally, conservation-oriented, private-land programs often associated with government agencies, such as the U.S. Fish and Wildlife Service, state wildlife agencies and the U.S. Department of Agriculture, provide at least short-term protections. In the case of programs like the Conservation Reserve Program, millions of acres of land were under protection for at least a 10-year period. Also, assemblages of government and nongovernment groups propagate the North American Waterfowl Management Plan, which continues to provide framework and funding for habitat protection, especially in migratory bird breeding areas.

Management of protected habitats is also crucial to ensure long-term functionality of these lands for associated wildlife. The prairie landscape evolved by natural disturbances caused by large herds of grazing ungulates and by uncontrolled fires. Current wildlife managers strive to emulate these natural processes by implementing a repertoire of management, including prescribed fire, mechanical haying and herbivore grazing. Further, the management of lands within cropland-dominated landscapes requires controlling and eliminating invasive plants using integrated pest-management strategies.

Restoration and Species Management

In cropland-dominated areas of eastern North Dakota and South Dakota, often restoration of grasslands and wetlands is necessary to return at least some portion of the landscape functionality. Reseeding cropland areas to grass and restoring hydrology to drained and filled wetlands are intense and costly measures that are routinely undertaken for the benefit of breeding waterfowl and other ground nesting birds. Cropland-dominated landscapes may also require the use of specific species-management techniques that address issues, such as hen survival, nest success and brood survival. A combination of habitat-restoration efforts and species-specific management will be necessary to improve viability for wildlife. The Hollevoet pyramid (Figure 2) includes habitat restoration and species management as necessary intensive management efforts that attempt to remediate historical changes prevalent on cropland-dominated landscapes.

Science and Limiting Factors

Nearing the peak of the Hollevoet pyramid (Figure 2), it is evident that science-based management decisions are necessary to lead the efforts described for the base of the pyramid. The art of habitat management in cropland-dominated landscapes requires a symbiotic relationship between management and biology that strives to make sense of the optimal functionality that can be achieved in balance with the overriding limitations. It is imperative to review the management practices through monitoring or research and to react to any limiting factors that may inhibit success. Essentially, current managers, in places like the Prairie Pothole Region of North Dakota and South Dakota, take on the role of bison, wildfire and the dominant predator. This concept of applied management increases the likelihood of success as managers attempt to provide the ecological functions of the prairie.

Partnerships

There is no doubt that conserving migratory bird species, such as waterfowl and other prairie nesting birds, is an incredibly challenging task. Birds, such as ducks, move across several international borders and rely on increasingly fragile and valuable habitat. Securing breeding waterfowl and other bird populations in cropland-dominated areas, such as North Dakota and South Dakota, is an uphill battle against the immense and sometimes immovable forces of agricultural economics. Although it is not necessarily an innate role, wildlife managers and biologists must foster partnerships to identify methods to integrate wildlife conservation into an agriculture-commodity-based landscape. A major step in this partnership effort was the development of the North American Waterfowl Management Plan (NAWMP) in 1986, which initiated or enhanced a new age in the conservation of waterfowl and habitats. NAWMP articulates that the success of a broad-scale conservation strategy would consist of landscape-level ventures being led and carried out by a large, cooperative, adaptive, conservation community. This community needs to include federal, state and local governments, conservation organizations, natural resource groups, private donors, and landowners. The original plan identified general objectives for habitat conservation in various regions with the belief that each region would further enhance and implement these broad objectives through the development of local action plans.

Stepping down this overarching partner framework, are the joint ventures that exist across the United States and Canada. These were intended to develop a means for governments, private organizations and individuals to plan, fund and implement local waterfowl conservation efforts. The joint ventures have grown into successful organizations that are now regional and are models for planning and delivering cooperative projects protecting important habitats and wildlife. These successful joint ventures also show a need to step down the implementation process to local action plans, such as the plan entitled *Ground Nesting Bird Management on Cropland Dominated Landscapes within the Prairie Pothole Region of North Dakota and South Dakota* (Dixon and Hollevoet 2005).

In the uncertain world of conservation that exists within cropland-dominated areas, partnerships are paramount to success. Not only do groups need to pool monetary and human resources to be successful, but they also need to capitalize on respective organizational strengths. For the progression of future partnerships, incorporating elements of creativity and seeking nontraditional partners is necessary for the protection of natural resources. As an example, cropland-dominated areas in North Dakota and South Dakota attract increasing numbers of tourists for recreation, especially recreation related to hunting, fishing and bird watching. Conservation groups in these two states are making strides to collaborate with new partners, such as state tourism groups who may actually be able to provide avenues to protect and restore grasslands and wetlands in these respective areas.

The apex of the Hollevoet pyramid (Figure 2) includes partnerships and science. Visually, these may appear as the pinnacle of this hierarchical image and are essentially resting on or are a product of the base. As a conceptual image though, the pyramid could easily be rotated to rest on the apex, demonstrating that partnerships and science support the other factors in the pyramid. Essentially, as partnerships and science develop and expand, elements in the base of the pyramid will follow suit. This adaptive process—be it science driven or innovation driven—will be a key to insuring that our planning and management actions are successful. Adaptive management is here for the duration.

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The Good, Bad and Ugly, Depending on Your Perspective

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Prior to the arrival of European settlers, the gray wolf (*Canis lupus*) was once distributed throughout North America (Nowak 1995). European settlers arrived in the New World with negative perceptions of the wolf, based on fairy tales and religious beliefs. In addition to being regarded as a threat to personal safety, the wolf was perceived to be a threat to livestock and as competition with human hunters for wild ungulates (Young 1944, Fritts et al. 2003). These conflicts and the historic, public hatred of wolves resulted in extirpation of wolf populations in the western United States by 1930 (Mech 1970).

The gray wolf was declared an endangered species in 1974 under the federal Endangered Species Act (ESA), a powerful law enacted in 1973, and their recovery became the responsibility of the U.S. Fish and Wildlife Service (USFWS). Wolf restoration in the western United States began in 1986 when a pack that originated in Canada denned in Glacier National Park (Ream et al. 1989). Wolves from Canada were introduced into Yellowstone National Park (YNP) and into central Idaho in 1995 and 1996 to accelerate restoration (Bangs and Fritts 1996, Fritts et al. 1997). The wolf population grew to over 1,000 wolves in the northern Rocky Mountains (NRM) of Montana, Idaho and Wyoming by 2005 (Sime and Bangs 2006). Many people opposed wolf restoration because of concerns about human safety, potential land-use restrictions, livestock depredations and competition with hunters for wild ungulates. Resolving conflicts, both perceived and real, between wolves and people has been the primary focus of the wolf-management program (Bangs et al. 2001).

When wolves were reintroduced to central Idaho and YNP, special regulations were established that offered more flexible, lethal take options than normally were allowed for federally listed species (Bangs and Fritts 1996, U.S. Fish and Wildlife Service 1994). The special regulations were further liberalized and expanded in 2005 (U.S. Fish and Wildlife Service 2005). Landowners can shoot wolves attacking and chasing their livestock, their livestock herding and guarding animals, and their dogs. These regulations apply to private property and to federal grazing allotments. In addition, authority to implement federal regulations could be transferred to Idaho, Montana and Wyoming, provided states submitted acceptable state wolf management plans to the USFWS that demonstrated adequate regulatory mechanisms for the long-term viability of wolves. Provisions within the regulations would allow the states and tribes to lethally take wolves in order to resolve significant ungulate-management issues but only after submitting a scientific, written proposal to the USFWS that had undergone peer and public review. The USFWS will only approve wolf take for ungulate management after it determines that the proposal is scientifically supported and reasoned and that it does not compromise wolf recovery.

Idaho and Montana wrote wolf-management plans that were approved by the USFWS. Montana's plan designates the wolf as a nongame species in need of management and received positive public reviews as a model approach. The Idaho Wolf Conservation and Management Plan, in its executive summary, contains House Joint Memorial No. 5, passed in 2001 by the state legislature, demanding that wolf recovery in Idaho be discontinued immediately and that wolves be removed from the state by whatever means necessary. The professional integrity of Idaho's wolf management plan is compromised by such statements. To further complicate matters, on January 11, 2007, newly elected Idaho Governor C. L. "Butch" Otter told *Associated Press* that he suggested that hunters, after delisting, killed 550 gray wolves in Idaho, leaving about 100 wolves, or 10 packs. Otter said, "I'm prepared to bid for that first ticket to shoot a wolf myself" (Alderman 2007:1).

Wyoming prepared a wolf-management plan that was not approved by the USFWS (U.S. Fish and Wildlife Service 2006). Wyoming proposed a wolf-management plan that would designate the wolf as a trophy animal in the northwest corner of the state—almost exclusively in YNP, Grand Teton National Park and contiguous wilderness areas—and as a predator elsewhere. The USFWS rejected the plan because state law (which classifies wolves as predators) and the plan are not sufficient in combination to conserve Wyoming's portion of a recovered NRM wolf population. Wyoming has taken legal action challenging the USFWS decision. The USFWS has not requested wolf-management plans from any tribe in the NRM, and any future delisting action is unlikely to be dependent on wolf management on tribal lands.

A news release by the Deputy Secretary of U.S. Department of the Interior on January 29, 2007, announced that the USFWS is removing the western Great Lakes population from the federal list of threatened and endangered species and is proposing to remove the NRM population of gray wolves from the list as well. If Wyoming's plan is not approved before the USFWS publishes a final rule on the NRM delisting proposal, the USFWS will continue to provide ESA protection to wolves in the significant portion of their range in Wyoming (U.S. Fish and Wildlife Service 2007).

An understanding of the public's perception of wolves was vital to developing an effective wolf- restoration program. Wolves are symbols representing a range of issues, with the perception of the importance of the species varying among various demographic and socioeconomic groups (Kellert 1985; McNaught 1987, Bath and Buchanan 1989; Bath and Phillips 1990; Bath 1991). Few wildlife issues are so driven by misconceptions that have so little basis in biological fact.

In 1978, approximately 50 percent of the public in the NRM region were found to like, and 30 percent to dislike, the wolf (Kellert 1985). Thirty-eight surveys conducted between 1972 and 2000 reported that a majority (51 percent) of people showed positive attitudes toward wolves, and 60 percent supported wolf restoration (Brown-Nunez and Taylor 2002, Williams et al. 2002). Survey respondents who held positive attitudes toward wolves were younger, college-educated, higher income, lived in urban areas and exhibited good factual knowledge about wolves. Negative attitudes toward wolves were expressed by livestock producers, rural residents, older and less-educated respondents. Support for wolves was based on a variety of ecological, aesthetic and outdoor recreation-related reasons. Negative attitudes reflected a fear and dislike of wolves, a loss of livestock and pets, and a possible reduction in big-game populations. Generally, people with the most positive attitudes toward wolves were those who have the least experience with them. Members of the public most likely to encounter wolves or to perceive being affected by them have the least favorable attitude toward them (Fritts et al. 1995).

Prior to wolf reintroduction in the NRM, critics predicted that children would be killed at bus stops, livestock herds would be slaughtered, ungulate herds would be decimated and that, despite all of this, wolves would be invisible to those who wished to see them. So far, no one has been killed by wolves in the United States. Since 1987, wolf depredation caused about 0.04 percent and 0.01 percent of all annual cattle and sheep losses in the NRM (Bangs et al. 2005), respectively. Eighty-three domestic dogs (mostly guard dogs and hunting hounds) have been reported killed during the same period (Bangs et al. 2005). Visitor surveys indicate conservatively that 325,000 YNP visitors saw wolves in 2005 (Duffield et al. 2006).

The relationship between wolves and big-game populations in the NRM has erupted into a national debate. Hunters, guides, outfitters, and the state and national organizations representing them have become vocal about their concerns that unregulated wolf populations are decimating ungulate populations in Idaho, Montana and Wyoming. The publicity generated in national newspapers, magazines, the Internet, radio and television has fueled a growing public debate between recreationalists and wolf advocates. "The wolf is an example of science ending up at the doorstep of public opinion, and public drama" Royster (2004:1) stated.

Wolves are the most controversial animal in Idaho, Montana and Wyoming because they prey on large ungulates, including white-tailed deer (*Odecoileus virginianus*), mule deer (*O. hemionus*), elk (*Cervus elaphus*) and moose (*Alces alces*). The restoration of ungulate populations by hunters and state game agencies was one of the most remarkable achievements of modern wildlife management, and, without it, wolf restoration would have been impossible. Understanding how wolves affect ungulates, from a scientific standpoint, is still under investigation, but a few facts are known: the average adult wolf eats more than 9 pounds (4 kg) of prey per day, and wolf predation may or may not reduce ungulate populations and hunter opportunity, depending on a wide number of variables (Boyce 1995, Kunkel 1997, Mech and Peterson 2003, Smith et al. 2004). Wolf predation on ungulates varies seasonally. Discovering exactly how wolves affect ungulates is complicated by the presence of other large predators, as well as winter severity, fire suppression, drought and hunting.

A herd of migratory elk that range from YNP to a northern winter range outside the park is the subject of intense study to discover factors influencing the herd's progressive population decline. The herd has fluctuated between 10,287 during 1990 to 1991, to 19,359 during 1993 to 1994, to 6,738 elk (not sightability corrected by 30 percent factor) during the winter of 2006 to 2007. Montana Fish, Wildlife and Parks (FWP) administers an antlerless late hunt to help manage elk numbers and has removed an average of 1,400 elk annually since 1988. While the herd's current size results from a variety of natural and human-caused factors, including hunting, wolf predation is often credited as the major cause of the herd's decline. "This decrease in counted elk likely reflects the continuing effects of predation by wolves and other large carnivores, as well as decreased detection of elk within Yellowstone due to anti-predation behaviors such as smaller group sizes, increased dispersion of groups and increased use of forested habitats, making them more difficult to locate" (Yellowstone National Park and Northern Yellowstone Cooperative Wildlife Working Group 2007:1) according to P. J. White, biologist for YNP. In the same news release Tom Lemke, a biologist for FWP is quoted: "In an effort to reduce hunter mortality on female elk, FWP has reduced the number of antlerless Late Elk Hunt permits over the last several years. For the last two years only 100 antlerless permits have been issued" (Yellowstone National Park and Northern Yellowstone Cooperative Wildlife Working Group 2007:1). He added, "from a winter elk management perspective we are currently meeting State Elk Plan population objectives. The number of elk wintering north of Yellowstone Park has been within objectives since 2003" (Yellowstone National Park and Northern Yellowstone Cooperative Wildlife Working Group 2007:1)

Research overwhelmingly concludes that no two predator-prey systems are alike and that the same system changes over time. Estimating impacts of wolves on big game is not clear-cut. Recent studies in YNP, primarily on elk, present opposing views on whether wolf predation is compensatory, additive or a combination of the two (Vucetich et al. 2005, White and Garrot 2005, Varley and Boyce 2006). If prey are at or above their carrying capacity where habitat resources are limited, wolf predation is often termed compensatory. In other words, the wolves may be killing prey that might otherwise not survive for reasons such as drought, disease or starvation. Where prey are below their carrying capacity and habitat resources exceed the survival needs of the prey, wolf predation can be termed additive because wolves may kill prey that otherwise would survive.

The Idaho Department of Fish and Game determined that wolves were having an unacceptable impact on wild ungulate populations in game management units (GMUs) 10 and 12 in the Lolo Zone in northern Idaho, and it has formally proposed a plan to reduce wolves there (Idaho Department of Fish and Game 2006). The GMUs 10, 12 and 17 have declining elk populations as a result of inadequate cow survival and recruitment. Data for GMU 17 does not exist because of logistical difficulties of capturing and monitoring elk in federally designated wilderness. Idaho proposed to reduce the wolf population in the Lolo Zone by no more than 43 of 58 wolves (75 percent) during the first year of the study and to maintain the population at 25 to 40 percent of preremoval wolf abundance for 5 years. The USFWS rejected Idaho's proposed plan, saying scientific data gathered by the state did not justify the action (Miller 2006). Jim Peek, a retired professor of wildlife biology and a member of the Rocky Mountain Elk Foundation board of directors said that, "at this point there is very little evidence that the presence of wolves has caused a decline in elk numbers anywhere, especially in Central Idaho" (Benson 2007:1). He went on to say, it's too early to tell how much wolves will influence elk populations in the long run and that while there may be "some lower levels of elk, it won't be a big deal from the standpoint of a hunter" (Benson 2007:1).

Wyoming currently is seeking to reduce wolf numbers to protect big-game herds from excessive killing by wolves while litigation over their unacceptable wolf-management plan continues. A bill in the Wyoming legislature proposes killing wolves that are: (1) impacting big game, (2) moving elk off of feedgrounds and (3) causing "mixing between livestock and ungulates" or causing "wild ungulates to pose safety hazards on state public highways" (Royster 2007:1). The USFWS has responded that changes needed in federal rules to accomplish the request could take as long as the delisting process.

While science, politics and public opinion determine the timetable for delisting and state management of wolves, most regular citizens follow the laws of the land. Fringe elements, like the Idaho Antiwolf Coalition, advocate the removal of all wolves from Idaho by whatever means necessary to the extent allowed by law. The group is raising money to sue for the removal of wolves and its spokesman, Ron Gillet, is quoted in the *Idaho Statesman*: "If we don't come out the way we expect, I can't guarantee there won't be civil disobedience. We are not going to lose our wildlife because of some liberal judge"(Barker 2004:1). One antiwolf activist in Idaho even provided instructions on how to poison wolves on his Website and was later charged in federal court with placing poison baits with intent to kill wolves (Barker 2005). Instead of killing wolves, the poison killed wildlife and sickened at least one dog. Results of this court case are still pending. In Wyoming, more than a dozen dogs have died from poison aimed at wolves.

The pandemonium resulting from the collision of wolf biology and wolf politics continues to play out in the national media. Delisting of wolves could be delayed by wolf-advocacy organizations filing lawsuits and demanding assurances from Idaho and Wyoming that wolves will have adequate protection. Wyoming has been the subject of ridicule in the press as the most prowolf state of them all because the state's uncompromising position on wolves prevents the delisting process from moving forward while allowing wolves to reproduce and expand their range (Schneider 2006). Today, 12 years after their reintroduction, the public is still extremely divided over the presence of wolves.

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Social and Ecological Benefits of Restored Wolf Populations

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Introduction

Our relationship with, treatment of and scientific understanding about the wolf (formally, the gray wolf, *Canis lupus*) have always been a reflection of humankind's beliefs about our own place in the universe. From at least the 18th century until the first part of the 20th century, western civilization, in particular the United States, based its perspective of the earth and of its natural resources, forests, wildlife, rivers and oceans on viewpoints developed in that period of human history known as the Enlightenment.

Humans were at the center of a mechanical, rational universe. Using rational powers of the mind, newly developed science and modern technologies, western civilization set out to conquer the rest of the world, to spread its enlightenment and to convert the natural resources of the world into wealth and power that would continue to fuel its progress. This was viewed as a social good that would benefit humankind.

The wolf was an unfortunate beneficiary of this enlightenment. When Europeans arrived in North America in the 1500s, perhaps 2 million wolves roamed the continent (Leonard et al. 2005). By the end of the 1940s, viable wolf populations had been largely purged from the continental United States (Coleman 2004).

Over a three-century period, wolves were relentlessly persecuted by various methods beyond trapping, shooting or poisoning, including live burning or dismemberment or being captured and released with muzzles or genitals wired shut (McIntyre 1995, Coleman 2004, Smith and Ferguson 2005). When strychnine was introduced in 1860, the killing of wolves was achieved at a wholesale level previously impossible to achieve (Lopez 1978). Nearly 100 years later, German wolf biologist Erich Zimen remarked, "We killed the wolf in Europe and we hated the wolf, but it was not anything like what you have done in America" (Lopez 1978:169).

In the 1500s, European colonizers brought their old-world myths about, fears toward and hatred of wolves to the New World. Wolves were perceived as and referred to as cowards, as gluttons and as vicious killers who killed for the pure joy of killing (Lopez 1978, Coleman 2004). In a colonists' world view shaped by immediate survival, the land and animals were resources that were here solely for human use; if it wasn't useful, if it had no economic benefit, then it would simply be destroyed.

Elimination of the wolf in this country and elsewhere was based on certain expected cultural biases in addition to a philosophical view of the wild that anointed humans as conquerors. European-Americans viewed the very existence of what was once the most widely ranging land mammal on the planet as incompatible with their way of life. Yet, historical attacks on humans by rabid wolves were prevalent enough in Europe to perpetuate rational fears and, when contrasted with far fewer wolf attacks (due in part to lower wolf-to-human transmission of rabies) in North America, go a long way in explaining how and why this cultural inertia against wolves persisted on this continent (Linnel et al. 2002). In any event, most nonindigenous peoples certainly did not view the wolf as providing any benefits to the landscape, to other wildlife, to individual humans or to social welfare.

Thus, a comprehensive discussion of the social and ecological benefits of restored wolf populations necessitates, as precursor, an evaluation of what is meant by benefit and answers precisely the question of who or what, exactly, is benefiting. A new discussion is justified now, too, for other reasons. First, recent research indicates that our immense effort devoted to lethal control of wolves and other canids has not resulted in mitigating livestock depredation and its associated costs to the extent desired, if at all (Musiani et al. 2005, Berger 2006). Second, reintroduced or restored wolf populations have not harmed the economic welfare of ranches and farms to the degree expected, if not feared (e.g., Chavez and Gese 2006).

Direct-, Indirect- and Passive-use Benefits

Benefits may be classified as direct-use, indirect-use or passive-use. Direct-use benefits refer to consumptive or nonconsumptive benefits, such as wildlife viewing, photography or hunting. Whereas, indirect-use benefits refer to ecological functions that lead to human benefits, such as ecosystem services (Manalo 2006). Ecosystem services may be thought of as those flows from a natural area that are of relatively immediate benefit to humans (Boyd and Banzhaf 2006, Brown et al. 2006). Passive-use benefits refer to the attachment of value we place on landscapes, ecosystems or species independent of actual use and include such things as existence value, stewardship or bequests (Manalo 2006).

Extrinsic versus Intrinsic Value

Benefits of a restored wolf population may also be classified according to whether they arise from the extrinsic or intrinsic value of wolves. Certain types of identifiable direct-, indirect- or passive-use benefits arise from the extrinsic, or the instrumental, value of wolves, that is, the value that wolves provide to human and nonhuman organisms and systems, not to wolves themselves (Lynn 2007). Seen through the lens of conservation, restored wolf populations provide ecological benefits to other entities or organisms. In this analysis, wolves play roles and provide services to the ecosystem by applying selective pressure that has ripple or cascade effects. Examples of this include selectively culling weak members of ungulate herds, providing food for other animals that feed on wolf-killed carcasses and initiating trophic cascades that result in increased growth of woody riparian plants, in nesting sites for songbirds, in materials for beaver dams and in cool, deep ponds needed by juvenile fish (e.g., Ripple et al. 2001, Wilmers and Getz 2005).

Economic analysis of the benefits of restored wolf populations presents wolf presence and visibility to nature-seeking tourists as a commodity that translates into tourism dollars that benefit local and regional economies. Or, it presents wolves as a source of passive-use benefits to people who simply cherish knowing that wolves again roam free in their native habitat. Other social sciences also focus on human benefits of restored wolf populations; a key example is the fact that wolf recovery has encouraged the development of a dialogue and partnerships between stakeholder groups who may otherwise be adversaries on this issue.

These extrinsic values contrast other benefits of restored wolf populations that are based upon the intrinsic value of wolves, i.e., the concept that wolves have value in and of themselves. Intrinsic value (also known as inherent value) suggests that, "one has importance or worth in and of oneself, without reference to what one's value is to someone or something else" (Lynn 2007:813). Acknowledging the intrinsic value of wolves allows us to evaluate how restored wolf populations benefit the species' ability to flourish. Such benefits to wolves might include ability to pass the wolf's genetic code on to future generations, an increase in hunting prowess and feeding efficiency, enhancement of pup survivorship, and transmission of "cultural knowledge"—behavior taught by learning from other individuals within the pack—in this social species for such life-history requirements as profitable hunting sites, traversable linkage corridors for dispersal, and safe denning locations for pup rearing.

Benefits Derived from the Extrinsic Value of Wolves

Ecological Benefits and Ecosystems Services

Age structure, health and foraging competition by ungulate herds. As a keystone species, wolves have a dynamic relationship with and influence on their prey. A commonly held assumption among early wolf biologists was that wolves selectively hunt the weakest members of their prey species, and ongoing studies of restored wolf populations demonstrate this to be generally true. Selection of individual prey takes place through a sifting and sorting process that includes testing a herd, identifying weak individuals and pursuing the inferior animals (Halfpenney 2003). In Yellowstone National Park, necropsies of elk killed by wolves showed that animals killed were very old, with wolf-killed cow elk (*Cervus elaphus*) averaging 14 years of age (Mech et al. 2001). Necropsied remains also reveal that many of the animals killed by wolves have age-related infirmities, such as arthritis, disease, injuries or severely depleted fat reserves (Mech 1970, Stahler et al. 2006). Removing these unhealthy, aging, postreproductive-age individuals from the population results in the availability of more forage for younger, healthier, more reproductively active members of the herd.

Recent research suggests that wolves could substantially reduce prevalence of chronic wasting disease (CWD) in deer and elk populations (Wild et al. 2005). The extent of such an impact, however, remains to be seen. So far, it is based exclusively on results of simulation modeling because of the current lack of overlap between CWD and occupied wolf habitat.

Predation by wolves on deer and elk also can also provide ecosystem services, as defined above. Such predation reduces forage competition between livestock and other ungulates, such as deer and elk, that constitute wolves' primary prey, with potentially positive impacts on livestock production (Unsworth et al. 2005). In some locations, reintroducing wolves is likely to generate net economic benefits by lowering densities of ungulates that have created financial burdens on stakeholders exposed to costs from ungulate over-abundance (Nilsen et al. 2007).

Scavengers. One of the most frequent and novel observations by wolf-watchers in Yellowstone National Park is the number of species besides wolves that show up to dine on wolf-kill leftovers. At least 12 scavenger species have been observed at wolf kills, including coyotes (*Canis latrans*), grizzly bears (*Ursus arctos horribilis*), black bears (*Ursus americanus*), eagles (*Haliaeetus leucocephalus and Aquila chrysaetos*), ravens (*Corvus corax*) and magpies (*Pica hudsonia*; Smith et al. 2003, Wilmers et al. 2003). Ravens, in particular, frequent wolf kills in large numbers, flying in close association with wolves even before the prey is down (Stahler et al. 2002). A Native American saying insightfully notes that the wolf acts as the raven's tooth and the raven as the wolf's eye (S. Strauss, personal communication 2004). Recent research also suggests that, because wolves make carrion available to other species during increasingly mild winters, these predators may buffer the effects of climate change and, thus, allow scavengers more time to adapt to (or seek alternatives for) otherwise negative impacts from altered climate (Wilmers and Getz 2005).

Impacts on populations of other predators and interspecific competition. The reintroduction of wolves to Yellowstone National Park and their subsequent aggression towards coyotes resulted in a 50-percent decline in coyote density on the northern range (up to 90 percent in core, occupied, wolf-pack territories) and reduced the size of coyote packs there. Interspecific competition between wolves and coyotes is well documented (Crabtree and Sheldon 1999, Smith et al. 2003). From this, one may speculate that, in the more-than-70-year absence of wolves, coyotes had expanded in number and distribution to fill a gap created by the absence of the ecosystem's top dog; the wolf's return shifted this balance back toward its prior state.

Wolves also reduce predation by other livestock predators, such as coyotes, feral dogs (*Canis spp.*) and mountain lions (*Felis concolor*), through interspecific competition with those predators (Crabtree and Sheldon 1999, Smith et al. 2003). Potentially most important economically is the effect of competition between wolves and coyotes, especially that of predation by the former on the latter. This may reduce the number of livestock depredation episodes by coyotes that accounts for the overwhelming majority of all livestock kills by predators (National Agricultural Statistics Service 2001).

In Yellowstone National Park, most pronghorn (*Antilocapra americana*) fawn mortality is caused by coyotes. While the data are preliminary, it appears that fawn survival correlates positively with wolf density and inversely with coyote density (Smith et al. 2003). Pronghorn are rarely part of wolf diet, due to the sheer speed of adult pronghorns (D. Smith, personal communication 2004). Indeed, it now appears that wolf presence indirectly enhances survivorship of pronghorn offspring.

Mesocarnivores. In Yellowstone National Park, some midsize carnivores (weasels [*Mustela spp.*], marten [*Martes americana*] and badgers [*Taxidea taxus*]) exist at robust levels. Whereas, others (fishers [*Martes pennanti*], wolverines [*Gulo gulo*], red fox [*Vulpes vulpes*], lynx [*Lynx canadensis*], bobcat [*Lynx rufus*] and otter [*Lutra canadensis*]) persist in low numbers. Reduced coyote populations, due to wolf presence, could increase the numbers of some of these midsized carnivores, e.g., red fox, which compete more closely with coyotes. Other mesocarnivores that scavenge, such as wolverines, could also increase in number due to the presence of wolves and wolf-killed carcasses (Smith et al. 2003).

Restoration of wild behaviors. The restoration of wolves may, over time, reinitiate antipredator responses in ungulates that have grown soft, in the absence of wolves. In experiments with different moose populations, reactions to wolf-odor cues were compared among naive and predator-habituated moose (*Alces alces*) populations (Pyare and Berger 2003). Odor cues in the form of wolf-urine-scented snowballs were placed near moose in Wyoming that, for the last 70 years, had lived without wolves until their reintroduction in the mid-1990s. The same odor cue was given to an Alaskan moose population from interior Alaska, whose exposure to wolves had been uninterrupted in evolutionary time, and to a second Alaskan moose population that lived on the Kenai National Wildlife Refuge within a 2500-acre (1,011.71-ha) research facility fenced off from all but the most occasional encounters with wolves. Very different reactions were elicited from the test populations. The reactions indicate antipredator types of behaviors, including vigilance, aggressive response and test-site abandonment. Interior Alaskan moose that had an unbroken relationship with and exposure to wolves were more vigilant and were more than three times as likely to respond aggressively to the odor cue as either the Kenai moose living in a fenced enclosure or the Wyoming moose that had only recently been re-exposed to wolf presence. More than half the trials of the interior Alaskan moose could not be completed because the subject animals departed the experimental area. We contend that these results demonstrate that recovery of an endangered species is not necessarily gauged solely upon reaching population and demographic goals but ought to include broader ecological and behavioral processes that have also been restored (for a broader discussion of this issue, see Berger 2002). Thus, an additional extrinsic value and indirect-use benefit of wolves is their potential to restore ecosystem processes involving predator-prey dynamics.

Vegetation effects and trophic cascades. Wolves have been documented to exert a biological control function through their impacts on the trophic structure of ecosystems (Ripple et al. 2001, White et al. 2003, Ripple and Beschta 2004, Hebblewhite et al. 2005). A trophic cascade is the "progression of indirect effects by predators across successively lower trophic levels" (Estes et al. 2001:859; Ripple and Beschta 2004). Studies of wolf-moose-balsam fir (*Abies balsamea*) relationships on Isle Royale and of wolf-elk-woody riparian plant (namely aspen [*Populus tremuloides*] and willow [*Salix spp.*]) relationships in Yellowstone National Park suggest that suppression by ungulate herbivory on the respective plants results in depressed plant growth rates. Reappearance of wolves in Yellowstone National Park and increased wolf populations on Isle Royale may release the plants from herbivory pressure as the ungulates change their foraging patterns due to fear of predation (McLaren and Peterson 1994, Ripple and Beschta 2004).

In Yellowstone National Park, following the reintroduction of wolves and apparent changed elk foraging behavior, the release and subsequent enhanced growth of plants, such as willows and aspens, has fostered many beneficial changes in the ecosystem. This includes providing pivotal nesting and roosting sites for neotropical migrant birds, root strength for soil erosion protection along streambeds, and food and building sources for beavers (*Castor canadensis*), with resultant dams that create cool, deep ponds needed by juvenile fish (Ripple and Beschta 2004, Hebblewhite et al. 2005).

Social Benefits

Direct-use Economic Values

Northern Rocky Mountains. When wolves were reintroduced to Yellowstone National Park and central Idaho, economic projections were a part of the initial environmental impact statement prepared for Congress for the proposed reintroduction. A survey of a national, random sample of households, as well as a subsample of all listed phone numbers in the three-state recovery region (Wyoming, Montana and Idaho), questioned individuals regarding their understanding of and attitudes towards the area's wolf reintroduction. By a two to one ratio, nationally, wolf supporters outnumbered opponents. Whereas within the three-state region opinion, it was very closely divided with 49 percent in favor, 43 percent opposed and 8 percent not knowing. The survey also estimated willingness-to-pay to support or oppose the reintroduction. It was estimated that wolf recovery in the Yellowstone National Park area would lead to benefits between $6.7 and $9.9 million per year, with total costs (value of foregone benefits to hunters, lost value due to livestock depredation and wolf-management costs) of $0.7 to $0.9 million per year. The study also estimated that increased visitation due to wolf recovery would result in additional, annual, regional expenditures of $23 million (Duffield 1992, Duffield and Neher 1996).

Fourteen years later, the results of a follow-up study regarding the economic impacts of wolf recovery in the Yellowstone National Park area yielded figures that far surpassed the original estimates (Duffield et al. 2006, Stark 2006). Between December 2004 and February 2006, approximately 1,900 park visitors were asked why they came to the park, what they hoped to see, what their opinions were about wolves and other wildlife, and how much they spent on these visits. Based upon study participants who indicated whether they would have come to Yellowstone National Park if wolves were not present, it was determined that the presence of a restored wolf population has brought an additional, average $35 million annually in tourism expenditures for the local economies of the three-state region. These expenditures, in turn, multiplied effects as they circled through the regional economy, resulting in an estimated total increase in output of about $70 million annually (Duffield et al. 2006).

As described above, wolves may affect browsing behavior by deer and elk, increasing riparian vegetation and decreasing stream temperature (Ripple et al. 2001, White et al. 2003, Ripple and Beschta 2004). This, in turn, is likely to improve habitat conditions for cold-water loving fish, like trout, that lie at the heart of a major sportfishing industry (U.S. Fish and Wildlife Service and U.S. Census Bureau 2002). The economic impact of sportfishing is substantial (American Sportfishing Association 2002). Hence, even a small increase in the quantity of trout fishing in an area could increase recreational expenditures and local incomes.

Minnesota. The single area where wolves were never fully eradicated in the contiguous United States was in far northeastern Minnesota, and some of the earliest (since as early as the 1930s), ongoing studies of wolves in the United States have taken place in this region. As a result, the International Wolf Center chose the remote northeastern Minnesota town of Ely as the location to build a world-class, public, wolf-education facility, first opening in a temporary building in 1989. Though members of the community initially were hostile to wolves and to the concept of the center (L. Schmidt, personal communication 2000), they have since embraced the center's presence. The center's draw of visitors to the region brings an estimated $3 million annually into the local economy, while stimulating the economic equivalent of 66 full-time jobs (Schaller 1996).

A recent survey conducted in Minnesota queried residents of two cities about their willingness to pay for two wolf-management options that would maintain a minimum wolf population of 1,600 animals in the state (Chambers and Whitehead 2003). Though overall the number of respondents willing to support each management option was smaller than the number opposing it, this may have to do with the fact that respondents were told the plans would be financed through tax increases, a financing mechanism that may negatively impact attitudes of respondents otherwise predisposed towards supporting such programs. Survey results indicated that people had seen or heard, or had planned to see or hear wolves—direct uses. Many respondents also believed that wolves have a right to exist—passive-use value for wolves. The benefits, rather than representing market output associated with wolves, indicated that Minnesotans would be willing to pay more for the wolf-management plan (and thus to preserve wolves) or for the wolf-damage plan than it would cost the state to implement those plans, resulting in net benefits of wolves to the state's residents (Chambers and Whitehead 2003).

North Carolina. The economic benefits of red wolf (*Canis rufus*) reintroduction to northeastern North Carolina and the Great Smoky Mountains National Park were estimated via surveys in an eight-state area, including the recovery states of North Carolina and Tennessee, plus six neighboring states (Rosen 1997). The surveys were intended to measure the attitudes towards reintroduction, the general knowledge of red wolves, and the potential regional and local impacts of reintroduction. Results showed very strong public support for reintroduction in both areas, and they indicated that people were more likely to visit the area as a result of the red wolf presence, even more so if activities related to the red wolf's presence were offered as part of an ecotourism draw. Increases in tourism due to presence of red wolves and to red wolf-related activities were predicted to generate additional annual visitor spending of between $10.75 and $24.66 million in northeastern North Carolina and additional annual visitor spending of between $105.83 and $185.67 million in the greater Great Smoky Mountains National Park region. Applying regional multiplier estimates (e.g., how these added dollars prompt more jobs, more income to newly employed people, etc.) to these initial figures, the regional impact of red wolf visitor activities was estimated at $35.36 million in northeastern North Carolina and at $291.51 million annually in the Great Smoky Mountains National Park.

In 2005, the national nonprofit conservation organization, Defenders of Wildlife (Defenders), commissioned a study of the potential contribution of red wolf-based ecotourism to economic development in coastal North Carolina. The results showed that landowners and residents were interested in locally based tourism efforts that would benefit communities and would protect the natural beauty of their counties. Tourists also expressed interest in participating in red wolf-related activities (G. Y. B Lash and P. Black, personal communication 2005). These findings spurred Defenders and its partners, the Red Wolf Coalition and the U.S. Fish and Wildlife Service, to create and install six red wolf educational displays on the Outer Banks and in other important tourist areas near red wolf country. The kiosk-style displays present general information about red wolves and promote "howlings," or guided, nighttime tracking and listening tours of the Alligator River National Wildlife Refuge in the heart of the region's red wolf habitat.

Passive-use Economic Values

Wolves also generate benefits that are not related to any direct use of or ecological benefit to humans. Many people assign value to the existence and preservation in the wild of charismatic species, such as the wolf, even though they may never come into contact with the species. Many also see it as society's responsibility to practice good stewardship towards other species and to pass a complete and healthy ecosystem to future generations. These passive-use values in economics commonly are referred to as existence, stewardship and bequest values (Krutilla 1967). The importance of passive-use values in the case of wolves has been documented in a number of studies. For example, Manfredo et al. (1994) examined perceptions and attitudes of Colorado residents towards wolf reintroduction to the state and found that passive-use values are strong motivation in the residents' attitudes toward reintroduction. Their findings were confirmed for other states (e.g., Chambers and Whitehead 2003) as well as for the United States as a whole (Duffield 1992, U.S. Fish and Wildlife Service 1994).

Indirect-use Economic Values

Ecosystem service values. In addition to direct-use and passive-use values described in the preceding paragraphs, wolves also generate indirect-use benefits through their provision of ecosystem services in wolf habitat. As described in the section on ecological benefits and ecosystem services, these services include the biological control function of wolves through their impacts on the trophic structure of ecosystem, which has been documented to affect browsing behavior by deer and elk. This tends to increase riparian vegetation and to decrease stream temperature, potentially improving habitat conditions for cold-water loving fish, like trout, a highly important species in many states' sportfishing industries. Other ecosystem services wolves may provide is reduction of forage competition for livestock from wolves' primary prey, deer and elk; a reduction in depredation levels by other livestock predators, such as coyotes, feral dogs and mountain lions; and a reduction in the prevalence of CWD in deer (*Odocoileus spp.*) and elk populations (Wild et al. 2005).

Human Discourse

State wolf planning stakeholder committees. Presence of restored wolf populations has borne far-ranging and intense dialogues between stakeholders that could best be characterized as having conflicting interests for achieving restored wolf populations. Several states have established stakeholder committees to develop wolf-management plans. This has been the case in the western Great Lakes region as well as in the northern Rocky Mountains. As the plans are adopted, either by a state wildlife commission or by a state legislature, public hearings have accompanied the planning process and, once again, have provided opportunity for individuals with diverse perspectives on wolves to exchange their views. Under these circumstances, stakeholders achieve enhanced understanding by exchanging views about wolves among livestock producers, hunters and trappers, conservationists, tribal representatives, biologists, economists, educators, agency personnel, elected officials and even schoolchildren.

Livestock compensation programs and proactive conflict-prevention partnerships. Several programs developed by nongovernmental organizations have also extended this discourse through development of compensation programs, designed to pay for wolf-caused losses, and through proactive partnership programs, designed to solve problems jointly and to implement methods to prevent wolf-livestock conflicts before they arise. Examples include the Bailey Wildlife Foundation Wolf Compensation Trust and The Bailey Wildlife Foundation Proactive Carnivore Conservation Fund, both operated by Defenders. Other examples include range-rider programs and marketing concepts being developed by the Montana-based, nonprofit organization, Predator Conservation Alliance, to protect livestock from wolves and to commercially market those products from ranches that use predator-friendly methods. Benefits derived from compensation and proactive programs include economic stability, enhanced survivorship for both wolves and livestock, and broadened communication and understanding among stakeholder groups.

Livestock producer advisory council and surveys. Expanded understanding and shared goals developed by participants in compensation and in proactive programs are broadened through forming advisory councils whose express purpose is to shape these programs so that the benefits will be the greatest for all involved and (through the development of surveys) to gauge livestock-producer response to the programs. In 2004, Defenders established a Livestock Producer Advisory Council that currently consists of five cattle producers and sheep growers from Idaho, Montana, Wyoming and Oregon. Defenders's staff involved in the organization's compensation and proactive programs meet several times each year with the Livestock Producer Advisory Council in order to seek guidance from ranchers regarding the implementation of these programs.

Recently, Defenders also conducted a survey of northern Rocky Mountain ranchers who had received compensation from the Defenders-operated fund over a 3-year period for wolf-caused losses. The survey gauged, through public opinion, how compensation might aid conservation of wolves. The survey of 138 individuals was sent to all northern Rocky Mountains ranchers who received compensation between 2002 and 2004. This represented more than 90 percent of the total, documented losses realized during the 3-year period, as well as the majority of livestock owners who experienced verified wolf-caused livestock losses since the compensation program's inception in 1987. The response rate was 44 percent (n = 61, where n represents the number of respondents); respondents answered standardized questions regarding their experience with and attitude towards wolves and the compensation program. Although other studies have suggested that an increase in tolerance for wolves does not necessarily accompany receipt of compensation (Linnell and Broseth 2003, Naughton-Treves et al. 2003, Nemtzov 2003), the Defenders study yielded slightly different results. When asked if receiving compensation increased their tolerance for wolves, more than 60 percent said it did not. However, when asked how their tolerance for wolves would be affected if the compensation program were halted, 59 percent said their tolerance would be lower or significantly lower if the program ended. None thought compensation should end. This study revealed that compensation functioned somewhat like a dam, at the very least preventing some erosion in acceptance of wolves from a stakeholder group most inclined to resist wolf presence (Stone, in press) The compensation fund also facilitated direct interactions between ranchers and conservation staff that furthered the interests of both parties. So, an additional benefit of restored wolf populations is development of human relationships, resulting in increased understanding and expanded opportunities to achieve goals through voluntary programs and direct action.

Institutions: Public Education, Polling, Politics and Media

Public education. Education about the natural world, including the role of carnivores in nature and the history of human-carnivore interactions in the United States, benefits the public by providing historical perspective for wildlife management and for large-carnivore conservation in this country. Since before reintroduction of wolves to Yellowstone National Park and central Idaho, concerted efforts have been undertaken by federal agencies, by nongovernmental agencies and by others to provide public education about wolf biology, behavior, the history of wolf extirpation and the subsequent recovery efforts in this country. These endeavors have allowed for the broad dissemination of information not only about wolves but about the ecological role of carnivores in general. This dissemination has occurred through a surprisingly broad array of outlets, spawning countless books and videos on wolves; displays at museums, libraries, zoos and nature centers; school curricula; poster contests; the creation of an annual, national Wolf Awareness Week; plus an incredible marketing onslaught of wolf imagery on t-shirts, coffee cups, bumper stickers and the like, which can be more-or-less educational in imagery and messaging.

Polling. As a result of the federal mandate to restore threatened and endangered species, such as wolves, numerous public polls have been conducted throughout the United States to survey attitudes of the public regarding wolf restoration. Poll results benefit state and federal agencies by informing them of public attitudes regarding active, species-reintroduction programs versus recovery via natural dispersal. And, they assist other entities, such as nongovernmental advocacy organizations, in gauging public response by locale, thus helping to shape where and what type of public-education campaigns are most needed. Over the last several decades, many polls have been conducted nationally and regionally; two examples, one from Oregon and the other from Colorado, illustrate the type of information that can be obtained from the public and then put to use accordingly.

In 1994, a survey conducted in Colorado (Manfredo et al. 1994) showed that more than two-thirds of its public would vote for wolf reintroduction to Colorado. The survey showed that, for those in support of reintroduction, the most important drivers were a belief that reintroduction would result in preservation of the wolf, in balanced deer and elk populations, in an increased understanding of the importance of wilderness, in greater control of rodent populations, and in a return of the natural environment to the way it once was.

A 1999 poll of 600 registered Oregon voters focused on the possible return of wolves to Oregon (Davis and Hibbitts, Inc. 1999). Seventy percent of respondents favored recovery of wolves in Oregon, either through active reintroduction by wildlife agencies or by allowing wolves that entered Oregon from other states to remain in the state. Fifty-seven percent of respondents felt that wild wolves should be allowed to stay in Oregon when they returned on their own; 13 percent believed that wild wolves should be actively reintroduced into Oregon; 23 percent felt that wolves should not be allowed in Oregon at all. On a region-by-region basis, there was little variance among those favoring active wolf reintroduction or among those agreeing that wolves who enter Oregon on their own should be allowed to remain in Oregon. Two-thirds (66 percent) of those surveyed felt that the best reason to support the return of wild wolves to Oregon was that they owe it to future generations to leave the most complete ecosystem possible, including predator species like wolves (Davis and Hibbitts, Inc. 1999).

Politics. The restoration of wolf populations to the lower 48 United States has set the stage for some of the most remarkable politics ever witnessed regarding wildlife. Restored wolf populations fuel arguments for and against the Endangered Species Act and for and against federal involvement in what some view as primarily a state issue. Wolf politics have resulted in the passage of a plethora of antiwolf resolutions at the county level, and they have been the basis for many bills introduced into state legislatures. Because of the political nature of wolf-restoration issues, a large number of people have been exposed to information about real and perceived impacts of wolves on livestock operations and on populations of wild ungulates preyed upon by wolves. Although the word "ethics" is rarely thrust into the spotlight on this issue, the emotionally charged nature of the arguments and discussions reveal what is essentially a values-laden foundation to the issues. As pointed out repeatedly here, one benefit of restored wolf populations is that it has increased involvement of citizens in the democratic process, simultaneously sparking widespread discussion of the scientific underpinnings to wolf management, the political forces attempting to exert influence over wolf management decisions and the ethical considerations throughout the process. Whether wolves have benefitted from this is yet to be answered, but it is clear that a normally apathetic U.S. public participates with great vigor in these debates.

Media. As a result of wolf restoration, the public has been treated to the opportunity to see how much or how little local and national journalists know about wolves and the associated issues. The public has also had the opportunity to note media biases in reporting sensationalized stories about wolves, as well as to appreciate the rare article that presents factual information in full context.

Benefits Derived from the Intrinsic Value of Wolves

Identifying benefits that wolves themselves can obtain from restoration requires acknowledgment that wolves, as a species and as individuals, have intrinsic value. Intrinsic value of nonhuman organisms, according to a range of philosophical theorists, may be said to arise from the sentience, sociality and intelligence of the organism in question. Regardless of the existence of these characteristics or other human-conceived standards of measurement, the concept of intrinsic value states that an organism has value in and of itself, independent of the use anyone else may have for it (Lynn 2007).

Genetic Transmission

An enhanced ability to transmit genes into future generations could benefit individual wolves in and packs of restored populations. A greater number of animals allows for more breeding opportunity and for successful reproduction. In wolf packs, one pair tends to be the dominant breeders; though, other adults in the pack may breed as well (Mech 1970). Furthermore, subadult wolves frequently disperse from the pack, locating mates and colonizing territories of their own. A larger wolf population creates greater likelihood that dispersers will encounter other lone wolves with whom to mate and reproduce.

Increased Hunting Success and Feeding Efficiency

Wolf-pack size can vary due to a number of factors, including but not limited to food competition, dispersal and size of prey species hunted. Wolf-pack sizes tend to be larger in areas where wolves are preying upon the largest ungulates (Mech and Boitani 2003). Though lone wolves can and do successfully kill prey, restoring a dwindling wolf population could allow for increased pack sizes and, therefore, could enhance ability to kill larger prey species. This, in turn, would allow adult wolves to subsidize the food needs of their pups by sharing large prey (Mech 1970), improving the inclusivity of the family social unit (Rodman 1981).

Enhancement of Pup Survivorship

Wolf packs do not restrict care of pups to biological parents. Wolves are highly social animals that exhibit hierarchical behaviors within packs and that demonstrate a high degree of social cohesion and a distribution of labor among the extended family members to care for the pack's litter of pups (Mech 1997). Pup-care duty by nonparent pack members is observed frequently enough by biologists that these animals are often referred to in observational reports as babysitter wolves. In one instance, a federal wolf biologist conducting observations in the Arctic National Wildlife Refuge reported an hours-long observation of one babysitter wolf transporting the pack's pups to a new location where the pups' mother lay waiting for their arrival. In the process, the babysitter wolf learned what types of activities pups initially were not willing to undertake, but the pups learned to overcome fear of obstacles and ground surfaces, which they would need to be familiar with to survive as adults (U.S. Fish and Wildlife Service 2001). A larger restored wolf population allows for larger packs, and for more members able to rotate pup-care duty, thereby providing valuable development lessons the pups need to survive as adults.

Transmission of Cultural Knowledge

All species benefit from knowing where to obtain sources of food, water, shelter and safety from predators. While some of these sources may be encountered through chance or through visual or olfactory sensory cues, indirect evidence suggests that the passing along of this critical, cultural knowledge from one animal to another, from one generation to the next, is a phenomenon exhibited by wolves. Wolf biologists have observed that wolves from multiple generations den in the same locations for hundreds of years (Mech 1997). Wolf dispersal takes place across trails and regions used by other wolves, with repeat travel even occurring on such human constructs as roads, railroad tracks and snowmobile trails; wolves living in close proximity to humans know where and when to travel safely (Mech and Boitani 2003) and may teach this to their offspring. Prey-seeking and hunting skills are taught by adult pack members to pups over territorial ranges well-marked and defended by the resident pack. Generations later, wolf packs continue to frequent and defend these same sites. Without written journals or illustrated maps to guide them, individual animals teach their young to follow in the footsteps of ancestors long gone.

Conclusion

Recognition that the wolf has both extrinsic and intrinsic value allows us to significantly expand our identification of the many benefits that result from restored wolf populations. The term benefits need not be limited or limiting if we are willing to broaden the philosophical discourse beyond extrinsic values attached to wolf presence. Such an expansion is taking place against a backdrop of simultaneous evolution in the breadth of Western Civilization's cultural, philosophical and scientific foundations. "It has been said that wolf's eyes are mirrors; what different people see in them is simply a reflection of ourselves. Could they reflect even more, not just a person's attitudes towards wolves, but towards the environment, wild lands, nature itself?" (Theberge and Theberge 1998:10). Our treatment of the wolf measures the scope of our own place in the world, with respect to the landscape and with respect to the human and nonhuman inhabitants with whom we share that world.

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Elk and Predation in Idaho: Does One Size Fit All?

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Introduction

Predation and predator-prey dynamics are particularly interesting and intriguing aspects of wildlife biology. Though predation is an integral part of population dynamics, the effect of predation on prey populations is less clear, largely because the interaction is complex. For example, the large-ungulate prey base in Idaho includes elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginianus*), moose (*Alces alces*), bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*) and pronghorn (*Antilocapra americana*). The suite of large predators includes black bears (*Ursus americanus*), cougars (*Puma concolor*), coyotes (*Canis latrans*), bobcats (*Felis rufus*), wolves (*Canis lupus*), and a few grizzly bears (*Ursus arctos*). Furthermore, the dynamics of individual predator and prey species vary across spatial and temporal scales, as do the interactions among those species.

Changing habitats, management philosophies, and social values also cloud our understanding of predator-prey dynamics (Schwartz et al. 2003). Messier (1991) points out that the emphasis on the limiting effects of predation has likely obscured identification and interpretation of other factors that may ultimately regulate prey populations. Consequently, describing and understanding the effect of predators on prey populations is a significant challenge.

To illustrate this, we have assembled relevant data sets for elk in Idaho. The data were collected as part of several Idaho Department of Fish and Game (IDFG) research efforts aimed at understanding bull-elk mortality, elk recruitment and population processes across large spatial scales. The data are from generally comparable telemetry-based projects with objectives related to survival and cause-specific mortality.

Our objective is to review and discuss these data sets within the context of predator-prey dynamics.

Background

Elk are Idaho's premier big-game animal. The statewide population has increased steadily since the mid-1970s, when hunting for antlerless elk was eliminated throughout most of the state. Idaho elk populations are near all-time highs and are at or near management objectives (Compton 1999). Today, about 125,000 elk are distributed throughout the state from the sagebrush-dominated deserts in southern Idaho to dense, cedar-hemlock forests of the north.

Managing elk populations and their habitats for a sustainable yield is a high priority for management agencies. Habitat-effectiveness models are the primary elk-habitat management tool in the northern Rocky Mountains (Lyon 1979), and harvest is the primary population management tool.

Idaho also supports viable populations of black bears, cougars, coyotes and bobcats. Small populations of grizzly bears occur near the Greater Yellowstone Ecosystem and in the Selkirk and Purcell mountains in northern Idaho. Wolves were reintroduced during 1995 to 1996. The population has grown from 35 to an estimated 512 wolves in 59 packs (Sime and Bangs 2006) distributed across the state.

Approximately 25,000 black bears occur throughout forested habitats in Idaho. Hunter harvest is about 2,000 animals annually, and the populations in most game management unites (GMUs) are considered stable-to-increasing (Nadeau 2005a). Harvest has generally increased since 1994, and management criteria suggest that harvest is "moderate" (Beecham and Rohlman 1994).

Cougars are found throughout Idaho, but they are difficult to monitor because they are secretive, and they occur at low densities. The statewide harvest increased through the late 1990s, peaking in 1997 when 798 animals were reported, then declined to 423 in 2005 (Nadeau 2005b). This suggests that the cougar population has likewise declined over the past decade.

The data sets that we present are derived from localized concern over declining bull-to-cow ratios or poor recruitment and from a general interest in ungulate ecology. Declining bull-to-cow ratios in north and northcentral Idaho in the late 1970s and early 1980s lead to a research effort designed to link elk-population processes with the landscape (Unsworth et al. 1993, Hayes et al. 2002). Hughbanks (1993) conducted a small-scale investigation in southeastern Idaho, and Montgomery (2005) used the combined data to address statewide bull-ecology questions.

Furthermore, concerns related to chronically low or declining calf-to-cow ratios led to two major investigations into the underlying reasons for poor recruitment (Schlegel 1986; Gratson, unpublished report 1992; Zager and White 2003).

More recently, the reintroduction of wolves into Idaho has resulted in renewed interest in broad, ungulate-population ecology and predatory-prey dynamics. In response, the IDFG launched an ambitious research effort in 2005 that includes GMUs (Figure 1) across the state. We provide some preliminary data from that research.

Results and Data Sets

Bulls

Elk-population growth and expansion was uneven across the state. Also, declining bull-to-cow ratios and quality of bulls in the harvest were evident in northern and northcentral Idaho GMUs by the mid-1980s. In response, IDFG launched projects during 1986 to 1995 in 3 in contrasting study areas (Lochsa study area, GMU 12; Coeur d'Alene study area, GMU 4; Sand Creek study area, GMU 60A) to identify the reasons behind this decline.

Across the 3 study areas, bull survival ranged from 0.54 to 0.69, and more than 80 percent of the mortality was related to hunting (Table 1). Therefore, intensive monitoring was limited to just before, during and immediately after the hunting seasons. Mortalities occurring during other seasons were often not promptly investigated, so determining cause of death was problematic. Other causes of death (less than 10 percent of the total mortality) included, but were not

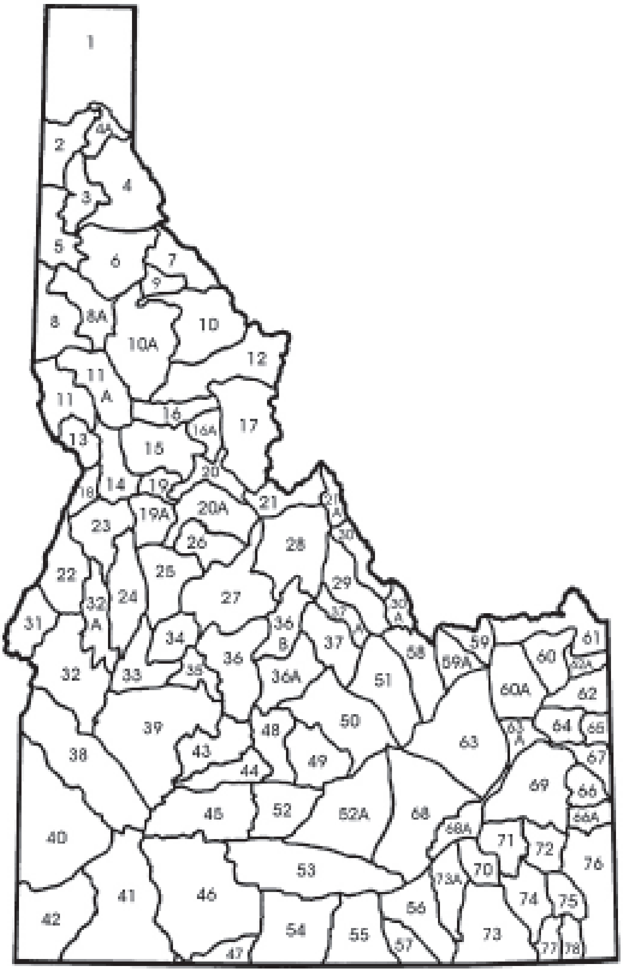

Figure 1. GMUs as delineated by the Idaho Department of Fish and Game.

limited to, predation. Therefore, predation accounted for less than 10 percent of the annual bull elk mortality on these three study areas during this period.

Furthermore, bull survival on the Lochsa study area was modeled using road density, hunter density and an index of topographic roughness as predictive variables (Unsworth et al. 1993). Survival on the Coeur d'Alene study was predicted by total road density and season timing (Hayes et al. 2002). Predation rate was not an important predictor of bull mortality.

However, the reintroduction of wolves during 1995 to 1996 may alter this dynamic. Smith (2005) reported that wolves in Yellowstone National Park prey

Table 1. Adult male elk annual survival rates and cause-specific mortality in Idaho. The time periods are indicated.

					Cause-specific mortality[1]							
GMU	N[2]	Survival	SE	N[2] deaths	Malnutrition disease	Harvest	Other	Bear	Cougar	Wolf	Un-known	Total predation
Panhandle												
GMU 4 (1988–1990)	63	0.549	0.063	28	0	96.4	3.6					
GMU 4 (1991–1994)	128	0.691	0.041	39		92.3	7.7					
Clearwater												
GMU 12 (1986–1990)	169	0.600	0.063	64	0	90.7	9.3					
GMU 12 (1991–1995)	231	0.634	0.065	80		98.8	1.2					
Upper Snake												
GMU 60A (1981–1988)	66	0.543	0.116	40	17.5	80	2.5					

[1] in percent

[2] N indicates mortalities that were investigated; it does not include censored animals.

upon adult bull elk in proportion to their availability. We currently have no data with which to address this question.

Cows

Since 1975, Idaho has managed antlerless elk conservatively, generally resulting in increasing populations and in little interest in data pertaining to survival and to cause-specific mortality of adult female elk. Furthermore, Unsworth et al. (1993) and Leptich et al. (1995) reported adult female elk annual survival rates greater than 0.85 (Table 2). Legal harvest was the primary mortality factor. No predation was documented, but it may have been undetected and reported in the "other" category. Because overall survival was considered adequate, determining mortality factors was a low priority.

More recently, elk populations in several southeastern Idaho GMUs have exceeded management objectives, so harvest goals have been adjusted to reduce the population. The reintroduction of wolves has also created renewed interest in elk population and predator-prey dynamics, and it coincided with IDFG interest in investigating ungulate population dynamics across the range of habitats in Idaho.

Recognizing that ungulate population dynamics likely vary with factors, such as habitat, landscape features, and predator and prey density, multiple study areas were selected to encompass that variability. During the first full year of monitoring (March 2005 to February 2006), preliminary data indicate that adult cow-elk survival ranged from 0.797 to 0.962. Predation (by cougar and wolf) and harvest were the primary proximate mortality factors (Table 2).

Adult-cow survival was less that 80 percent in GMUs 43 and 44, in 10 and 12, and in 60A (Table 2). Coincident with relatively low survival, these populations declined since about 2000 (Compton 2005).

Predation, primarily by wolves, was an important mortality factor in GMUs 43 and 44 (33 percent of the mortality). However, the radio-collared portion of the elk population in GMUs 43 and 44 was concentrated around permanent winter feeding stations, presumably predisposing these animals to predation.

Though predation is the dominant mortality factor for adult cows in GMU 10 and 12, the population decline began in the mid-to-late 1980s, suggesting that factors other than predation initiated the decline.

Body-condition scores (Gerhart et al. 1996; Cook et al. 2001a, 2001b) likely reflect either habitat quality or population density. Because the Lochsa

Table 2. Adult female elk annual survival rates and cause-specific mortality in Idaho. Unless indicated otherwise, the survival period is March 2005-February 2006, cause-specific mortality is derived from March 2005-February 2007.

					Cause-specific mortality[1]							
GMU	N[2]	Survival	SE	N[2] deaths	Malnutrition disease	Harvest[3]	Other[4]	Bear	Cougar	Wolf	Un-known[5]	Total predation
Panhandle												
GMU 4 (1988–1994)	169	0.855	0.018	23		82.5	17.4					0
Clearwater												
GMU 12 (1986–1990)	46	0.886	0.094	5		40	60					0
GMU 10/12 (2005–2006)	44	0.797		25			4		4	80.2	12	96
GMU 15	33	0.878		5					60	40		100
GMU 23	26	0.962		7		42.9	57.1					0
Southwestern Idaho												
GMU 32/32A	29	0.931		7		85.7	14.3					0
GMU 39	27	0.926		6		67			33			33
GMU 43/44	24	0.740		6			33		16.7	33	16.7	67
Salmon												
GMU 28	28	0.893		14	7.1	57.1			28.6	7.1		35.7
GMU 36A	31	0.806		9		44.4			33.3	11.1	11.1	55.6
GMU 36B	31	0.839		14		35.7	14.3		28.6	21.4		50
GMU 50	30	0.833		5		60			40			40
GMU 60A (1981–1988)	53	0.553	0.044	35		74.3	25.7					
GMU 60A (1981–1988)	30	0.733		6	16.7	66.7			16.7			16.7

[1] in percent
[2] N = number of elk years; deaths indicates number of elk that died during the period.
[3] Harvest includes legal harvest, wounding loss and poaching.
[4] Other includes, e.g., vehicle collision, disease ore accident.
[5] Unknown predation includes animals that were killed by a predator, but the species of predator could not be determined with reasonable certainty.

population declined dramatically over the last 20 years, it is more likely that body-condition scores reflect habitat quality in this case.

Body-condition scores for adult female elk were lower in GMUs 10 and 12 than in the other study areas in March 2005 and were lower than GMU 15 in previous sample years pregnancy rates have been variable (Zager and White 2003). If body condition scores reflect habitat quality, it suggests that Lochsa habitats are not as productive as the other study areas, which can result in reduced fecundity, declining recruitment and increased vulnerability to starvation or predation. In fact, Lochsa habitats have changed dramatically during recent decades (U.S. Forest Service 1999). Wildfires in the early 1900s created extensive shrubfields and other early seral habitats used by elk. As these habitats have matured, they became less suitable for elk (Skovlin et al. 2002). Though 96 percent of the mortality is linked to predation, it appears that habitat is contributing indirectly to the elk-population decline in the Lochsa study area.

The elk population in GMU 60A exceeded management objectives. Therefore, the management direction is to increase harvest to bring the population to objective. Lower survival is anticipated and desired under these circumstances.

Cow survival was greater than 80 percent (according to 2005 to 2006 preliminary survival data), and populations were stable-to-increasing since 2000 in the other study areas where recent aerial-survey data are available. Hunter harvest and predation were the primary mortality factors in most of these GMUs. Each of these areas supported viable cougar populations, and wolves were well established by 2000. Predation accounted for approximately 50 percent of the mortality.

Calves

Though elk populations generally increased throughout Idaho after 1975, recruitment remained chronically low in several northcentral Idaho GMUs. Concern over poor recruitment lead to two major investigations into neonatal calf survival and cause-specific mortality in GMUs 10 and 12, the Lochsa study area (Schlegel 1986; Gratson, unpublished report 1992; Zager and White 2003).

During 1973 to 1975, neonatal calf survival from birth to October 1 averaged 37.5 percent. Predation by black bears was the primary proximate cause of mortality (Table 3). In 1976, 75 black bears were removed from the study area. Calf survival increased to 67 percent, then approximated preremoval

Table 3. Survival and cause-specific mortality of elk calves captured and radio-collared as neonates in Idaho. The time periods are indicated.

					Cause-specific mortality[1]							
GMU	N[2]	Survival	SE	N[2] deaths	Malnutrition/ disease	Harvest	Other	Bear	Cougar	Wolf	Un-known	Total predation
Lochsa (1973-1975)	56	37.5		35	2.9	71.4	14.3			11.4		85.7
Lochsa (1976)	18	67		6		83.3				16.7		83.3
Lochsa (1979)	12	25		9		33.3	55.6		11.1			100
Lochsa (1997-2004)	97	0.26		62		54.8	40.3		1.6	3.2		96.7
Lochsa (2000-2004)	57	0.55		21	9.5	38.1	28.6	9.5	9.5	4.8		85.7
South Fork (1996-2004)	102	0.68		30	3.3	40	36.7		10	10		86.7
South Fork (2000-2004)	99	0.39		53	5.7	47.2	26.4		13.2	7.5		86.8
GMU 28 (2006)	34	50			5.9	23.5	11.8	17.6	35.2	5.9		88.1
GMU 36B (2006)	27	52				7.7	15.4	38.5	30.8	7.7		92.4

[1] in percent
[2] N = number of elk years; deaths indicates number of elk that died during the period.
[3] Harvest includes legal harvest, wounding loss and poaching.
[4] Other includes, e.g., vehicle collision, disease ore accident.
[5] Unknown predation includes animals that were killed by a predator, but the species of predator could not be determined with reasonable certainty.

levels 2 years later. Calf-to-cow ratios (an index of recruitment) from aerial surveys showed a similar pattern (Schlegel 1986).

Concurrently, the trend in calf-to-cow ratios was similar in surrounding GMUs, where the bear population was not reduced, compromising interpretation of these results (Schlegel 1986). Nevertheless, these data suggest that predation by black bears is additive and can be a significant factor limiting elk recruitment and population growth.

The second investigation was initiated in 1996, also in GMUs 10 and 12, but north and east of the Schlegel (1986) study. This project was designed to build upon the earlier work (Schlegel 1986) by broadening the scope and addressing some of the criticisms (Gratson, unpublished report 1992; Zager and White 2003).

This investigation contrasted elk population dynamics in a study area with poor recruitment (in the Lochsa study area, GMUs 10 and 12; there were less than 20 calves per 100 cows) and in another with adequate recruitment (South Fork study area, GMU 15; there were more than 30 calves per 100 cows).

Summer (birth to 1 August) calf survival averaged 0.26 on the Lochsa reference area during 1997 to 2004. Predation was the primary proximate cause of mortality. Black bears were implicated in most calf deaths during the first month of life, and cougars were an important mortality factor throughout the remainder of the year (Table 3).

To determine whether predator-caused calf mortality was additive or compensatory, beginning in 2000, black bear and cougar populations were reduced on a 270 square mile (699 km^2) portion of the Lochsa study area. The remainder of the study area served as a reference area where bear and lion populations were not manipulated.

Calf survival increased to an average of 0.55 on the treatment area, but did not change significantly on the reference area. Black bears and mountain lions continued to be the primary proximate mortality factors on both areas (Table 3). Wolves had been well established on the Lochsa study area since about 2000. They are an important source of mortality for older (more than 6-months-old) elk calves but not for younger calves (Tables 3 and 4).

Because few calves radio-collared as neonates survived more than 6 months on the Lochsa, we captured and radio-collared 6-month-old calves in December 2005 and 2006. Comparable data were collected in GMUs 28 and 36B. Among older calves on the Lochsa, wolves were the primary cause of mortality (Table 4).

Table 4. Survival and cause-specific mortality of elk calves captured and radio-collared in December 2005, when they were 6-months-old, through October 2006.

					Cause-specific mortality[1]							
GMU	N[2]	Survival	SE	N[2] deaths	Malnutrition disease	Harvest	Other	Bear	Cougar	Wolf	Un-known	Total predation
GMU 10/12	33	70.0		10			30.0	60.0		10.0	90.0	
GMU 28	36	61.1		14	14.3		42.9	7.1	7.1	28.6	57.1	
GMU 36B	24	58.3		10	10.0		10.0	30.0		50.0	40.0	

On the GMU 15 study area, summer calf survival averaged 0.68 on the reference area during 1997 to 2004. Like the Lochsa study area, predation, mostly by black bears during June and by cougars during the remainder of the year, was the primary proximate mortality factor (Table 3).

To further investigate additive versus compensatory mortality, black bear and cougar populations were allowed to increase (harvest season closed) on a 221-square mile (574 km^2) portion of the area during 2000 to 2004. The remainder of the study area served as a reference.

Calf survival declined significantly on the treatment area, averaging 0.39. Predation, especially by black bears and mountain lions, continued to be the primary proximate mortality factor (Table 3).

Furthermore, White et al. (in prep.) modeled calf survival on both study areas within the context of predator management, landscape and habitat features, and biological factors. Their preliminary models include calf birth weight (index of physical condition) and habitat/landscape features as predictor variables. An index of predator density also contributed significantly to the "best" model for each area (White et al. In Press).

That calf birth weight (index of condition) is an important predictor suggests that neonatal mortality is partly compensatory. That predator density contributes suggests that additive mortality also plays a role.

Discussion

The role of predation in ungulate-population dynamics is unclear, largely because these interactions are complex and difficult to study. Among the wildlife biologists, the traditional view is that most predation is compensatory, i.e., that predators take only those animals that are going to succumb to other factors (e.g., old age, malnutrition, disease) and prey populations respond with increased production and survival. Therefore, predation does not affect prey-population size, but it keeps the population vigorous by removing substandard animals. On the other hand, some recent research suggests that growth rates of prey populations, especially those at low densities, may be limited by predation. In this case, predation is additive because it is in addition to, rather than a substitution for, another form of mortality.

Determining the effect of predators on ungulate populations is difficult because it is a moving target. Predator-prey interactions occur within a matrix of prey species, and several species of predator are distributed across a diverse landscape with changing habitats. Furthermore, the biology of each species is unique and segments (e.g., neonates, juveniles) of populations respond uniquely to the biological setting (Coulson et al. 1997, 1999). In addition, each segment of a population plays a different role in shaping the dynamics of a particular population (Gaillard et al. 1998, 2000).

Evaluating the vital rates (e.g., birth rate, survival rates) of ungulate populations is the best way to assess the effect of predation on an ungulate population. Populations are most sensitive to changes in adult-female survival, followed by reproductive rates of prime-aged adults, age at first reproduction and juvenile survival (Gaillard et al. 1998, Eberhardt 2002).

Cows

We found that adult-female survival was consistently high through time and across the state, and most populations are at or near management objective (Compton 1999). These study areas also support viable populations of black bears, cougars and wolves. Legal harvest and predation were the primary proximate mortality factors. Harvest, assumed to represent additive mortality, was used to reduce cow survival and to maintain those populations within objectives.

Exceptions to this were the Lochsa, GMUs 43 and 44, and the GMU 60A study areas, where survival was less than 80 percent. The elk population in GMUs

43 and 44 is compromised by the presence of permanent winter feeding stations where elk concentrate, presumably making them more vulnerable to predation. The feeding stations were originally established to alleviate excessive winter loss. It is unclear whether they met that objective. Whether survival would improve in the absence of such elk concentrations is also unknown.

The Lochsa elk population decline began in the mid-1980s. Though data establishing cause and effect are not available, this long-term decline may be a result of interactions among factors, including poor or declining habitat; poor or declining calf survival and recruitment; poor adult female body condition; increasing black bear, cougar and wolf populations; and significant mortality associated with the 1996-97 winter. It is not likely that the declining Lochsa elk population is solely a result of predation

The sum of the evidence suggests that inverse density dependence may operate on the Lochsa study area, wherein the elk population has declined to a low level (due to a variety of factors), and predation is maintaining the population at that level. If this is the case, Gasaway (1992) suggested that a regulated predator control may release the ungulate population, and a new predator-prey equilibrium could establish at a higher prey density. The Lochsa study area would provide an interesting test of this hypothesis.

Calves

Our data illustrate the variability in neonatal calf survival across four contrasting study areas. Summer survival was low where the overall population was performing poorly (Lochsa study area). Whereas it was at least 50 percent where populations were stable-to-increasing.

Predation was the primary proximate mortality factor in each area. Bears were important factors in June but not thereafter. Additional data may be required to clarify the relative roles of black bears, cougars and wolves in these areas.

As predicted, summer calf survival increased when bear and cougar populations were reduced on the Lochsa study area and declined when those populations were allowed to increase on the GMU 15 experimental areas. This suggests that calf mortality due to predation was largely additive on these study areas during this investigation. Taken out of context, this implies that predator control is warranted. Though poor calf survival contributes to the Lochsa population decline, addressing adult-female survival should be the first priority (Gaillard et al. 1998, Eberhardt 2002).

Furthermore, advocating predator control is risky. It may be effective over the short term if the ungulate population is below carrying capacity, if predation is additive and if the predator population can be reduced significantly. Generally, increased harvest of predators by sportsmen and sportswomen is not an effective tool for increasing ungulate populations because those efforts are typically spatially and temporally restricted (Stewart et al. 1985). Thus, agency intervention or extreme measures are necessary to reduce predator populations significantly (e.g., Ballard 1991, Boertje et al. 1991, Zager and White 2003). The effectiveness of such measures is temporary and can be costly.

The Future

With the reintroduction of wolves in 1995 to 1996, the predator-prey dynamic in Idaho is in transition, and it may be decades before an equilibrium is achieved (Coulson et al. 2004; White and Garrott 2005a, 2005b). It is unlikely that the data we presented represent that equilibrium because they are limited spatially and temporally. The data should be viewed within the context of larger scale and longer term ecosystem dynamics. Defining and identifying the equilibrium will require long-term research and monitoring of the predator and prey populations, of their habitats and of relevant human influences. For instance, we found little evidence of predation on adult-bull elk in hunted populations. However, these data were collected before wolves were an important component of the community. We expect this dynamic will change because wolves select adult bulls in proportion to their availability in the Greater Yellowstone Ecosystem (Smith 2005).

Furthermore, ecosystems are dynamic, and habitats change as part of the natural process. The dynamics of predator and prey populations undoubtedly change concurrently (e.g. Schwartz and Franzmann 1991), even without human intervention. This argues for using the historical range of variability (Morgan et al. 1994) within an ecosystem as a starting point for conservation and management activities. Such an approach will provide a more reasonable framework for decision making and for temper expectations.

Research Needs

Important questions need to be answered before we can fully understand the effect of predation on ungulates. The first step is to clearly differentiate between the fact of predation and the effect of predation. Further, if we are to advance our understanding, research should focus on pertinent concepts such as ultimate versus proximate factors, compensatory versus additive mortality, density dependence versus density independence versus inverse density dependence, and predation rates.

Significant recent research in Alaska (e.g., Gasaway et al. 1992, Keech et al. 2000, Bertram and Vivion 2002) has provided important insights and offers a sound basis for developing hypotheses and appropriate experimental designs. Additional work in other ecosystems will also provide important insights.

This research will be difficult because understanding predation is expensive and time consuming. Furthermore, some fundamental management and research tools are missing. It is difficult to estimate ungulate population size and even more difficult to estimate predator numbers. Population estimates form the backbone of population dynamics research. Inaccurate or imprecise population estimates hamper interpretation of the data and may lead to incorrect conclusions.

The universal nature of the questions, the difficult logistics, and expense of such investigations argue for an adaptive management approach (Walters 1986) and collaboration across jurisdictions. This approach can be used to test hypotheses and experimentally investigate important questions and, if conducted thoughtfully and properly, will bridge the gap between research and management.

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Cause-specific Mortality of Rocky Mountain Elk Calves in Westcentral Montana

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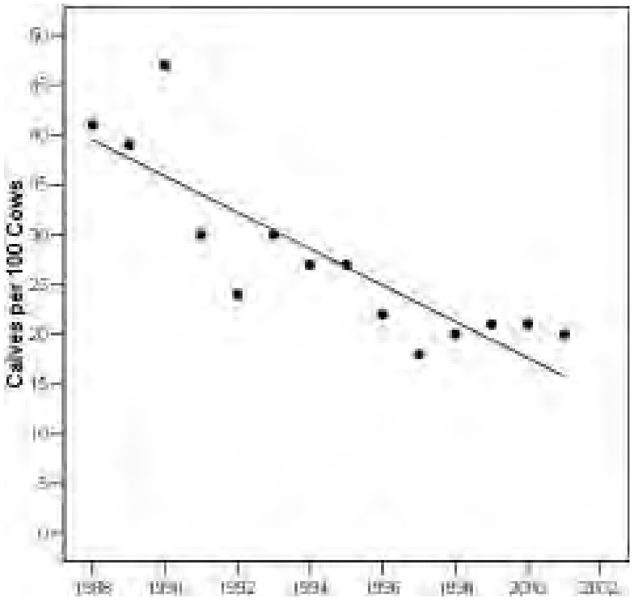
Introduction

Managers are faced with the daunting task of successfully monitoring populations and of assuring the persistence of elk (*Cervus elaphus*) and of other ungulate species. Elk provide both economic and aesthetic value despite being abundant and widespread. In 2002, elk hunting expenditures from nonresidents and residents in Montana generated more than $67.7 million for the state (Hamlin 2004). Currently, statewide elk population estimates are 130,000 to 160,000, compared to the estimated 55,000 in 1978 (Hamlin 2004).

Often, agencies conduct aerial surveys to monitor ungulate populations and to document changes in population size or recruitment rates (Rabe et al. 2002). Recruitment is the addition of calves into the adult age classes and is generally indexed by the ratio of calves per 100 cows or the proportion of cows with calves at the heel (Houston 1982). Recruitment rates in Rocky Mountain elk (*C. e. nelsoni*) appear to be declining in Montana and in neighboring states. In Montana's Hunting District (HD) 292, the ratio of calves per 100 cows apparently declined from 41 in 1988 to 20 in 2001 (Hamlin 2004, Figure 1). Declining calf to cow ratios in elk have also been documented in the Glacier National Park area (Kunkel and Pletscher 1999), Gravelly Mountains in Montana (Hamlin and Ross 2002), Lochsa and South Fork Clearwater areas of Idaho (Zager 2001), and statewide in Colorado (White et al. 2001). This decline in

Figure 1. Calf to cow ratios in Rocky Mountain elk obtained from 1988 to 2001 annual spring green-up aerial surveys in westcentral Montana study area (Hamlin 2004).



recruitment is of great concern to wildlife managers because recruitment replaces the loss of adults from predators, harvest and other factors (Gratson and Zager 1999, 2000) and may lead to decreases in population size.

Managers and some segments of the public are concerned that predators are limiting the recruitment of young in many ungulate populations. Substantial predation rates upon neonate ungulates have been documented in some areas for elk (Smith and Anderson 1996, Singer et al. 1997), mule deer (*Odocoileus hemionus*, Bishop et al. 2005), white-tailed deer (*O. virginianus*, Whittaker and Lindzey 1999), caribou (*Rangifer tarandus*, Valkenburg et al. 2004) and moose (*Alces alces*, Keech et al. 2000). Our objectives were to estimate survival and to document the causes of mortality in elk calves in Montana's HD 292 in westcentral Montana. We chose this study area because of the declining trends in the ratio of calves per 100 cows observed during aerial surveys. In addition, Montana Department of Fish, Wildlife and Parks (MTFWP) biologists were simultaneously monitoring and estimating densities of the top predator in this study area, the mountain lion (*Puma concolor*). Other large predators in our study area include grizzly bears (*Ursus arctos horribilis*), black bears (*U. americanus*) and coyotes (*Canis latrans*).

Methods

We captured and equipped elk calves with radio collars or ear transmitters shortly after birth during late May to early June to estimate survival and cause-specific mortality rates. We monitored calves one to three times daily after instrumentation until September 1, from 2002 to 2006, to estimate summer survival. We also obtained an annual survival estimate in 2005 by monitoring calves through their first year. We estimated survival from the marked samples as the number of individuals that died divided by the total number of uncensored individuals. We censored calves when transmitters failed or could not be found, and when tracking devices dropped off calves prematurely.

We located transmitters usually within 12 hours of detecting mortality signals, and we examined the site for remains to determine cause of death. We concluded malnutrition as the cause of death when we observed empty or nearly empty stomachs, red and gelatinous femur marrow, absent kidney fat, low weight gain or weight loss, and no abnormalities (e.g. lesions) associated with disease were present. We concluded predation as the cause of death when hemorrhaging was present and calves did not exhibit signs of malnutrition or disease. Identification of predator species followed O'Gara (1978) using consumption patterns, canine punctures, tracks, scat and hair. We also sent complete carcasses with no sign of hemorrhaging to the MTFWP Research Lab (Bozeman, Montana) to search for signs of malnutrition and disease. We calculated chi-squared statistics and used Fisher's exact test to test for differences in the sources of mortality across years.

Results and Discussion

Survival Estimates

We captured 221 elk calves from May 25 to June 8 between 2002 and 2006 (Table 1). Summer survival estimates ranged from 0.29 to 0.89, with an average rate of 0.74 (standard error = 0.11) across the study period. The annual survival estimate was 0.61 for 2005, compared to the summer survival estimate of 0.79 for marked calves. We censored an additional 11 calves and documented 4 additional mortalities after the 2005 summer period.

Table 1. Fate of calf elk radio marked as neonates during summer (May 25 to August 31) by year on the Garnet Mountains study area, westcentral Montana, 2002 to 2006. Proportions of total mortality for that year are presented in parentheses.

Fate	2002	2003	2004	2005	2006	Total
Mortality	15	3	7	10	6	41
Predation	10 (0.67)	3 (1.00)	4 (0.57)	5 (0.50)	5 (0.83)	27 (0.66)
Bear	6	2	2	1	0	11
Cougar	2	0	1	3	1	7
Coyote	1	0	0	0	1	2
Unknown	1	1	1	1	3	7
Malnutrition	2 (0.13)	0	2 (0.29)	2 (0.20)	1 (0.17)	7 (0.17)
Abandonment	2 (0.13)	0	0	0	0	2 (0.05)
Disease	1 (0.07)	0	1(0.14)	0	0	2 (0.05)
Other[a]	0	0	0	2 (0.20)	0	2 (0.05)
Unknown	0	0	0	1 (0.10)	0	1 (0.02)
Survived	6	25	42	37	41	151
Censored	6	14	3	2	4	29
Total sample	27	42	52	49	51	221

[a] Other mortalities included one drowning and one fence entanglement

Cause-Specific Mortality Rates

Forty-one of the 192 calves (21 percent) retaining their radio transmitters died during their first 13 weeks (Table 1). Predation was the greatest source of mortality, accounting for 27 (66 percent) of all known mortalities. Bear predation was the only source of mortality that differed across years (÷2 = 24.80, df = 4, P < 0.001,), occurring more often in 2002 than in all other years. In addition, bear predation (27 percent of all mortalities) was the greatest single source of mortality in elk calves across years. Mortality varied temporally throughout the summer with 76 percent of all mortalities occurring during the neonatal period from capture to 6 weeks postcapture (Figure 2). Most bear predation (91 percent) and malnutrition (86 percent) mortalities occurred early in the summer during the neonatal period, while the first lion mortality occurred 5 weeks after capture.

Marked calves also died from malnutrition (17 percent), abandonment (5 percent) and disease (5 percent) in addition to predation. Calves died from malnutrition (n = 7, where n represents the sample size) in every year of the study except in 2003. The only cases of capture-related abandonment occurred in 2002, when 2 intact calves were recovered 4 and 5 days postcapture and had lost 3.9 and 7.9 pounds (1.8 and 3.6 kg), respectively. Two marked calves also died from disease (pneumonia) during our study. One calf died from *Escherichia coli* and

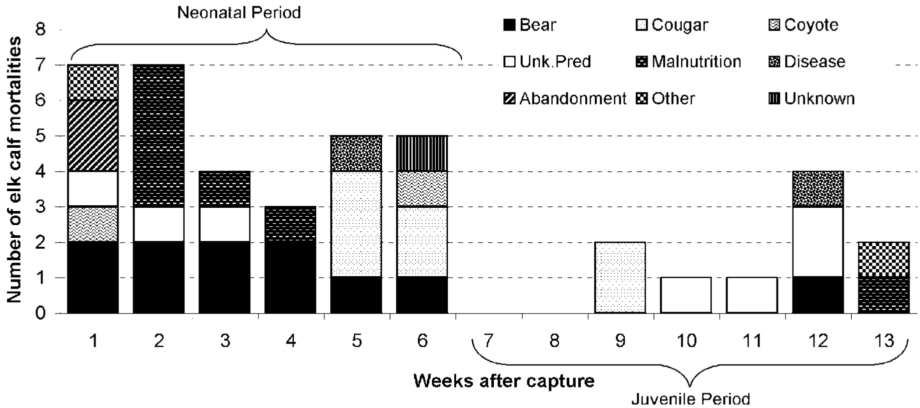


Figure 2. Temporal component of cause-specific mortality (n = 41) of calf elk radio marked as neonates within 13 weeks of capture on the Garnet Mountains study area, westcentral Montana, 2002 to 2006.

Streptococcus (spp.) that infected the lung tissue 5 weeks postcapture in 2002. Similarly, *Streptococcus* (spp.) and *Arcanobacterium pyogenes* infected the lung tissue of the other calf that died 12 weeks postcapture in 2004.

Comparison to Other Cause-specific Mortality Studies on Neonatal Ungulates

The percentage of summer mortality attributed to predation (66 percent) in our study was remarkably similar to rates reported in other elk calf mortality studies (68 percent, Smith and Anderson 1996; 72 percent, Singer et al. 1997; 95 percent, Barber-Meyer et al. 2008). However, the overall summer predation rates (calves killed per total uncensored calves) across elk calf mortality studies were lower in our study (14 percent) than in studies conducted in Yellowstone National Park (YNP) prior to wolf (*Canis lupus*) reintroduction (22 percent, Singer et al. 1997), a more recent YNP postwolf reintroduction study (67 percent, Barber-Meyer et al. 2008) and in Idaho (29 percent, Zager et al. 2002). Bear predation was the primary source of mortality in elk calves across all studies but was much lower (27 percent of all mortalities) in our study, compared to rates reported by Smith and Anderson (50 percent, 1996), Singer et al. (52 percent, 1997) and Barber-Meyer et al. (63 percent). In contrast, summer mortalities attributed to mountain lion predation was higher in our study (17 percent of all mortalities) than in Wyoming (0 percent, Smith and Anderson 1996), YNP prewolf (0 percent, Singer et al. 1997), and YNP postwolf (3 percent, Barber-Meyer et al. 2008).

The level of summer malnutrition (17 percent of all mortalities) in our study was higher than previous mortality studies on neonatal ungulates. Summer malnutrition rates in elk calves ranged from 0-9 percent (Smith and Anderson 1996, Singer et al. 1997, Barber-Meyer et al. 2008). However, Pojar and Bowden (2004) assessed the nutritional condition of mule deer fawns based on thymus gland condition and on weight. They reported that 38 percent of known mortalities died from sickness or starvation from capture to mid-December. We believe cause-specific mortality studies often underestimate neonatal loss due to malnutrition because it is difficult to assess, is generally not assessed when a predator sign is present, is generally assessed only with intact carcasses or is evaluated only during winter months. For example, winter malnutrition was primarily identified by intact carcasses and evaluated from femur marrow fat measurements in mule deer fawns (Bishop et al. 2005). Underestimation of malnutrition may lead to overestimation of mortality caused by predators. We relied on degree of weight loss, absence of milk curds or vegetation in stomach, color and texture of femur marrow, and kidney fat to assess malnutrition. We assessed the nutritional condition of carcasses even when predator signs were present (whenever possible), which resulted in the nutritional condition assessed in 60 percent of the calves killed by predators. For example, one carcass in 2005 had obvious cougar-predation signs (heart and liver partially consumed, spherical entrance wound, tufts of hairs removed, and broken ribs), but the femur marrow was dark red and gelatinous and the rumen was filled with dirt. Therefore, we concluded that malnutrition was the ultimate cause of death.

Conclusions

Many studies have emphasized the high contribution of predators to mortality in neonatal ungulates. In such cases, managers could manipulate the densities and assemblages of predators to change survival of young. Though predation was the primary source of mortality in calves, we believe that predators are not limiting recruitment in the elk population in our study because summer survival estimates were consistently high. However, relating predation to ungulate recruitment and population growth depends on how much of this mortality is additive versus compensatory. We documented relatively high summer malnutrition rates (at least 17 percent of all mortalities) in our study and suggest that some predation is compensatory. In cause-specific mortality studies, it is necessary to investigate mortalities promptly and to assess the nutritional condition of individuals killed. Despite its difficulty with partially consumed carcasses, it is essential to determine whether poor nutrition predisposed young to predation. Otherwise, predation rates reported may be biased high and factors affecting habitat quality and forage availability may be overlooked.

The elk population in our study area is probably more representative of areas across the western United States than to studies conducted on refuges and national parks where hunting is limited or when elk are fed. We also chose a study area that represents conditions where there are currently no wolf packs. However, the presence of wolf-predation signs has continued to increase throughout the study area. We have received several reports of wolf sightings and we have documented a spike elk killed by a wolf (or by wolves) in the study area in 2006. Therefore, our study will serve as a reference to assess the impact of wolves on elk calf survival and recruitment, should they recolonize and establish viable packs.

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Predator-Prey Management in the National Park Context: Lessons from a Transboundary Wolf, Elk, Moose and Caribou System

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Introduction

Wolves (*Canis lupus*) are recolonizing much of their former range within the lower 48 states through active recovery (Bangs and Fritts 1996) and natural dispersal (Boyd and Pletscher 1999). Wolf recovery is being touted as one of the great conservation successes of the 20th century (Mech 1995; Smith et al. 2003). In addition to being an important single-species conservation success, wolf recovery may also be one of the most important ecological restoration actions ever taken because of the pervasive ecosystem impacts of wolves (Hebblewhite et al. 2005). Wolf predation is now being restored to ecosystems that have been without the presence of major predators for 70 years or more. Whole generations of wildlife managers and biologists have come up through the ranks, trained in an ungulate- management paradigm developed in the absence of the world's most successful predator of ungulates—the wolf. Many questions are now facing wildlife managers and scientists about the role of wolf recovery in an ecosystem-management context. The effects wolves will have on economically important ungulate populations is emerging as a central issue for wildlife managers. But, questions about the important ecosystem effects of wolves are also emerging as a flurry of new studies reveals the dramatic ecosystem impacts of wolves and their implications for the conservation of biodiversity (Smith et al. 2003; Fortin et al. 2005; Hebblewhite et al. 2005; Ripple and Beschta 2006; Hebblewhite and Smith 2007).

In this paper, I provide for wildlife managers and scientists in areas in the lower 48 states (where wolves are recolonizing) a window to their future by reviewing the effects of wolves on montane ecosystems in Banff National Park (BNP), Alberta. Wolves were exterminated in much of southern Alberta, similar to the lower 48 states, but they recovered through natural dispersal populations to the north in the early 1980s, between 10 and 20 years ahead of wolf recovery in the northwestern states (Gunson 1992; Paquet, et al. 1996). Through this review, I aim to answer the following questions: (1) what have the effects of wolves been on population dynamics of large-ungulate prey, including elk (*Cervus elaphus*), moose (*Alces alces*) and threatened woodland caribou (*Rangifer tarandus tarandus*), (2) what other ecosystem effects have wolves had on montane ecosytems, (3) how sensitive are wolf-prey systems to top-down and bottom-up management to achieve certain human objectives, and (4) how is this likely to be constrained in national park settings? Finally, I discuss the implications of this research in the context of ecosystem management and long-term ranges of variation in ungulate abundance.

Study Area

I only briefly review details of the BNP ecosystem and refer readers to more detailed accounts in (Holroyd and Van Tighem 1983; Holland and Coen 1983; Hebblewhite et al. 2005, 2006). BNP itself is 2,564.10 square miles (6,641 km^2) and is on the eastern slope of the continental divide in the Canadian Rocky Mountains (51° 15" latitude, 116° 30" longitude). The park has extreme, mountainous topography (1,531.06 to 3,718.29 yards [1,400–3,400 m]) and a climate characterized by long, cold winters and short, dry summers. Vegetation is described in detail by Holland and Coen (1983). Importantly, BNP has conducted an aggressive prescribed-fire restoration policy since the 1980s, burning approximately 77.22 square miles (200 km^2) of predominantly forest communities (White et al. 2003), with expected benefits for ungulate foraging habitat (Sachro et al. 2005). Seven species of large ungulates exist in BNP; in approximate order of abundance they are: elk, bighorn sheep (*Ovis canadensis*), mule deer (*Odocoileus hemionus*), white-tailed deer (*O. virginanus*), moose, mountain goat (*Oreamnos americanus*) and a small, threatened population of woodland caribou. Elk were the most abundant ungulate in BNP, comprising 40 to 70 percent of the diet of wolves (Hebblewhite et al. 2004), and are partially migratory in BNP; some elk migrate and others are resident year round. Other predators included cougars (*Felis concolour*), coyotes (*Canis latrans*), grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*). However, wolves were the only species to recover from extirpation (Paquet et al. 1996).

I examine effects of wolves in two study areas in and adjacent to BNP: the Bow Valley of BNP, which lies almost completely within the protected areas of the national park, and the Ya Ha Tinda (YHT) area, which is a transboundary system spanning the national park's boundaries into adjacent provincial lands. The Bow Valley study area comprises the best winter range habitat for elk inside BNP, with low elevation valley bottoms between 1.24 to 3.11 miles (2–5 km) in width and 1,476.38 to 1,749.78 yards (1,350–1,600 m) elevation. The Bow Valley system has pervasive human impacts with the national railway and highway system, secondary roads, and human developments (ski resorts, golf courses) fragmenting the valley bottom. Wolves avoided human developments in the Bow Valley (Paquet et al. 1996). This led to very low wolf use in a large area surrounding the townsite of Banff, and high wolf use in the remaining area, providing a serendipitous experimental comparison of elk with and without wolf predation.

The YHT winter range lies outside of BNP and is considered much higher quality winter range for elk that migrate seasonally from summer ranges inside BNP. YHT means "mountain prairie" in the Stoney-Sioux language, aptly describing the azonal, high elevation, 7.72 square mile (20 km^2) montane, rough, fescue grasslands along the north side of the Red Deer River. The YHT area represents one of the most pristine and largest rough fescue montane grasslands left in Alberta (Willoughby 2001), and has much lower levels of human use. Summer ranges of the Bow Valley and YHT elk populations have minimal overlap (Hebblewhite 2006). Migrant elk in the YHT population have been declining; in 2006, I used a comparative research design to compare migrant and resident elk to determine the causes of migratory changes.

Effects of Wolves on Ungulates

Elk

In the Bow Valley, Hebblewhite et al. (2005) compared adult female elk survival and recruitment between the low and high wolf areas during 1997 to 2000. Differences in wolf-caused mortality were tested using chi-square tests. In the high wolf zone, adult survival equaled 0.62 ± 0.06; n equaled 22, where n represents the number of adult female elk. And, calf recruitment equaled 14.6 ± 1.97 percent. The combination of this survival and recruitment led to rapid population decline (Hebblewhite et al. 2005). But, in the low-wolf area, survival equaled 0.89 ± 0.06; n equaled 23. And, recruitment equaled 27.4 ± 1.58 percent, which both are high and the same as before wolf recolonization; it led to a stable or increasing population (Woods 1991; Hebblewhite and Smith 2007). The main survival difference was wolf mortality increasing from about 16 percent to 56 percent; Hebblewhite and Smith 2007) between the low and high wolf area, which was consistent with an increase in wolf-kill rate of elk in the high-wolf area (Hebblewhite et al. 2004). These strong differences in mortality and demography led to elk densities in the high-wolf zone that were 10 percent of prewolf density (Hebblewhite et al. in press). The mechanism for elk declines was because kill-rates increased with winter climatic severity. Whereas, in the low-wolf areas, elk were regulated by their own density presumably through resource limitation (Hebblewhite 2005). Wolf recolonization was correlated with a decline in the ratio of migrant to resident elk in the population from about 0.75 before wolves to 0.15 following wolf recolonization (Woods 1991; McKenzie 2001). The exact mechanisms causing migratory changes were unknown in the Bow Valley but were the focus of research in the YHT area.

In the YHT study area, Hebblewhite et al. (2006) showed that the migratory behavior of elk changed since the 1970s in three ways. First, both the proportion and number of elk migrating into BNP declined. The ratio of migratory to resident elk declined from 13:1, in 1980, to 2.5:1, in 2004; the numbers of migrants declined from 980, in 1984, to 580, in 2004. Second, the spatial distribution of elk shifted to the winter range year round. Third, the duration of migration declined because fall migration occurred almost a month earlier. Of eight broad hypotheses proposed to explain these migratory changes, winter range enhancements, access to hay fed to wintering horses, recolonization by gray wolves and management relocations of elk were closely associated with observed elk population dynamics and migratory decline (Hebblewhite et al. 2006). Importantly, prescribed fires, competition with horses for winter forage, and human harvest were unrelated to changes in the ratios of migratory to resident elk.

To examine causes of migratory changes, Hebblewhite (2006) examined the forage and predation risk mechanisms generating these differences between migrant and resident elk between 2001 and 2005, 20 years after wolf recolonization. Migrants exploited phenological gradients by selecting intermediate forage biomass to maximize exposure to high forage quality (Fryxell et al. 1988). This resulted in a 6-percent higher average digestibility of forage for migrants, which translated to higher fecal diet quality, pregnancy rates and calf weights (Hebblewhite et al., in press). Based on elk nutrition studies (Cook et al. 2004), these differences would be expected to result in higher migrant survival rates and population growth rates from just a bottom-up perspective. However, because wolves were avoiding human activities near the winter range (Hebblewhite and Merrill 2007), residents successfully reduced fine-scale risk to only 15 percent higher than migrants. And, by living in larger group sizes during summer, resident elk were able to reduce relative predation risk by 20 percent (Hebblewhite 2006). Thus, migrant elk failed to realize any predation risk reduction benefits of migrating. In fact, we found that risk of mortality was highest during actual spring and fall migrations when elk had to move through low elevation areas close to wolf dens (Hebblewhite and Merrill 2007).

These differences in resource selection translated to similar demographic differences. Despite the benefits from migration from a forage perspective, migratory elk populations were declining due to predation by wolves and grizzly bears, which were responsible for 47 percent and 29 percent of all migrant mortality, respectively. In comparison, resident elk died more from human hunting (35%) than from wolf predation (30%) and experienced almost no grizzly bear predation (Hebblewhite 2006). Treaty hunting by First Nations peoples is 60 percent of all mortality. These mortality differences translated to slight survival differences between strategies. Residents had higher adult (0.87 ± 0.032, $n = 53$) and calf (0.19 ± 0.067, $n = 46$) survival than migrant adults (0.84 ± 0.035, $n = 68$) and calves (0.16 ± 0.08, $n = 33$) (Hebblewhite 2006). When combined in Leslie-matrix population models, these low survival rates resulted in a stable or slightly declining resident elk herd, but a migrant segment was declining rapidly at about 12 percent per year. The ratio of migrant and resident population growth rates matched long-term trends in the decline in this system as determined from population surveys (Hebblewhite et al. 2006). Therefore, given the low survival caused by high wolf and grizzly bear predation, it is difficult to envision high elk densities as a long-term ecosystem state.

Moose

Hurd (1999) undertook a 4-year study (1993–1997) in BNP of competition between moose and elk to understand causes for moose declines following wolf recolonization. Hurd examined both exploitative competition for forage and apparent competition mediated by predation by wolves. The study revealed, at fine-spatial scales, that elk were exploitatively outcompeting moose because of their greater diet breadth and higher abundance. Yet, at large spatial scales, apparent competition mediated by wolves seemed the most compelling reason for moose declines. Wolves were the leading cause of moose mortality, causing 56 percent. Adult moose (male and female were the same) survival rates were very low (0.71 ± 0.03, $n = 45$) and were combined with low calf recruitment (23 ± 7.5 percent, most likely a result of predation but unknown). Moose populations were declining at about 8 percent per year because of wolf predation. Moose and elk in the high-wolf area had similar demography evidencing the strong top-down effect of wolf predation. In summary, Hurd found apparent competition mediated by wolves was occurring in combination with exploitative competition in a negatively additive fashion, which caused moose population declines.

Caribou

A similar example of conservation concern is apparent competition between elk and threatened woodland caribou, which have declined during wolf recolonization (Hebblewhite et al. 2007b) in the Canadian Rocky Mountains. Elk and caribou diets differ enough to make exploitative competition an unlikely explanation for caribou declines. Instead, similar to moose, the likely mechanism for caribou declines is competition between elk and caribou mediated by wolf predation, and this hypothesis was supported by modeling work by Hebblewhite et al. (2007b) and Lessard (2005). Because of the strong numeric response of wolves to elk density, even at low caribou densities and even with extremely low wolf-kill rates of caribou, wolves would continue to kill caribou in an inversely density-dependent fashion (Messier 1995, Hebblewhite et al. 2007b). Consequences of this for national park management in the Parks Canada system are dramatic; with current densities of wolves and elk in BNP, the Banff caribou subpopulation will almost certainly become extirpated. Even in Jasper, Wyoming, where caribou densities are higher, high elk densities could lead to enough wolf predation to cause caribou declines. The main management recommendations of Alberta's and British Columbia's woodland caribou recovery plans and modeling studies are to reduce high, primary, prey densities, followed, if necessary, by wolf population reductions (Alberta Woodland Caribou Recovery Team 2005). Within the national park context, caribou viability may well depend on low density elk populations (Hebblewhite et al. 2007b).

Ecosystem Effects of Wolves

The effects of wolves on ecosystems will manifest in terrestrial ecosystems through direct and indirect effects. Direct effects include predation, competition between wolves and other carnivores, and trophic cascades caused by wolf predation. Indirect effects occur when the effects of wolves are mediated by intermediate species, such as apparent competition between elk and caribou mediated by wolf predation, but they can also include behaviorally mediated effects. Hebblewhite and Smith (2007) provide a comprehensive review of the ecosystem effects of wolves, as do other authors (Smith et al. 2003, Berger and Smith 2005), and here we briefly summarize recent studies in BNP.

The strong top-down effects of wolves on elk density was felt on lower trophic levels including the important forage plant species of willow (*Salix* spp.) and aspen (*Populus tremuloides*). In low-wolf areas, willow and aspen regeneration was essentially zero. Whereas, in high-wolf areas, willow productivity was seven times higher, and aspen sapling densities were significantly higher than in low-wolf areas (Hebblewhite et al. 2005, Hebblewhite and Smith 2007). These differences translated down trophic levels to result in double the riparian songbird abundance and diversity in areas with high wolf predation (Hebblewhite et al. 2005), similar to studies in the Greater Yellowstone Ecosystem (Berger et al. 2001). This link between wolves and willow extended to perhaps the ultimate keystone species, beavers (*Castor canadensis*), because, as elk densties declined with wolf recolonization, the number of active beaver lodges in the Bow Valley of BNP increased (Hebblewhite et al. 2005). Wolves also outcompeted cougars through exploitative competition for ungulate prey (elk) and intraspecific mortality (Kortello et al. 2007). Wolves also successfully stole 57 percent of kills from adult grizzly bears (Hebblewhite and Smith 2007). But perhaps the most pervasive ecosystem effects of wolves will be felt through the scavenger community. In BNP, we detected a minimum of 20 species of vertebrates scavenging on wolf-killed prey, including ravens (*Corvus corax*), coyotes, wolverines (*Gulo gulo*), marten (*Martes americana*), golden eagles (*Aquila chrysaetos*) and grizzly bears. In Yellowstone National Park (Yellowstone), wolves provided a supply of carrion in a much more consistent and spatially dispersed fashion when compared to carrion produced by human hunters (Wilmers et al. 2003). Field studies confirmed the importance of scavenging to literally hundreds of species in Yellowstone. Sikes (1994) documented 445 species of beetles using wolf-killed carcasses during just 2 field seasons. Clearly, the ecosystem effects of wolves will be broad and, likely, beneficial for the conservation of biodiversity.

Evaluating Potential Management Scenarios

Given the strong effects of wolves on ungulates and other important ecosystem components, a natural question for achieving other management objectives will be how sensitive are wolf-prey systems to manipulation. For example, managers may want to maintain levels of ungulate harvest management from before wolf recolonization in the postwolf era. I now review the relative sensitivity of ungulate populations to bottom-up changes in forage and top-down control of wolves in BNP. Based on experiences in BNP, I show that wildlife managers face tough choices ahead and must come to terms with the truth that maintaining prewolf ungulate harvest regimes may be a fantasy in postwolf landscapes and, moreover, may be incompatible with ecosystem management.

Relative Sensitivity to Management Changes in Forage

There was essentially no evidence that the extensive prescribed fires (more than 77.22 square miles [200 km^2] of burns) actually translated to increased elk populations in BNP. This was despite the higher forage biomass in burns (Sachro et al. 2005) and the higher forage quality for migrants in general (Hebblewhite et al. in press); migrants still declined due to wolf and grizzly predation. Furthermore, time-series modeling in both the Bow Valley and YHT area suggested that burning in areas with high-wolf density can actually reduce elk population growth rates (White et al. 2005, Hebblewhite et al. 2006). Although speculative, these studies suggest a bottom-up effect of fire on wolf numbers instead of elk mediated by rapid numeric responses of wolves. In essence, any increased elk productivity from fires translated to increased wolf productivity through a rapid numeric response. One caveat is that prescribed fires had high overlap with areas of high predation risk, which may have attracted elk to low-elevation fires where they were killed by wolves. This suggests that prescribed burns in low wolf-predation risk areas might maximize benefits to migratory elk. The success of this hypothesis will depend, however, on the strength of the wolf numeric response to increases in elk (Messier 1994). Because migration decouples predator numeric responses (Fryxell et al. 1988), burning in low-predation-risk areas inhabited seasonally by elk would be expected to generate the largest increases in elk following fires. Within an ecosystem management context, this management prescription to burn low-predation-risk areas is likely incompatible with long-term ranges of variation in forest-fire frequency. This is because both wolf-predation risk and fire frequency will decline at high elevations in most montane systems (White et al. 2003, Hebblewhite and Merrill 2007), and the approach of burning low-predation-risk habitat to maximize benefits to migratory elk would require burning habitats that burn only infrequently. Thus, the best management recommendation to increase elk in this transboundary system is counter to the principles of ecosystem management that are based on long-term range of variation in montane fire frequencies, and it provides indirect evidence that the stable state for montane systems was low elk densities.

In contrast, nonmigratory, resident elk may be more sensitive to changes in forage biomass for two reasons. First, winter range enhancements outside parks increased resident elk numbers (Hebblewhite et al. 2006). Second, because human use of areas outside parks was higher and because wolf harvest in Canada is quite liberal, wolf avoidance of resident winter ranges (whether because wolves avoided them or were shot) allowed residents to benefit from habitat enhancements (Hebblewhite et al. 2006, Hebblewhite and Merrill 2007). Management implications of the increased sensitivity of resident elk to forage are clear. Any further enhancements to forage within elk ranges that are outside the parks but still are inside areas of high human activity will further contribute to migratory changes. This situation seems to be occurring near the townsites of Gardiner, in Montana, and Estes Park, in Colorado, both areas of high human activity.

Relative Sensitivity of and Management Constraints to Changing Wolf Predation

The typical conclusion of previous studies where wolves limited prey densities to low numbers was usually a recommendation to reduce predation via large-scale wolf control (Hayes et al. 2003). While there is some controversy over the success of wolf controls (Orians et al. 1997), there is some experimental evidence that wolf control—when applied consistently to reduce wolf populations by greater than 80 percent over huge areas (more than 3,861.02 square miles [10,000 km^2]) for long terms (5-years) at great financial costs can be partially successful at enhancing ungulate populations (Boertje et al. 1996; Bergerud and

Elliot 1998; Hayes et al. 2003; Valkenburg et al. 2004) for short periods of time. I feel compelled to reiterate, however, that the main conclusions of the authors of perhaps, to date, the best executed wolf-control study in the Yukon (Hayes et al. 2003) pointed out the seeming futility of their wolf-control program as a long-term solution to ungulate population declines. Within 2 years of the end of wolf control, wolf densities and ungulate vital rates returned to precontrol levels. To be successful, wolf control needs to be conducted for long periods of time with greater than 70 percent of the wolf population removed from huge areas (Hayes et al. 2003). While future harvest plans for wolves once delisting occurs will undoubtedly include some wolf harvest, it remains difficult to conceive of states being able to conduct wolf control at the spatial and temporal scales required to even obtain short-term increases in ungulate populations.

Within transboundary park systems, the spatial structure of land management will make the necessarily large-scale and sustained wolf-control measures very unlikely. For example, migrant elk, which suffer the highest mortality from wolves and grizzly bears, migrate into BNP, where wolves and grizzly bears are protected from hunting. Similar transboundary migrations often occur in U.S. national parks (e.g., Yellowstone). There is no precedent within the Canadian National Parks Act or the U.S. National Parks Act to permit wolf control within park boundaries. Moreover, in the successful Yukon wolf controls cited above (Hayes et al. 2003), Parks Canada and the Yukon Territorial Government came to an agreement to not kill any wolves within a set buffer of Kluane National Park because of the controversies surrounding wolf control in the public arena (Parks Canada 1995). Given that the viability of both wolves and grizzly bear populations has become a regional concern (Herrero et al. 2000, Callaghan 2002) in many montane systems, such as the Canadian Rocky Mountains, it seems very unlikely that large-scale wolf controls in or even adjacent to BNP would be implemented.

A second option of reducing wolves only outside of national parks (notwithstanding buffer management, such as in the Yukon) may only exacerbate the problem of growing resident elk outside parks because: (1) mortality of both migrants and residents was lowest during winter when migrant elk would benefit from any provincial wolf reductions, thus benefits of provincial wolf control would accrue more to residents, and (2) resident elk already have slightly lower wolf mortality than migrants which contributed to their increase. Therefore, despite the potential for elk populations to change in response to changes in wolf predation, the jurisdictional structure of transboundary park systems makes it unlikely that wolf control would result in increased densities of migratory elk and could potentially contribute to migratory declines.

Implications for Transboundary Management in the National Park Context

Long-term Stable States for Elk Population Dynamics and Management

Given the high mortality rates, elk density and the proportion of migratory elk will likely decline following wolf recolonization in transboundary systems. Reviews of the wolf-bear-moose literature support the interpretation that bear and wolf predation will regulate elk to a low- density equilibrium (Messier 1994; Orians et al. 1997; Testa 2004). This suggests that the long-term stable state under wolf recovery will be low migrant elk density in western montane ecosystems. Indeed, wolf predation was required to achieve aspen regeneration, riparian willow regeneration, and an associated doubling of riparian songbird diversity (Hebblewhite et al. 2005). The case of woodland caribou persistence in the Canadian Rocky Mountains suggests that low- density elk is a prerequisite for caribou persistence (Alberta Woodland Caribou Recovery Team 2005, Hebblewhite et al. 2007b). Evidence from alternate methods of scientific inquiry also supports this interpretation of the long-term state for low elk densities. Archaeological studies and historical accounts conclude the long-term range of variation for the Canadian Rocky Mountains may have been characterized by low elk density (White et al. 1998, Magne 1999). Early historical explorer accounts indicates that elk were observed with one third the frequency of bison, less than one fifth the frequency of bighorn sheep, and less than one half the frequency of moose and mountain goats (Kay et al. 2000), roughly opposite to present day densities. A large-scale experimental test of herbivore optimization with grassland dynamics indicates that many western rangeland systems may also be adapted to between low and moderate ungulate densities (Stewart et al. 2006). Similar findings have also been reported throughout many other western transboundary park ecosystems (Smith 2001, Hessl 2002, White et al. 2003). These convergent lines of inquiry across disciplines suggest that long-term ecosystem dynamics in the Canadian Rocky Mountains were characterized by low elk densities.

Wolves may, therefore, be a keystone species (Power et al. 1996) capable of moving terrestrial ecosystems between two stable states, as predicted by theory and data (Messier 1994) for moose-wolf-bear systems. Like other keystone species, such as sea otters (*Enhydra lutris*), that prey on sea urchins (Estes and Duggins 1995), these effects manifested through large population declines in herbivores following wolf recolonization. Without wolves, ungulate densities increase, vegetation communities become overbrowsed, specialist herbivores (e.g., moose and beaver) decline through competitive exclusion by the generalist elk, and biodiversity is reduced (e.g., loss of riparian songbirds). As wolf populations recover, wolf numbers rapidly increase, causing alternate prey species (e.g., woodland caribou and moose) to decline through competition. But, declines in species (e.g., elk) bring about slow changes to the vegetation community that lead to enhanced aspen and willow regeneration and to increased biodiversity. In this context, wolf predation should be viewed as a critical component of an ecosystem management approach across jurisdictions.

A Proposed Approach to Reconcile Conflicting Paradigms

Within national parks, where management objectives are often ecosystem based, low- density elk populations may be consistent with long-term management objectives. However, in the managed lands surrounding national parks, management objectives include both consumptive and nonconsumptive wildlife use. In this context then, low-density population of elk may not meet historical agency management objectives. This contradiction will become a common management problem in ecosystems with recovering wolf populations.

First, it should be recognized that objectives that call for high densities of large ungulates for human consumption have little basis in the principles of ecosystem management for montane systems. The evidence presented here, along with growing body of literature (White et al. 1998, Magne 1999, Stewart et al. 2006) strongly suggests, especially with wolf predation, the long-term ecosystem state was characterized by low elk density. Thus, wolf recolonization provides an opportunity for agencies to implement for broader ecosystem management, such as managing for riparian biodiversity.

I recognize, however, that cultural and social systems are slow to change. Some areas outside national parks will still include management for high densities of large ungulates despite the conflict with an ecosystem management approach. In transboundary settings, the difficulty with these objectives will be in defining common management goals despite different management paradigms (Clark 1999, Pedynowski 2003). In the similarly complex transboundary Jackson Hole elk population, Clark et al. (2000) concluded exactly that the lack of an effective, common framework for problem definition and for management objectives had contributed to management conflicts. I believe jointly defining common management objectives for transboundary predator-prey systems will be a crucial step to build a consensus approach to managing these important areas. The lack of a common definition between management agencies itself may be the biggest obstacle to overcome (Clark et al. 2000, Clark 2001).

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Intensive Management of Wolves and Ungulates in Alaska

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Introduction

Across Alaska, all species of terrestrial wildlife and, in particular, big game currently occupy their historic range. Wolves (*Canis lupis*) and brown bears (*Ursus arctos*) are not, and have never been, listed under the Endangered Species Act. Wolves and brown bears are generally absent from the state's few urban areas, but both are often found within a few miles of downtown areas. Ungulates, including moose (*Alces alces*), caribou (*Rangifer tarandus*) and Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) occur across the state. Moose and caribou numbers are regulated by many factors, such as range health, habitat type, weather, disease, human harvest and predation. Wolves, brown bears, and black bears (*Ursus americanus*) have, within their respective ranges, significant impacts on ungulate populations in northern regions. Understanding these relationships has been the subject of various research efforts over the past few decades (e.g., Gasaway et al. 1983, Gasaway et al. 1992, Boertje et al. 1996, Hayes et al. 2003). Over the same period, there has also been constant, public debate across Alaska about how to manage prey and predators, particularly control of predators to increase ungulates for human harvest (e.g., National Research Council 1997, Regelin et al. 2005). In fact, this debate has existed since before statehood in 1959 (Harbo and Dean 1983) and is ongoing (Decker et al. 2006).

High public interest in wolves and brown bears is confounded by some unique Alaskan laws and perspectives. Many Alaskans maintain a subsistence culture, tradition and lifestyle that depends on wild foods. This dependence is protected under both state (state subsistence statute) and federal (Alaska National Interest Lands Conservation Act [ANILCA]) laws. Therefore, despite the changing times, the public demand for access to food in the form of ungulates, salmon and other subsistence foods remains a cornerstone of fish and game management in Alaska. As a result, many Alaskans support intensive management programs, such as predator control. However, despite the subsistence legislation and other legal requirements, some Alaskans and others from outside the state oppose active predator management aimed at increasing ungulate (particularly moose) densities for human harvest. For Alaskan wildlife managers, the complexity of the social, cultural and biological issues surrounding ungulate and predator management presents many challenges (e.g., Brown and Decker 2003, Decker et al. 2006). My objective is to provide background and context for understanding the current wolf-control programs in Alaska that are designed to increase moose populations for human harvest.

History, Background and Relevant Law

There is a long history of wolf control in Alaska that is related to promoting increases in ungulate populations. Policies regarding control of wolves have changed from one administration to the next and have changed under the federal government prior to statehood. Different administrations have been involved in planning and stakeholder processes, in land and shoot programs, in wolf reduction programs using state employees, in lawsuits, and in tourism boycotts (National Research Council 1997, Regelin et al. 2005). Some governors instituted wolf control; others did not. I will not review that history in detail here; rather, I will focus on the current laws and the status of the program over the past few years. Detailed reviews are provided elsewhere (National Research Council 1997, Regelin et al. 2005).

There are a few key sections of Alaska's constitution relevant to management of Alaska's wildlife. The constitution directs that natural resources shall be developed for the maximum benefit of the people and that natural resources such as wildlife, "shall be utilized, developed, and maintained on the sustained yield principle, subject to preferences among beneficial uses," (Article VIII, section 4, Constitution of the State of Alaska). The sustained-yield principle is a central theme of Alaska's wildlife management programs.

Under state law, wildlife regulation and policy are set first by the Alaska Board of Game through the regulatory process. The Alaska Department of Fish and Game (ADFG) then applies these regulations (seasons, bag limits, harvest methods) to meet a specified management objective. The commissioner of the department, who is appointed by the governor, also has authority to set and institute some regulations, as is the case with some aspects of predator control.

Alaska passed a subsistence law in 1978 requiring that a preference be given for hunting and fishing opportunities to those who customarily and traditionally use these resources. Many Alaskans have a direct dependence on subsistence foods, especially through the harvest of ungulates. Moose and caribou are key subsistence species over large areas of interior Alaska where access to salmon may be lower than in coastal areas. While management must still occur under sustained-yield principles, the Alaska Board of Game must provide for subsistence opportunity, sometimes to the exclusion of other uses, such as hunting by nonresidents if harvestable surpluses are inadequate to satisfy all use. In addition to the state requirement to provide a preference for subsistence uses, the federal government also has a somewhat similar requirement in ANILCA. That provision provides a preference for rural residents of Alaska to harvest fish and wildlife resources on federal lands where allowed. Combined, both sets of laws direct regulatory bodies and wildlife managers to provide for species, like moose, in sufficient numbers to ensure that subsistence harvest can occur. This demand is unlike nearly any other state in the United States, and many rural subsistence users strongly support predator control to increase moose populations (Brown and Decker 2003).

In recent history, when Governor Tony Knowles was elected in 1994, he suspended the then-extant, ground-based, wolf-control effort and called for a review of the department's wolf-management program. The review was conducted by the National Academy of Science (NAS). The governor also established three guiding principles that must be met for wolf control to proceed. He directed that control programs: (1) be based on sound science, (2) be cost effective and (3) be broadly acceptable to the public.

The NAS review committee concluded that management and control of wolves could work in some circumstances (National Research Council 1997). The report indicated that the department's wolf- and ungulate-management programs were based on sound science, noting that there could always be more study and that the experiments could always be improved. The report also emphasized that wolf control would be controversial, costly and time consuming. Results from this report have been used by both critics and supporters of Alaska's predator-management programs.

After this review, a year-long, citizen-planning effort related to ungulate and predator management took place in one part of interior Alaska. The citizen group proposed a nonlethal, wolf-control program to increase the size of the depleted Fortymile caribou herd. After an intensive effort by trappers to reduce wolf densities, the department sterilized the alpha male and female wolves in specific packs and moved subdominant wolves elsewhere (Boertje and Gardner 2000). In combination with a carefully planned harvest plan, the reduction in wolf predation helped the caribou population to increase from 22,000 to 38,000 during this period; the nonlethal program was controversial but not to the extent of earlier lethal programs.

The Alaska legislature passed an intensive management law in 1994. This law requires the Alaska Board of Game to identify big-game prey populations in the state that are to be managed for high human harvest, to establish population size and harvest objectives for these populations, and to develop regulations for intensive management. The board is precluded from significantly reducing hunter harvest of these populations through restrictions without enacting intensive management regulations unless the board can demonstrate that intensive management would: (1) be ineffective, based on scientific information, (2) be inappropriate due to land-ownership patterns or (3) be against the best interest of subsistence uses.

Predator control is an important tool for managers who are legally required to increase or maintain ungulate densities at high levels. Establishing a predator-control program is a lengthy process and not all requests for predator control have been approved by the Alaska Board of Game. The intensive management law has established a number of steps and qualitative thresholds that must be passed for a program to be approved. Legally, it takes at least 1 year and 2 public meetings to establish a predation-control program, but, in practice, the process usually spans between 2 and 3 years.

At the same time that the Alaska Board of Game was beginning to implement the intensive management law, a voter initiative (1996) and a voter referendum (1999) were passed related to banning same-day, airborne hunting of wolves. This practice had been legal in Alaska because federal requirements were met that required the hunter to be more than 300 feet (91.4 m) away from an aircraft before taking a wolf. And, it had contributed to keeping wolf populations reduced in some areas of the state. However, the same statute allows the same-day, airborne control of wolves through a permitted, nonhunting program when certain conditions are met. Five areas with predator-control plans have control programs for wolves that use aircraft, and all have been litigated by groups opposed to the practice.

Moose and Wolf Populations and Their Management

Moose are widespread in Alaska and constitute one of the most important hunting and food resources in the state. Hunter harvest of moose ranged from 6,700 to 8,700 during 1996 to 2005, with a mean annual harvest of 7,500. Hunter harvest may be managed by restricting the harvest to one sex, by imposing antler restrictions, such as the spike-fork, 50-inch and 4-brow-tine regulations, and by issuing a limited number of permits. Three types of permits mainly are used to manage hunter participation in an area. In areas with very high hunter demand where subsistence is not a priority, a drawing (lottery) hunt may be used to limit the total number of hunters. In registration hunts, the number of permits is usually not limited, but these hunts are sometimes restricted to residents or to specific locations. In areas where there are not enough moose to satisfy the subsistence need, a subsistence permit hunt may be held. Subsistence permits are awarded only to residents based on a demonstrated history of use and dependence on the resource for food and on the availability of alternative resources. In some remote areas of the state, there is a late-winter, moose-hunting season designed to provide moose for subsistence hunters. Where moose numbers are at very low levels, locals have sometimes asked the Alaska Board of Game to completely close the hunting season in an attempt to eliminate all poaching and to help increase the moose population to allow for a future harvest.

Across much of interior Alaska, both north and south of the Alaska Range, large predators (wolves, brown bears and black bears) can maintain moose and sometimes caribou at low population levels (e.g., Gasaway et al. 1992, Boertje et al. 1996, National Research Council 1997). This can leave little harvestable surplus for humans. Alaska has an estimated 7,700 to 11,200 wolves. Wolves have never been threatened or endangered in Alaska, and they inhabit all of their traditional range, except within the largest cities. Wolves are harvested across the state, traditionally by trapping and hunting (Figure 1), with the total annual harvest averaging 1,500 from 1996 to 2005. Seasons and bag limits vary depending on whether wolves are harvested via hunting or trapping regulations, which differ.

Intensive Management and Wolf Control

There have been two intensively managed areas where predator control was either never implemented or has been terminated. One area with a program for nonlethal, wolf-control was for the Fortymile caribou herd, mentioned previously; the program is no longer in effect.

The other area is Game Management Unit 20A (6,796 square miles [16,601 km^2]), south of Fairbanks (Figure 2), which is an example of how lethal

Figure 1. Total annual harvest of wolves, by method, in Alaska, regulatory years 1986 thtough 2005.

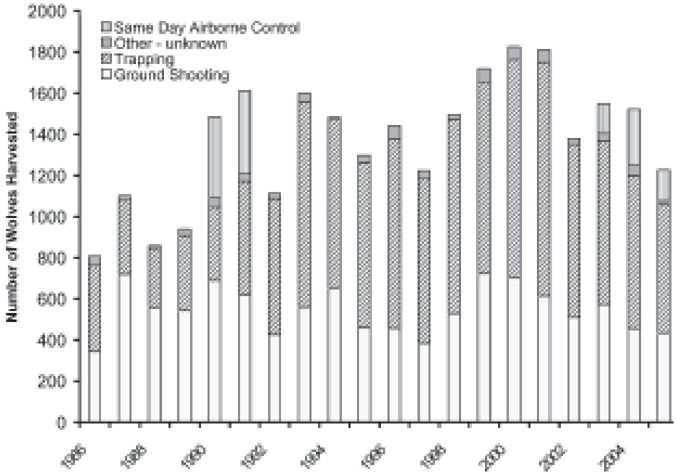
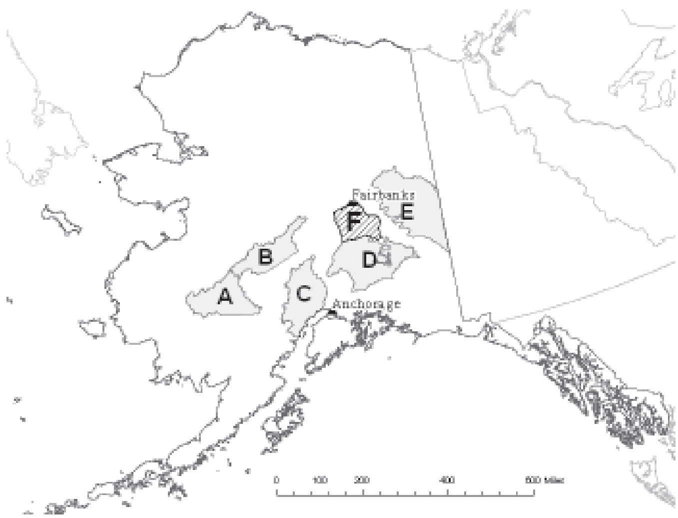


Figure 2. Locations of six areas in Alaska intensively managed to increase moose populations. Five of the areas (A, B, C, D, E) involve same-day airborne or aerial gunning of wolves since 2004 through a permitted control program. In one area (F = game management unit 20A), management of predators has been through hunting and trapping regulations.



Predation control areas are: (A) unit 19A, middle Kuskokwim; (B) unit 19D East, near McGrath; (C) unit 13, Nelchina Basin; (D) unit 16, upper Cook Inlet; (E) units 12, 20 and 25, upper Yukon-Tanana.

wolf control can lead to an increase in moose densities. The area contained only about 2,500 moose when wolf control was implemented in 1975. That wolf control program ended in 1982 and the moose population increased to between 10,000 and 11,000 moose by 1989; it remained near that level until 1992. Moose harvest at that time consisted of about 400 bulls each year. In 1993 and 1994, a wolf-control program was implemented to reverse a dramatic decline in caribou numbers, but the primary beneficiary appeared to be moose. The wolf population was reduced by about 60 percent and the moose population increased to over 15,000. Harvest of antlerless moose was eventually implemented to meet intensive harvest objectives and to regulate the moose population (Boertje et al. 2007). Annual harvests of up to 1,100 moose have occurred over the last few years and appears to regulate the moose population. After 1995, wolves recovered to precontrol levels and the Unit 20A wolf population is now the highest-density wolf population in interior Alaska. Wolves are currently harvested by trapping and hunting, but their population is not being regulated by that harvest, and no control program is in place. Favorable habitat and weather conditions appear to have facilitated the increase in this moose population. This successful program suggests that, even in a northern system with multiple predators (wolves and brown bears in this case), wolf control can shift a moose population from a low-density to a high-density equilibrium where favorable habitat occurs. In these situations, the moose population can increase markedly.

Current (2006 to 2007) Intensive Management Programs Using Wolf Control

The intensive management law requires that the Alaska Board of Game establish predator- and prey-population objectives prior to instituting a predator-control program. The board sets prey-population objectives at a public meeting, after considering department staff reports on historic prey population and harvest levels, population parameters, habitat status, predation levels, as well as testimony from the public and local advisory committees. Once the prey-population objectives have been set, the department determines the size to which the wolf population would need to be reduced to achieve the desired prey densities. This wolf-population objective is included in a predation-control-area implementation plan that is then presented to the board for adoption into regulation. Wolf-take objectives represent the difference between the regulatory management objective and the department's current best estimate of wolf-population size. Wolf-population estimates are derived from results of aerial surveys, sealing information, productivity estimates and on immigration information. Population estimates and take objectives are revised annually as updated information becomes available. Wolf-take objectives for the winter of 2007 are between 382 and 664 wolves across all 5 predator control areas (Table 1). This figure includes wolves taken by normal hunting and trapping. Most wolves are taken during the last month of the wolf-control program, which closes on April 30.

Table 1. Wolf-population estimates and management objectives for five predation control areas in Alaska, fall 2006. Population estimates are adjusted annually as are control objectives depending on harvest and survey results from the previous year.

Predation control area	Size in square miles (km^2)[b]	Wolf population estimate (fall)	Wolf population objective	Wolf harvest control objective
Unit 13	15,416 (39,927)	217–256	135–165	52–91
Unit 16[a]	11,102 (28,754)	139–176	30–60	79–146
Unit 19(A)	10,035 (25,991)	45–71	30–36	9–35
Unit 19(D)-East	8,541 (22,121)	85–100	40	45–70
Upper Yukon/Tanana	18,745 (48,549)	300–425	88–103	197–322
Total	63,839 (165,342)	786–1,028	323–404	382–664

[a] Population estimates and objectives are for the entire game management unit.

[b] Size is the area of the predation-control areas as defined in the overall regulation. The actual control activities are permitted on a smaller area.

Present wolf-control programs began in 2004 and rely on aerial gunning or on landing and shooting wolves. Pilot-gunner teams are permitted by the department after a review of experience and qualifications. The individuals act as agents for Alaska, which meets the requirements of the federal Airborne Hunting Act. Under that act, the department annually reports to the U.S. Fish and Wildlife Service the number of wolves taken under the intensive management programs. The permits are control-program specific, and the department has wide discretion in who obtains them. The control programs are directed management activities with an emphasis on effectiveness; as such, there is no requirement for fair chase such as there is for hunting activities. The programs incorporate strict reporting procedures, and those taking wolves must also have a trapping license. Once sealed, the wolf hide is the property of the permittee, and it may be sold or used just like a wolf taken through the state's normal trapping program. Permittees have received no compensation other than the fur value of the pelts they have taken.

Although the control programs occupy large portions of some game-management units (Table 1), lands managed by the U.S. Fish and Wildlife Service (refuges) and the U.S. National Park Service (parks and preserves) are excluded from the program without direction to the contrary by the respective federal agency. Federal land status has been one important factor in the Alaska Board of Game not authorizing control in some areas with depressed moose and caribou populations and where much of the game-management unit is composed of one or more federal conservation units.

In all of the active control areas, moose hunting has become much more restrictive over the past one to two decades. In four of five control areas, nonresident hunting as been eliminated by the Alaska Board of Game, meeting the legal requirement of the state's subsistence law. Typically, the board restricts ungulate hunting before initiating intensive management, and hunting seasons and bag limits for wolves, brown and black bears are also liberalized.

The first area where intensive management was applied (in December 2003) was the area surrounding McGrath (Unit 19D-East; Figure 2, area B), a rural village on the Kuskokwim River without road connections to the rest of the state. The department conducted a stakeholder planning effort there and established a small experimental micromanagement area (EMMA) of 528 square miles (1,368 km^2). The objective was to enhance moose survival rates by culling wolves. In addition, black and brown bears were captured and were moved from the area by department personnel for two summers. Before and during the predator control period, an intensive research project monitored the status of the moose population. Preliminary results suggest that calf-survival rates have increased significantly with the reduction in predators. In the past year, lethal control of bears was added to a portion of the plan area, with black and brown bear population reduction being authorized under baiting conducted by predator control permittees.

A second area with wolf control is Unit 13, the Nelchina Basin northeast of Anchorage and south of the Alaska Range (Figure 2, area D) where a program has existed since January 2004. Like Unit 20A, Unit 13 has an extensive history of intensive research and management involving moose, caribou, wolves and brown bears (e.g., Ballard et al. 1987). The area is large (15,413 mi^2 [39,919 km^2]) and has long been an important area for hunting by local residents and by many in Anchorage and Fairbanks, who have road access to the area. Historical predator and prey management in this unit has shown that, when the late-winter (spring) wolf population was maintained at 135 to 165 wolves, annual moose survival was adequate to allow the population to increase. The precontrol wolf estimate (in 2000) in the area was more than 500 wolves. A total of 128 wolves were taken in regulatory years 2004 and 2005 using land-and-shoot control methods. This harvest, combined with additional wolf hunting and trapping harvest and with liberal brown bear hunting regulations, has helped to arrest the decline of the moose herd. This moose herd has increased 14 percent from 2000 to 2006, based on annual surveys.

A third program north and east of the Nelchina Basin was established in the winter of 2004 to 2005 and is known as the Upper Yukon/Tanana wolf predation control area (Figure 2, area E). The original objectives of wolf control in this area were to increase the moose population across the area. But, more recently, the program was expanded to continue the growth of the Fortymile caribou herd. Similar to Unit 19D-East, brown and grizzly bears were added to the program, again as a ground-based, baiting program by permittees. Moose populations in much of this area have been at a low density since the late 1970s. Wolf harvest, combined with recent large burns that should enhance habitat, are expected to help the moose herd grow in this area.

A fourth area in the central portion of the Kuskokwim River is known as the Unit 19A wolf-predation control area (Figure 2, area A). Moose are heavily relied on in this area for fall and winter food by local residents who live in a number of small villages along the river. Habitat is not thought to be a limiting factor, and wolves are believed to be the primary factor limiting moose populations in this area. A total of 90 wolves were taken by aerial-control permittees in the first two winters of aerial control.

A fifth and more recent wolf-control program was established in Unit 16 on the western side of Cook Inlet, across from Anchorage (Figure 2, area C). As the moose population declined in this area during the 1990s the female-moose age structure became older because few calves were being recruited into the population. Habitat is not limiting. In this control area, both wolves and bears are thought to limit moose numbers. In the first winter (2004 to 2005) of wolf control in this area, 91 wolves were taken. It is believed that, in combination with lower wolf densities, a large increase in the harvest of black bears will be necessary to increase moose-calf survival and a resultant rise in moose density.

Conclusions

Alaska's intensive management law requires that the Alaska Board of Game and state wildlife professionals institute programs to increase certain depleted ungulate populations, so they are capable of sustaining high levels of human use. The ADFG has implemented intensive management regulations promulgated by the board, resulting in five same-day, airborne, wolf-control programs at the present time. The predator-control plan for each of the areas requires that viable wolf populations be maintained in those areas and that the control programs are meant to be temporary measures, albeit sustained over multiple years to achieve desired results. Concurrent bear-control baiting programs have also been established in two of these areas. These intensive wildlife management programs are controversial, and the public wants a continuous evaluation of program efficacy. The ADFG is conducting research and is monitoring predator and prey populations in the control areas, both to guide adaptive management and to document the effects of predator reductions. These research and monitoring programs will not occur with equal emphasis in all areas, but I believe that the intent of the recommendations made by the National Research Council (1997) is being met. Recent funding from the Alaska legislature has been critical in ensuring that the research and monitoring programs are scientifically sound.

Information on responses of ungulates, predators and habitat over at least a few years will be necessary to adjust program goals in a given area. There are a number of factors that influence how moose and caribou populations will respond to predator reductions. First, not all ungulate populations are at the same population size, trend and age structure at the same time. Therefore, ungulates will not necessarily respond the same way to high wolf harvest. Second, habitat varies in quality and quantity. Third, winter-weather severity varies from year to year and from one area of the interior to another. Winter weather and snow cover can be important factors influencing ungulate survival, predation efficiency and success in meeting annual wolf-harvest goals. Over the next few years, each program will be evaluated by the public, the Alaska Board of Game and the ADFG to determine whether predator control will continue to be needed to meet predator and prey population and harvest objectives.

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Policy Issues Regarding Wolves in the Great Lakes Region

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History and Status of the Wolf in the Great Lakes Region

Though native to the region, by 1970 the gray wolf (*Canis lupus*) was nearly extirpated from the Great Lakes states (Michigan, Wisconsin and Minnesota), with breeding populations largely relegated to portions of the Superior National Forest in northern Minnesota (Hendrickson et al. 1975; Thiel 1993; Thiel and Hammill 1988). A failed reintroduction effort in Michigan in 1974 concluded that public sentiment was so overwhelmingly antiwolf that recovery through translocation was likely to fail unless public attitudes changed significantly (Weise et al. 1975). However, shortly after being federally listed as an endangered species in 1974, wolves began to expand their range in Minnesota, and they were known to breed in Wisconsin by 1975 and to breed in Michigan by 1989 (Michigan Department of Natural Resources 1997). By 2005, these naturally recovering populations grew to estimated overwinter numbers of 405 in Michigan, between 435 and 465 in Wisconsin and of 3,000 in Minnesota, without the aid of reintroduction. Michigan and Wisconsin have typically had a 15-percent annual rate of increase in the number of wolves since 1977. The Minnesota population has also continued to grow but at a slower rate of roughly 4 percent annually (Wydeven et al., 2008). Figures 1 and 2 illustrate wolf population growth in the Great Lakes states.

The Great Lakes states all had a similar history of wolf persecution, with government-sponsored bounties enacted in the 19th century ending in the later part of the 20th century. These early policies resulted in the near extirpation of wolves in the region. Currently, wolves are protected by state statutes in all three states. As a result of the numerical recovery and of the existence of state recovery and management plans, the U.S. Fish and Wildlife Service (USFWS) announced on February 29, 2007, its intent to delist gray wolves as a federally endangered species in the western Great Lakes area. The western Great Lakes distinct population segment proposed for delisting is shown in Figure 3. When delisted, states within the recovery area will have primary responsibility for wolf

Figure 1. Wolf population growth in Michigan and Wisconsin, 1980 to 2005. (Wydeven et al., 2008)

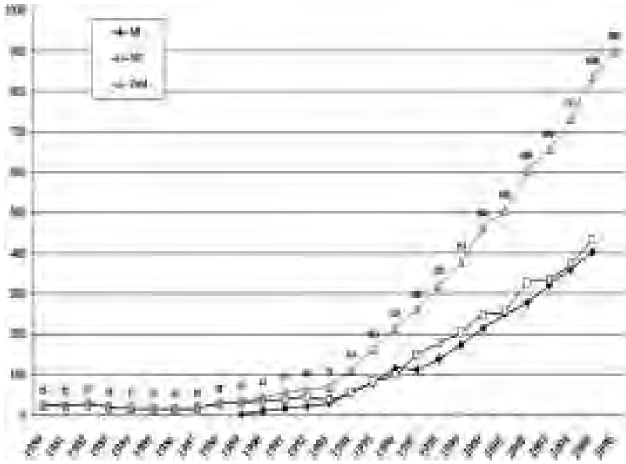


Figure 2. Wolf population growth in Minnesota, 1980 to 2005. (Wydeven et al., 2008)

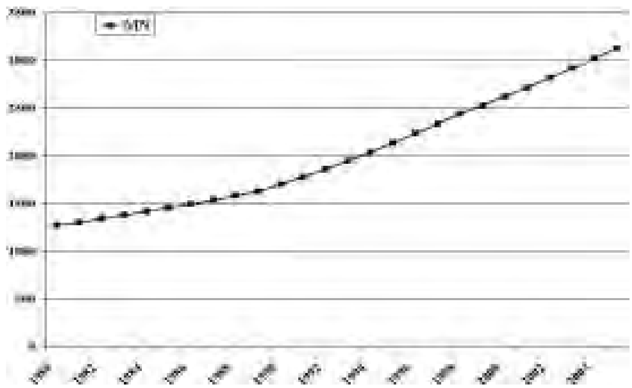


Figure 3. Distinct Population Segment boundary. (U. S. Fish and Wildlife Service 2007)

management. In all three states where core wolf populations currently reside, that authority will rest with each state's department of natural resources. This change in administrative responsibility for wolves takes place as habitat changes are occurring, as the societal costs for maintaining an increasing wolf population are mounting and as public support for wolves in wolf country is eroding. Further, public value for wolves is becoming increasingly polarized.

Wolf Habitat

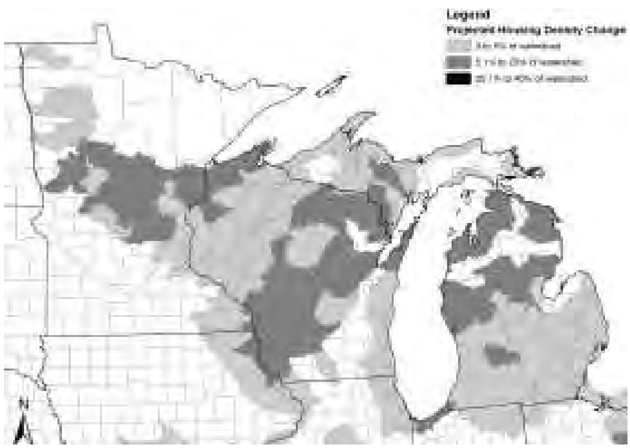
The Great Lakes states wolf population is thriving in close proximity to major metropolitan areas like Minneapolis-St. Paul and Duluth (Minnesota), Milwaukee (Wisconsin), and Chicago (Illinois), with a combined population of nearly 9 million people. The combined, total population of the Upper Peninsula of Michigan and of Chicago, Wisconsin and Minnesota is nearly 18 million people. The forested landscapes of these states are major outdoor recreation destinations for people from these states, and most of these forests are actively managed for a variety of amenities. Wolves in the Midwest do not have access to large, designated wilderness areas where human contact is limited or can be avoided.

Gray wolves are thought to be habitat generalists that, historically, survive best in areas with relatively low road densities (Thiel 1985). In recent years however, wolves have demonstrated much higher tolerance to road densities that are significantly above a threshold of 1 lineal mile per square mile, previously thought to represent the upper limit of wolf tolerance for roads. Midwest forests are a major woodshed for a variety of forest-product industries. Accessing this raw material for industrial use has resulted in forests that are roaded and very accessible to people. In addition, the universal use of all-terrain vehicles has increased accessibility on most forest ownerships. Today, wolves thrive in many areas of the Great Lakes states that are easily accessed by people, which has resulted in increased wolf-human contact.

Private industrial forestlands exist on more than 5 million acres (2,023,500 ha), which are well distributed across current wolf range in the Great Lakes states. This acreage represents 13 percent of the entire forested land base. The previous model for managing these lands was based on industrial landowning firms growing and harvesting trees for their own consumption from their holdings. Industrial firms now purchase most of their wood from the open market. Ownership of these lands is undergoing major changes and the rate of ownership turnover of industrial forestland has increased in recent years. Since 2002, 1.6 million acres (647,520 ha) have been sold to real estate investment trusts or to closely related landholding businesses (Davies 2007). These new owners, in turn, manage the areas not only as a source of wood but, primarily, as real estate. Portions of these lands that are most suitable and profitable for real estate development will be subdivided and sold.

In addition to the change in ownership of forestland, a substantial portion of currently occupied wolf range in the Great Lakes states is located in watersheds where private lands are projected to experience housing density increases of up to 20 percent by the year 2030. Figure 4 illustrates the areas where these projected changes are likely to occur within currently occupied wolf range (Stein et al. 2005). Note that the northern lower peninsula of Michigan is likely to experience these changes across much of its land base. This is also one of the areas thought to be a likely area of wolf population expansion.

Figure 4. Projected housing density change (Stein et al. 2005).



The direct effects of these large-scale land changes to wolves is difficult to predict. However, both forest fragmentation in wolf range for real estate development purposes and increases in housing densities are likely to result in more human-wolf interactions and conflict. An efficient system is needed for dealing with likely increasing human-wolf conflicts in newly fragmented wolf range and settled but newly occupied wolf range.

Social Costs

The Great Lakes wolf population began to expand naturally shortly after being listed as an endangered species. With this increase, depredation losses to livestock and pets have increased. Livestock operators and some pet owners feel that they are carrying the burden of wolf recovery for the remainder of society. Since 1978, 2,590 wolves have been killed in the Great Lakes states in response to livestock or pet depredation complaints by the public. These wolf removals have been accomplished primarily by U.S. Department of Agriculture (USDA) Wildlife Services employees or state department of natural resources employees under permit from USFWS. These removals have normally represented a low percentage of the total estimated state wolf population in any one year (average 4.09 percent). However, in 1997, agents in Minnesota removed 216 wolves, which was 9.2 percent of the estimated total population (Wydevan et al., 2008). One of the often publicized effects of wolf impact on humans is their depredation on livestock and pets. All Great Lakes states have a compensation program available to indemnify livestock owners for verified losses due to wolf depredation. Wisconsin also indemnifies owners for pet losses. Through 2004, Minnesota has paid $1,072,725 to livestock owners for wolf depredation compensation (J. Erb, personal communication 2007); Wisconsin has paid $581,463.90 (A. P. Wydeven, personal communication 2007); Michigan payments have totaled $21,746 (B. Rowell, personal communication 2007). Historical data of chronic wolf depredation on farms and on predictive modeling of farm-wildland interface has helped managers anticipate the areas that depredation on livestock is likely to occur (Treves et al. 2004). In many cases, removing wolves from depredation sites creates a void soon filled by other wolves and is only a short-term solution to the problem.

As the wolf population has increased, time and personnel necessary to address the wolf-livestock depredation issue has increased in the Great Lakes states. USDA Wildlife Services agents assist all three states with handling wolf-human conflicts. Also, state agency personnel in occupied wolf habitat have been devoting an increased amount of time to dealing with wolf-related issues. Wolf depredation reports require immediate attention and action to alleviate the problem. Besides the actual budgetary implications of this, other important resource management activities are receiving less attention as a result of the need to handle depredation events. Typically, other equally deserving issues are prioritized below handling wolf depredation complaints. Further, several thousand wolves have been killed in the process, resulting in little direct public benefit as a result of the loss of these animals.

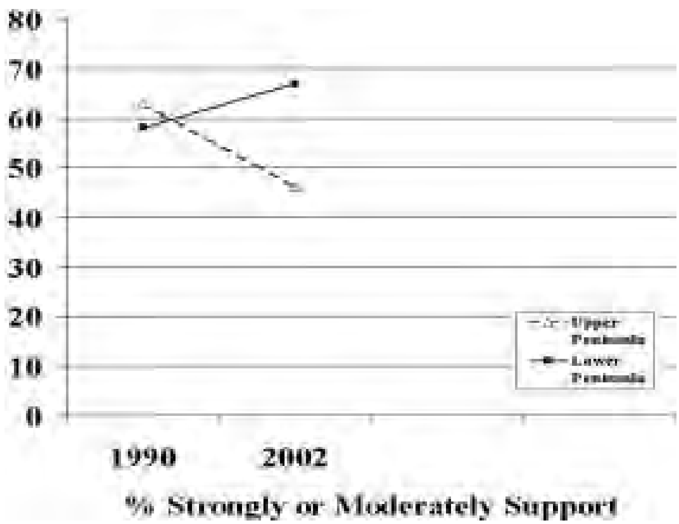
With the combined wolf population in the Great Lakes states currently at nearly 4,000 animals, societal costs are mounting. Wolf conflicts with pets have been increasing and have proven to be a very difficult issue to deal with in Wisconsin and Michigan. Both states have a strong tradition of bear hunting with hounds, and most wolf-dog conflicts in these two states involve bear dogs. However other dogs attacked by wolves include upland bird hunting breeds, hounds used for raccoon hunting and household pets. Minnesota does not allow the hunting of bears with dogs, but it has not been immune to loss of pets by wolf depredation. Wolves have attacked and killed pets in the immediate vicinity of homes and within city limits of rural communities in all three Great Lakes states.

Public Attitudes

Since 1989, public surveys of people's attitudes toward wolves have indicated strong support for wolf recovery. In 1990, a survey indicated that 80 percent of upper Michigan deer hunters favored a reintroduction of wolves to Michigan (Kellert 1990). In 1993, as part of the wolf-planning process in Michigan, 15 public forums were held throughout the state. At that time there were fewer than a dozen wolves known to live in the Upper Peninsula of Michigan. Eight-hundred and twelve people either attended one of these meetings or provided written comments. All comments were categorized as supportive, nonsupportive or undetermined of having wolves in Michigan. Ninety percent of written and oral comments were supportive. In contrast, a dozen public meetings were held in 2005. The wolf population in Michigan at the time of the 2005 survey was estimated to be 405 animals. Three-hundred thirty-four people attended meetings in the Upper Peninsula during this survey and were asked how many wolves they would prefer in the Upper Peninsula. Twenty-two percent indicated they preferred that no wolves exist in the Upper Peninsula, and 36 percent said that they preferred some but less than there are now. Neither of these surveys represented a cross section of the general public, but they are comparable because they represent people who attended similar informational meetings about wolves. The results reflect a decline in tolerance for wolves.

A 2002 study of attitudes toward wolf recovery in the Upper Peninsula is revealing (Mertig 2004). Parts of this survey were directly comparable to Kellert's 1990 study. The surveys reflect Michigan citizens as a whole. During the Kellert study period, wolves were newly discovered as a recovering species in the Upper Peninsula, with fewer than 10 animals present. The Mertig study was conducted when the population of wolves in the Upper Peninsula had risen to about 250 animals. Mertig found that support for wolf recovery by Upper Peninsula residents had significantly declined. Whereas, support for Upper Peninsula wolf recovery had increased among persons who reside in the Lower Peninsula of Michigan, where wolves were known not to be present (Figure 5). Further, in direct comparison to the Kellert study, people in Michigan had become more supportive of management options, such as the need to control wolves. Also, support for wolf recovery in the Upper Peninsula for the purpose of harvesting pelts or for hunting increased between the two survey periods. The study also revealed that people in wolf range prefer to have occasional sightings of wolves rather than regular contact with them.

Figure 5. Change in support for wolves in Michigan from 1990 to 2002 (Mertig 2004).



Although no survey data exist, Wisconsin Department of Natural Resources personnel working with wolves believe there has also been an erosion of support for wolves among the public in that state (A. P. Wydeven, personal communication 2007). In Minnesota, no recent public surveys gauging wolf support exist, but wolf program personnel there feel that there has not been a significant change in public support (J. Erb, personal communication 2007). As wolf populations have increased in the Great Lakes states and elsewhere, the number and frequency of articles concerning wolves in popular sporting magazines has also increased. Most of the articles reflect an antiwolf sentiment and focus on concern for predation effects on cervids, primarily white-tailed deer (*Odocoileus virginianus*). Hundreds of thousands of periodicals carrying these articles are sold monthly. It is not known to what extent this literature helps to form public opinion. However, with the volume of antiwolf articles being produced, it is likely that public demand for treatment of this topic is high. The long-term prospects for the wolf's persistence on Great Lakes states landscapes will be tied to the public's tolerance of wolves and to developing a larger segment of the public who value having wolves present. The current trajectory of public attitudes, especially in Michigan and Wisconsin, is not favorable to sustaining wolves in those states. After delisting, wolf monitoring plans of Great Lakes states do not require the states to monitor public attitudes toward wolves. Public education about wolves in the Great Lakes states is primarily handled by nongovernmental organizations, despite the fact that public outreach is identified in the states' plans as being important. It seems unlikely that current efforts in wolf education alone will be enough to change public attitudes about wolves.

As wolf populations continue to grow and expand in the western Great Lakes states, the management paradigm for wolves may need to shift from near-complete protection to active management, including the general reduction of wolf numbers to protect societal interests. If this major shift in management direction does occur, extensive public input will likely be necessary. Wolf-management policy that incorporates human-dimensions research findings and appropriate scientific knowledge of the species will need to be developed. Midwest wolf policy will need to be developed with consideration given to societal costs of maintaining wolf numbers, to changes in wolf habitat and to people's attitudes toward this predator.

North American Model

Management of wolves in the continental United States where the wolf is delisted or is under consideration for delisting has been or may soon be transferred to the states within the affected, distinct population segment. Except for postdelisting monitoring requirements, the USFWS (under authority of the Federal Endangered Species Act) will no longer be responsible for wolf populations in delisted areas. As such, there is a broad spectrum of options before us regarding wolf management at this critical juncture. We're now in a position to ponder what management paradigm may be the best for wolves and for future generations of North Americans. The answer may lie within the philosophical framework of the North American model of wildlife conservation, the most successful wildlife management philosophy in the world. The basic tenants of the North American model are that wild animals belong to all of us, that future generations are deserving of wildlife undiminished by our actions and that they should be managed using the best science available (Mahoney 2004). Indeed, with the help of this philosophical framework, wolves have rebounded from near-total extirpation in the continental United States, as have elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), white-tailed deer, wild turkeys (*Meleagris gallopavo*), wood ducks (*Aix sponsa*), and bald eagles (*Haliaeetus leucocephalus*). We have witnessed an incredible recovery and the evolution of our collective thinking about wolves—from conquerors to custodians. As with many other species that benefited by the North American model, wolves have now become a species in which many people see personal identity and relevance. At one time, our nation was at war with the wolf. As wolves were driven nearer to extirpation, new knowledge about wolves offered the opportunity to see wolves in a new way, where facts slowly replaced myths, the descendents of generations of hate and fear. Wolf research has benefited this transition greatly. This metamorphosis of thought was also a necessary component of early conservation efforts to save many other species we have in great abundance today.

Conclusion

The recovery and delisting of the Great Lakes states wolf population represents a significant accomplishment for the Endangered Species Act and is a milestone for wildlife management. Wolves in the Great Lakes states have demonstrated that they are adaptive to the presence of people and numerically have increased to a metapopulation of approximately 4,000 animals occupying 42,607 square miles (110,352 km^2). The management of this newly recovered population is now the responsibility of the states of Minnesota, Wisconsin and Michigan. Policy for management of wolves within these states is the responsibility of each state's department of natural resources. Although people living in wolf country are significantly less supportive of wolf recovery now than they were in the earlier days of recovery, the support for a regulated wolf population is still strong. Survey data suggests that the public is more supportive of wolf-control measures to help farmers avoid livestock depredation and to maintain wolves within social carrying capacity. Further, support is shown to be increasing for population control using time-honored methods, like hunting and trapping.

At this important juncture in wolf management, it may be enlightening to reflect on what has worked historically for North American wildlife. The North American model has laid the foundation of recovery for many of our economically important species and for hundreds of other species that share the same habitat. Indeed, the North American model has been so successful that some of our greatest challenges in wildlife management exist not because of a failure to produce wildlife, but in our inability to control wildlife populations. This failure to regulate numbers has resulted in great social cost and environmental degradation. A well-documented example of this can be seen with white-tailed deer. In many states, white-tailed deer populations are at unprecedented highs. As a result, direct social costs have been high, and environmental degradation is becoming increasingly apparent. Over 1 million car-deer crashes occur yearly in the United States. Research data that implicates white-tailed deer herbivory in ecosystem damage is mounting. One of the key tenets of the North American model is its dependence on science to guide management decisions. Although the wolf is among the world's most studied animals, there will always be the need for additional research. However, many of the basic questions for managing wolves have been answered, setting the stage for a new paradigm of wolf management.

If current population trajectories continue, wolf numbers may double in Wisconsin and Michigan to approximately 1,700 animals by the end of the postdelisting monitoring period in 2012. Assuming a slower, 4-percent rate of increase for Minnesota, populations there could top 4,000 animals in the same time frame. The western Great Lakes states wolf population in 2012 could be 5,700 animals, i.e., 44 percent above current population levels. Social costs associated with this projected population would likely be significantly higher than present levels. It is unknown how a population increase such as this would affect public attitudes about wolves. We do know, however, that public tolerance for wolves has declined as the population of wolves has increased.

During the past 50 years, attitudes toward many predators in the Great Lakes states have undergone a significant evolution. Bounties were paid by states for coyotes, wolves, foxes and bobcats. Black bears, for most of the past five decades, were considered vermin. The repeal of bounties on all predators and the elevation of the black bear to trophy big-game status happened in recent times. This change has elevated the status and value of these species in the public eye. Now, a segment of the public (consumptive users) places a high value on the wellbeing of these predators and takes keen interest in their protection and management. Because of this interest, populations of these predators now are managed by regulated seasons. Established through the use of best available science, this has resulted in sustainable populations and an annual harvest through hunting and trapping. Predator hunting is becoming an increasingly popular outdoor activity, and demand for black bear harvest permits far exceeds supply in several Great Lakes states. Human attitudes toward wolves, it seems, have also undergone great transformations. Once despised and slated for extirpation by both public attitude and government policy, the wolf's fortunes improved as bounty systems were eliminated. The pendulum then swung to complete protection by federal law. Now, with expanding populations, society needs to redefine a place for wolves. Fortunately, wildlife management success in North America has identified a template that may serve wolves and people equally well.

The story of wolf recovery represents the first great wildlife success story of the new millennium. Wolves have been saved from extirpation in this country in spite of their low economic value, high social intolerance and government-sponsored programs to eliminate them. The fact that wolves are either delisted or in the process of being delisted in significant portions of their former range is testimony to a management philosophy—the North American model—that has worked again. Now, it seems appropriate that the model be allowed to proceed to its next logical and time-tested step, which is to allow control of wolf numbers by allowing a public take of wolves while we apply the best wildlife science and human-dimensions science to the process. This critical step has been part of the success of many wildlife recovery programs in the past and a template for ensuring that wolves will be present for generations to come. Allowing a public harvest of wolves could create a new opportunity for many people to find new value in wolves, thus gaining support for wolves from a critical segment of the public in wolf range. Such a strategy would also create an efficient, cost-effective way to control wolf populations that currently does not exist, reducing financial burdens on society. In addition, a message would be sent to U.S. citizens that we have learned the difficult lessons that wildlife overabundance and its associated social costs have taught.

Kellert (1996) notes that a common problem of many endangered species programs is that value differences among critical stakeholders is not adequately incorporated into recovery efforts. Wolves have recovered or in the process of meeting numerical recovery standards in significant parts of suitable habitat. As a result, many people who have a wide range of values for wolves presumably have already been served. Clearly, wolves generate strong expressions from people. This makes policy decisions concerning wolves more difficult because there are likely to be more strongly held values being expressed and demanding equal consideration. Wolves have strong opponents as well as supporters. Consensus decision-making for policy makers in such an environment may not be possible. Except for the most ardent antiwolf element, a common thread among other stakeholders is that wolves should be allowed to exist in sustainable numbers for this and future generations. With this nearly universal value in mind, states will need to make policy for wolf management that is sensitive to the values of their citizens and that assures the sustainability of wolf populations. Most importantly, it is imperative that gridlock be avoided and that a new era of wolf-management leadership become a reality. Wolf population, available habitat for wolves and human attitudes about wolves are rapidly changing. The decision-making process must be sensitive to the trajectory of these factors and to the speed at which changes are occurring.

The recovery of wolves in the Great Lakes states is truly a success story. We have protected wolves, which has allowed them to return to the Midwest. Now, it is up to us, as their stewards, to manage the recovered population from overabundance and within social carrying capacity. While we show respect for people's values, unless we are successful in this effort, history may repeat itself. Negative, adversarial attitudes towards wolves are likely to grow, and we may again be struggling to assure the wolf's survival.

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Policy Issues Related to Wolves in the Northern Rocky Mountains

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Introduction

Wolves were extirpated from the Northern Rocky Mountains (NRM) by the late 1930s (Young 1944). Wolves began to naturally recolonize the region in the early 1980s, with the first reproductive pack documented in 1986 in the North Fork of the Flathead River in northwest Montana (Ream et al. 1989). Wolf numbers and distribution increased gradually with local, but limited, public controversy in northwestern Montana from the late 1970s through the early 1990s. Throughout this period, wolves in the region were classified as endangered under the Endangered Species Act (ESA).

To accelerate NRM wolf recovery, the U.S. Fish and Wildlife Service (FWS) reintroduced wolves to wilderness areas in Central Idaho (CI) and to Yellowstone National Park (YNP) in 1995 and 1996 (Bangs et al. 1998). Large parts of Idaho (ID) and Montana (MT) and all of Wyoming (WY), where the reintroduced wolves were expected to range, were designated as experimental, nonessential population areas (Figure 1). This classification provided greater management flexibility under rules adopted under section 10(j) of the ESA, compared to the ID panhandle and northwestern MT where wolves retained endangered classification.

Following the reintroductions, wolf numbers and distribution in the CI and YNP areas increased rapidly. Wolves continued to increase in northwestern Montana at a slower rate (Figure 2). The overall NRM population met the recovery target 30 breeding pairs and of at least 300 wolves with an equitable distribution in each of the 3 subpopulations for 3 consecutive years at the end of 2002 (Sime and Bangs 2006). By the end of 2006, the minimum tristate population

Figure 1. Northern Rocky Mountain federal wolf recovery areas of northwestern MT, where wolves are currently classified as endangered under the federal Endangered Species Act, Central ID Experimental Area, and the Greater Yellowstone Experimental Area, where wolves are classified as experimental, nonessential. Note that the states of MT and ID contain portions of all three federal recovery areas.

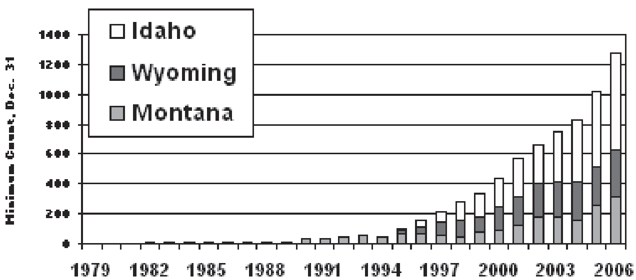

Figure 2. Northern Rocky Mountain minimum estimated wolf population by state, December 31, 1979 to 2006.

was about 1,300 wolves with about 86 breeding pairs, and the 3 subpopulations had effectively merged into a regional metapopulation (Sime and Bangs 2007).

Although the magnitude of biological effects varies across the region based on a range of environmental circumstances, wolf restoration in the NRM through natural colonization and reintroduction has altered ecological relationships in the region. Profound changes have also occurred in the political and socioeconomic realms. The public policy issues and responses vary, based on the cultural and political values within and among the three states. This paper discusses some of the policy issues related to the recovery, delisting and anticipated state management of wolves in the NRM.

Policy Issues Related to Management of Prey Populations

Among the most biologically, socially and politically complex policy issues are those related to ungulate management following wolf recovery. During the years when wolves were absent from the NRM, ID, MT and WY managed ungulate populations to provide various public benefits, including recreational hunting for both food and trophies and prevention of game damage to agriculture. Although mountain lions, coyotes, black bears and grizzly bears have always preyed on ungulates, managers have been able to allocate a substantial, annual harvest to hunters and have used hunting as a tool to regulate population size and age structure.

Given wolf recovery, agencies and commissions are faced with a new and highly variable element in the management equation. Wolf predation, alone or in combination with other environmental factors, may alter recruitment and survival rates, ungulate distribution and availability, harvestable surplus, or hunter success. These factors must be considered when setting seasons, bag limits, permit numbers or other aspects of ungulate management.

The impact wolf predation could have on harvestable surplus of ungulates for hunters differs from species to species, place to place, and through time; thus, it is difficult to generalize. In a few, high-profile cases, such as the northern YNP elk herd and the Upper Gallatin drainage south of Bozeman, Montana, wolf predation is one of several factors contributing to population declines and has, in part, led managers to reduce antlerless and late-season elk harvest opportunity (Montana Fish, Wildlife and Parks, unpublished data 2006). Changes in elk behavior in response to wolves (Creel et al. 2005, Gude 2005) may also have contributed to reduced hunter success in some areas, particularly if hunters do not adjust their hunting strategies. Apparent shifts in elk habitat use or increased wariness has also led some hunters to believe elk numbers have declined even more than agency surveys indicate. At the same time, in northwestern MT, where wolves first returned to the NRM 25 years ago, elk populations have not declined long-term, and no significant, sustained changes in hunter success or harvest levels are evident. Relatively small fluctuations through time are more habitat (forest fires or lack thereof) or weather related.

At present, there is considerable speculation about the impact of wolf predation in other areas, but relatively little scientific data from which to draw informed conclusions. In the absence of data, both pro- and antiwolf interests are free to attempt to influence decision makers through purely political means. Both sides advance simplistic, direct cause-and-effect arguments to support their "reality," and often proposed solutions are also simplistic and are exclusive of other interests. However, the ultimate reality is that wolves and ungulates exist in complex ecosystems with varying degrees of human influence and agency mandates, and there are no simple solutions. The debates related to the effects of wolf recovery, the allocation of ungulate mortality to wolves, hunters or other predator species, and other causes will be long and contentious, at least until managers in the NRM gain additional information and experience in the new environment.

Policy Issues Related to Wolf Harvest and Population Management

ID, MT and WY wolf-management plans all address the need for some level of population management and provide for public hunting or trapping. In some respects, managing wolf populations should be no more difficult than managing other wildlife populations. Managers know what is required to increase or decrease wolf numbers or distribution. In other respects it will be completely different.

As with all wildlife-management programs, managing wolves will require surveys to estimate population size, reproduction, mortality from all causes, distribution, harvestable numbers, etc. Wolf-monitoring methods can be relatively straightforward and practical, though costs per unit of data gathered are often high. Political or public pressure to acquire more detailed information through radio telemetry than is necessary to make management decisions will likely inflate costs, as well.

Some controversy will surround any proposal for wolf hunting or trapping. State agencies and commissions should anticipate competition between hunters and trappers for the opportunity to take any harvestable surplus. There will also be debate about the relative merits and potential outcomes of limited licenses and permits, compared to quota-based management systems. State agencies will need to gain experience in managing harvest under various local conditions before they can provide commissions with firm recommendations. Public-harvest levels will also be affected by the number of wolves killed—either legally (in defense of property) or illegally—and by nonhuman factors influencing wolf reproductive and mortality rates.

Commissions should also expect that people opposed to any wolf killing will enter the debate, particularly if they perceive the purpose of wolf harvest is to reduce wolf numbers to benefit big-game hunters. They may choose to participate through an agency's traditional, public-involvement process, through other political processes, through litigation or through a combination of these. This poses a dilemma for policy makers who will be faced with one segment of the public that strongly promotes using hunting or trapping to reduce wolves to reallocate ungulates to hunters and another segment that strongly opposes such actions. Agencies and commissions will hear from the most polarizing, vocal individuals having the strongest beliefs that they will lose. Engagement by the "masses in the middle," with more moderate viewpoints, will define the middle ground and the management strategies, rendering the polarizing viewpoints as extreme. Data gaps, limited experience managing wolf populations under conditions similar to the NRM and unequal political power among interest groups will likely frustrate policy makers.

The policy debate related to control actions involving government removal of wolves to benefit hunters will be even more contentious. Given the greater degree of habitat fragmentation and hunter access in the NRM, compared to Canada and Alaska, and given the need to remove wolves to reduce livestock depredation, agency-implemented, wolf-control programs may not be necessary to achieve wolf- and ungulate-population objectives that are acceptable to most people in the NRM. One exception could be the core wilderness areas of CI, where wolf harvest is likely to be lower due to limited access and because wolves are less likely to be killed to address wolf-livestock conflicts. In addition, prey populations that range in and out of YNP may be subject to impacts from wolves that cannot possibly be addressed through management of a fully protected wolf population within the park.

Based on experience in Alaska, it is reasonable to predict that any agency-implemented control intended to reallocate ungulate mortality from wolves to hunters will be met with in-state, national and international resistance through both legal and political challenges (Stephenson et al. 1995). Legal challenges will rely on the ESA, the National Environmental Policy Act and, possibly, the airborne hunting act at the federal-court level and on procedural or substantive law at the state level. The specific basis of the challenges will depend on state laws. Political challenges will be based on the prevailing beliefs about the appropriateness of reducing wolf numbers to increase hunter harvest, the role of humans in manipulating ecosystems, cost-benefit analyses of programs, etc. Again, based on experience in Alaska, managers should expect volatility and frustration on the part of top-level policy makers in regard to this issue because choices will not be clear-cut. No single solution will likely satisfy most people, and all three branches of government will be involved.

Policy Issues Related to Livestock Depredation

Wherever wolves and livestock overlap, some depredation will occur. The USFWS in WY, the ID Department of Fish and Game (IDFG), and the Montana Department of Fish, Wildlife and Parks (MFWP) in their respective states, rely on U.S. Department of Agriculture, Wildlife Services (WS) to determine whether wolves were the cause of injured or dead livestock and to remove wolves causing depredation. Under both the original and updated 10(j) rules in the experimental, nonessential areas (Figure 1), the responsible managing agency generally authorizes WS to remove one or more wolves to prevent further losses following any depredation caused by wolves. Under the updated 10(j) rules now in effect in MT and ID, livestock producers also have significant flexibility to kill wolves that threaten, attack or kill their animals.

In the endangered-species area (Figure 1), however, MT and ID must be more conservative and can only authorize lethal control under the 1999 Interim Wolf Control Plan, adopted by the USFWS (U.S. Fish and Wildlife Service 1999). Further, in the endangered-species area, livestock producers cannot intervene at all when wolves harass or kill their animals. Producers near the boundary who may have livestock on both sides of the line and can protect some but not others from wolves are frustrated by the two classifications. This adds to the urgency to achieve delisting of the biologically recovered population in the NRM.

The fact that wolves were reintroduced to the NRM despite opposition from livestock interests, among others, creates an atmosphere in which some citizens seek to assign liability and blame for real or perceived impacts and changes brought about because the landscape is now shared with wolves. Policy makers and agency managers are thrust into positions in which public demands for redress or specific outcomes are significant. And, some sectors of the public believe agencies have to take responsibility.

Defenders of Wildlife (DOW) established a program to reimburse livestock producers in the NRM for confirmed and probable losses to wolves while wolves are listed under the ESA. From 1987 through September 2006, DOW has paid $638,292 (Defenders of Wildlife 2007) though many producers do not submit claims.

ID, MT and WY have different legal and political frameworks for compensating livestock producers for wolf losses. ID currently uses federal funds secured by their congressional delegation to reimburse some producers for losses. WY does not currently reimburse producers for losses to wolves, but, when wolves are delisted, WY Department of Game and Fish will be required by state law to pay for losses using license funds in any area where wolves are designated as trophy game. Concern about the impact of these payments is one of the factors affecting the ongoing debate over trophy game versus predator status in portions of WY (T. Cleveland, personal communication 2006).

The 2007 Montana legislature is considering a bill that would establish the Livestock Loss, Reduction and Mitigation Program. This bill, if approved, would create a seven-member board to oversee a program designed to help producers reduce the risk of loss and to reimburse producers at fair market value for both probable and confirmed losses. Funding for the program is uncertain, and the Montana administration has taken the position that no state funds will be appropriated. Efforts to obtain federal and private funds are ongoing.

Issues Related to Public Safety

Although wolf attacks on humans in North America are rare, they have occurred historically. More recently, wolves have injured humans in circumstances where wolves became habituated or food conditioned (Linnell et al. 2002, McNay 2002). In most cases, these conditions arise in national parks or on preserves where wolves are protected from human harassment or killing.

The state wildlife-management agencies anticipate using hunting and trapping, as well as outreach, to prevent habituation and food conditioning. All state management plans in the NRM also call for immediate removal of any wolf or wolves that threaten or injure humans.

In addition to public concern about physical attacks by wolves, an emerging concern is the potential for disease transmission from wolves to people or domestic animals. Although the real risk of disease transmission (e.g. rabies) or parasitic outbreaks (e.g. *Echinococcus* spp.) is negligible, they manifest as one more threat or problem with wolf restoration that is seized upon politically by wolf opponents. Addressing and responding to disproportionately elevated public concern diverts managers' time from other, more significant, issues.

Issues Related to Funding

Wolf recovery has added significant costs to agencies in ID, MT and WY. One reason for this is the high level of information about wolves demanded by the public and elected officials. Each state is investing some hunting-license dollars in wolf management, but all three have consistently argued that restoring wolves to the NRM is a national priority, i. e. driven by federal law (ESA) and should be funded, primarily, by federal dollars. To date, U.S. Congress has appropriated funds to ID and MT through the USFWS budget. However, with the increasing federal deficit, changes in the federal-budget process and the potential delisting of the NRM wolf population, it is uncertain whether federal funds will continue to support wolf management.

If states must rely on their own sources, the impacts to states' general funds or to state hunting-license accounts could be significant. State wildlife agencies will likely have to redirect federal-aid funds from either the Pittman-Robertson Act or from state wildlife grants programs to fill the gap. This will change funding levels for wolf management and for other wildlife management. And, it will fuel more debate among legislators and the public regarding the appropriate sources and amounts of funding for wolf management. Alternatively, elected officials and the public could adjust their expectations downward to be commensurate with available funding or to be commensurate with their comfort levels with wolf conservation and management, which (in theory) should improve as everyone gains more experience.

In addition to affecting costs, wolf recovery may affect agency revenue. Any reduction in ungulate-license sales due to wolf predation, will adversely affect revenue. Conversely, after delisting, sales of wolf-hunting licenses may enhance revenue. It is impossible at this time to predict whether the net will be positive or negative.

Issues Related to Jurisdiction and Application of the ESA

The NRM wolf population is considered a regional population that ranges across several states. Although this population achieved the biological recovery threshold in 2002, the USFWS did not initiate delisting until recently, based on their finding that WY laws and the state's management plan do not provide adequate regulatory mechanisms. WY has challenged that finding in federal court.

As an interim step to provide greater management flexibility in 2003, the USFWS created a western distinct population segment (DPS) that included most of the continental United States west of the Mississippi River (except Arizona, New Mexico and parts of Texas and Colorado, where efforts are ongoing to recover the Mexican wolf). And, it reclassified wolves in that DPS as threatened (U.S. Fish and Service 2003). However, that action was successfully challenged in federal court and the entire final rule was vacated (Boyd and Bangs 2005).

On February 8, 2007, the USFWS proposed a new western DPS that includes all of ID, MT and WY, as well as parts of Oregon, Utah and Washington (Sime and Bangs 2007). In the same federal register notice, the USFWS proposed to delist all or most of this DPS, depending on ongoing negotiations with WY regarding the adequacy of regulatory mechanisms in that state. If WY amends its law and its plan to the satisfaction of the USFWS, the entire DPS will be delisted. If WY does not adopt adequate regulatory mechanisms, a portion of northwestern WY would retain experimental, nonessential ESA status while the remainder of the DPS would be delisted.

ID and MT have advocated this innovative approach to delisting for several years, in the face of continued disagreement between WY and the USFWS. Although the states have continued to work together well at the field level on wolf management, at the policy level, there has been disagreement over whether MT and ID should join WY's litigation, or should increase pressure on WY to accept USFWS's terms.

The USFWS will make a final decision on delisting the NRM DPS in early 2008. Regardless of the decision, litigation is certain to follow.

Conclusion

The natural and accelerated recovery of NRM wolves has significantly affected both the biological and sociopolitical environment. Just as the return of wolves to the YNP ecosystem has cascading ecological effects that reach down through trophic levels reflected in changes in willows and even insects (Sime and Bangs 2007), there are equally profound and complex social, political and economic effects. Some of the issues raised are factually and socially straightforward and can be resolved with limited additional effort and resources. Many others will continue to challenge wildlife managers, policy makers and the citizens we serve for generations to come as landscapes, human attitudes and values evolve.

In theory, adaptive management principles should successfully link decisions to wolf ecology and population status, to the land, and to people. But, state agencies are also in a unique position to influence the outcome of the ongoing policy debates. Beginning with the decision in 1999 to enter this arena, MFWP chose to embrace the controversy in an open, inclusive manner that respects all interests and that demands all parties rely on scientific information and constructive dialog, as opposed to speculation and political rhetoric, as the basis for decision-making. Evidence of the benefits of this approach include the opening line of the report of the Montana Governor's Wolf Advisory Council, a 12-member citizen panel appointed to develop consensus-based recommendations as the foundation for Montana's Wolf Conservation and Management Plan: "We recognize wolves as a native species" (Montana Wolf Management Advisory Council 2000:1). It is also evidenced by broad support for the state's wolf plan by all segments of the public and by the recent comments of a Montana rancher at a hearing on the proposed rule delisting wolves in the NRM. Wolves have as much right to be here as I do, but they don't have the right to steal my livestock (Quigley 2007).

Taking and maintaining this approach has not been easy and certainly has its detractors who opportunistically seize and exploit perceived weakness or inconsistencies. It is challenged by litigation initiated by participants in collaborative processes, leading other participants to question whether all parties acted in good faith and are truly committed to consensus-based outcomes. Agencies will also find it difficult to affirm and sustain collaborative agreements through time, particularly given the involvement of all three branches of state governments and the national and international attention western wolves command. Furthermore, there are limits to the degree to which this approach can influence decisions by other jurisdictions, given the fact that MT is linked to other states.

Wildlife managers and policy makers face numerous unknown and unpredictable factors related to wolf management in the NRM. How we respond to that uncertainty and the political forces at play will determine whether the path forward is contentious and frustrating or constructive and progressive.

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Managing Human-Lion Conflicts

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Introduction

Of all the continents on earth, Africa contains the poorest countries, the least urbanized human population, and the most rapid human population growth. Of all conflicts between humans and large carnivores, the most challenging involves the African lion. No major wildlife African ecosystem is completely fenced, lions attack thousands of livestock throughout the continent each year and lions kill over a hundred people a year in southern Tanzania and northern Mozambique. Of the less than 50,000 lions still in Africa, about a quarter are found in four large well-protected ecosystems (Serengeti, Selous, Okavango/Chobe, Kruger); the rest are exposed to varying degrees of human contact and may not survive until the 22nd Century without intensive management.

Recent studies of human-lion conflict in eastern and southern Africa have shown three consistent patterns:

1. Humans directly retaliate against lions for killing livestock and people.
2. Traditional practices of livestock husbandry reduce but do not eliminate the risk of lion attacks.

3. Far fewer livestock are lost to lions than to disease or drought.

While these findings suggest that human-lion conflict might be managed to produce an acceptable level of risk to local communities, it is clearly urgent to identify effective low-lost mitigation strategies. Highly invasive responses such as erecting fences are not only infeasible (e.g. the Selous is the size of Switzerland) but ecologically unacceptable (e.g. trapping migratory ungulates inside fenced reserves), whereas translocating people or problem lions would be politically unacceptable.

For the past five years, my research group has conducted intensive field research on the ecology of human-lion conflict across three geographical regions of Tanzania:

1. The Tarangire/Manyara ecosystem is typical of many migratory systems where only a core dry season refuge was gazetted as a National Park, while the wet season dispersal area has become increasingly occupied by agriculturalists and pastoralist Maasai over the past 20+ yrs.
2. The Ngorongoro Conservation Area was the world's first multiple land-use area, where pastoralist Maasai were allowed to remain inside the equivalent of a national park, provided that they retained their traditional way of life. Livestock predation is a way of life in the NCA, and the Maasai rely entirely on traditional husbandry practices.
3. Two southern coastal districts, Rufiji and Lindi, suffer the highest rates of lion attacks on humans in Africa. Rufiji District is adjacent to the Selous Game Reserve, but Lindi has no obvious source for its lion population.

In this paper I briefly outline the highlights of our group's work so far and outline possible mitigation strategies, first focusing on cattle-killing and then on man-eating. Our research is still at a formative stage of development, so any conclusions must be considered tentative.

Cattle-killing

Tarangire. Bernard Kissui's research in the greater Tarangire ecosystem has shown that lions, leopards and spotted hyenas are the three major predators on livestock, but the lion is most vulnerable to retaliatory killing (Figure 1). Lions are exceptionally vulnerable to retributive killing by pastoralists compared to hyenas and leopards for several reasons (Kissui, in review). First, lions are more likely to defend a livestock carcass against humans, exposing them to frequent confrontations which they inevitably lose. In contrast, hyenas are shy of people, moving well beyond the reach of humans after a livestock attack, whereas leopards can successfully hide themselves. Second, lions engender more human resentment by mostly killing cattle, which have more value to pastoralists than the sheep and goats typically attacked by hyenas and leopards. Third, in contrast to the nocturnal attacks of leopards and hyenas, most lion attacks occur during the day, when people are armed and prepared to defend their stock, and searching for predators is far easier during the day. Fourth, Maasai culture contributes to the vulnerability of lions to retaliatory killing through the practice of *Ala-mayo* where a young warrior can prove his courage by killing a lion (see below). But over the past few years, almost every lion hunt in Tarangire has been in retaliation for cattle killings.

Ngorongoro Conservation Area. Dennis Ikanda's research in the NCA has revealed two factors that greatly increase the risk of lion attack on Maasai grazing cattle (Figure 2). Lions can apparently distinguish warriors from children and monitor how well herds are tended (Ikanda and Packer, in review), because attack rates were over five times higher when cattle herds were tended solely by children than by warriors (*Morani*) and nearly four times higher when over 150 cattle were tended by each herder. But in contrast to studies elsewhere (e.g. Woodroffe and Frank, 2005), we were largely unable to explain why some bomas suffered higher predation at the kraals than others. The risk of attack was not deterred by the presence or number of domestic dogs or by the type of building materials used to construct the kraals. Perhaps the average level of defense against nocturnal depredation is so high in the NCA that livestock attacks at the kraals are essentially random, and some families are merely unlucky.

Also in contrast to Tarangire, the Maasai in the NCA do not strictly kill lions in retaliation for cattle depredation. Although there is a broad correlation across the major regions of the NCA in the number of lions killed vs. cattle killed by lions, far more lions were killed in one area (known locally as Angata Kiti) compared to cattle predations (Figure 3a). This is the same area that is most commonly visited by nomadic lions from the Serengeti following the annual wildebeest migration each wet season (Figure 3b), and most lions are killed during the wet season in Angata Kiti whereas there is no seasonal pattern to livestock depredation in this area. Interviews with Maasai revealed that young *Morani* would come to Angata Kiti each year just for the opportunity to participate in an *Ala-mayo*, or ritual lion hunt.

Mitigation strategies for Maasai-lion conflict. Results from the NCA project suggest that the incidence of lion attack on cattle could be greatly reduced by simply encouraging the Maasai to send their children to school (consistent with Tanzanian Government policy of attaining universal literacy) and to break their herds into smaller units so as to maintain a more favourable number of livestock per herder (also consistent with Tanzanian Government policy of reducing the environmental impact from overgrazing). Although lions are less likely to attack the kraals at night when compared to other predators, nocturnal lion attacks are sufficiently common to fuel widespread resentment by the Maasai. Bernard Kissui has found that many of the bomas around Tarangire are so flimsy that a nocturnal predator merely has to provoke a stampede to get the livestock to break out of their kraals, whereupon they can be easily caught. Kissui has successfully convinced five Maasai families to reinforce their kraals with chain-link fencing, which has so far prevented any nocturnal losses to predation. Most importantly, each family paid for the fencing themselves – in most cases by selling off a large cow and using the money to buy the fencing and a small calf – effectively maintaining a constant herd size. More and more families are expressing interest in the program, and it remains to be seen whether the strategy will remain effective as reinforced kraals become more common and spread through the region.

Man-eating

The Problem. Figure 4 shows the number of lion attacks on humans reported across Tanzania between 1990 and 2004. The incidence of attacks increased from an average of about 30 cases per year in the early 1990s to over 100 in 2004. Most cases were concentrated in the coastal districts in the southern part of the country, and reports suggest that the problem extends a similar distance across the border into northern Mozambique (C. & K. Begg, pers. comm.). The most striking aspect of this problem is the remarkable boldness and persistence of these man-eaters, attacking people in the middle of a village, pulling people out of their thatched houses, snatching children out of their parents' arms. The repeated emergence of man-eating lions in this southern coastal area stems from two primary ecological factors: a low density of "normal" lion prey (e.g. wildebeest, zebra, buffalo, gazelle) and a high abundance of bush pigs (Figure 5).

The role of bush pigs can hardly be overstated. People in this part of the country are agriculturalists who mostly grow rice, maize and cassava, as well as cashews and coconuts. The coastal climate promotes the growth of thick vegetation, and cashew trees also provide excellent cover for lions. Although plains ungulates have largely been extirpated by the agricultural communities, the omnivorous bus pigs thrive in disturbed habitats and are serious nocturnal crop pests. The impact of the nocturnal pigs is so great that a farmer and his family will often sleep in a temporary structure (*dungu*) in the middle of their field so as to be able to chase away any pigs during the night. The lions here appear to live primarily on bush pigs, so they often follow the marauding pigs into the farmers' fields where they eventually encounter easy prey in a *dungu*. Lions mostly attack humans at the same time of night when they catch their normal prey, and most human victims are alone at the time of the attack.

Mitigation strategies for man-eating lions. Our research has suggested several possibilities for reducing the villagers' risks of attack. First, in other parts of Tanzania, agriculturalists dig trenches around their fields specifically to exclude bush pigs. This technique is not employed in the southern part of the country, perhaps because the population is mostly Muslim with an aversion to pigs and pork. Even if a pig-exclusion project did not greatly reduce the long-term risk of lion attack, it would at least reduce crop losses to the bush pigs – generating more revenue that villagers could apply to other strategies. A corollary to this approach would be to encourage trophy hunting or meat consumption of bush pigs. Pigs are impossible to eradicate, but systematic harvest of the pig population could have positive consequences for humans and reduce their conflict with lions.

Second, a surprising number of people are attacked while going to their outhouses during the night. Most villagers lack any sort of fence around their houses, and although chain-link fencing would be prohibitively expensive for these communities, any sort of visual barrier (bamboo or woven sticks) between themselves and the lions might lower their risks of attack.

Third, local people are ill-equipped to respond to man-eating lions themselves, and lions in these areas appear to be extremely secretive. A well-trained team might be able to eradicate a man-eater before it could kill again. Slow government responses to man-eating outbreaks in the past have often led people to fight back with fishing nets, sticks and spears, resulting in further human fatalities. Recently, though, people have discovered that rat poison is a simple way to kill a lion, and they have taken to lacing the carcasses of half-eaten people, livestock and bush pigs, so perhaps lions will simply be exterminated in many of these areas in the next few years. But some proportion of man-eating lions presumably originate from the Selous Game Reserve (and in Niassa Reserve in northern Mozambique), so the problem will never go away entirely.

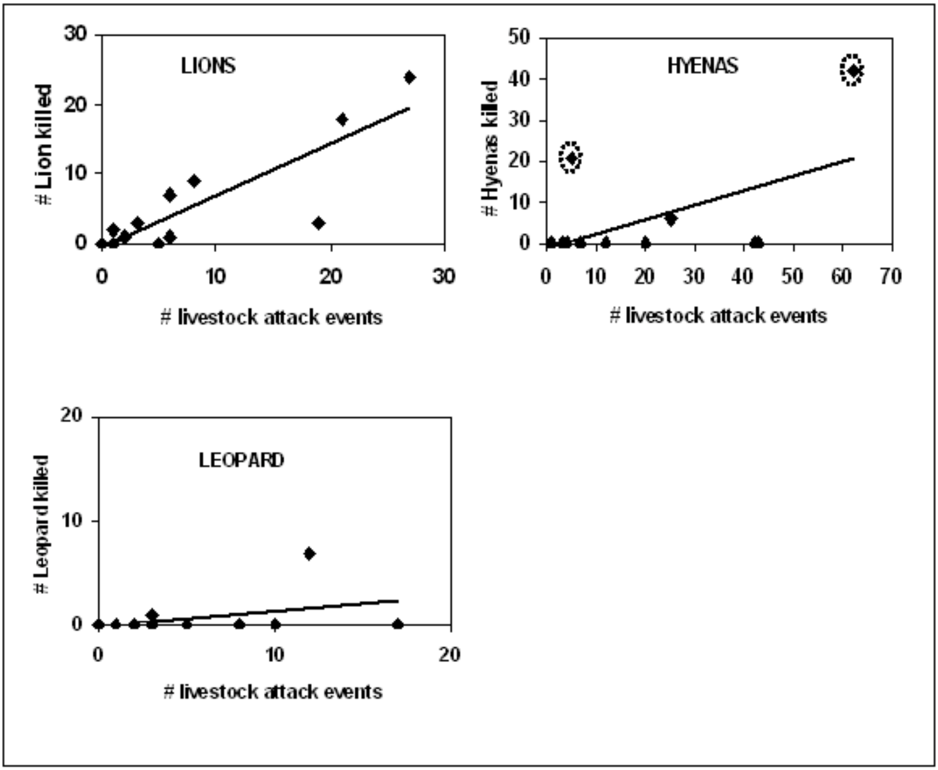


Figure 1. Relationship between the number of lions, hyenas and leopards killed by pastoralists in each village and the associated number of attack events by each species. Dotted circles indicate two villages that reported frequent use of poison against hyenas. Taken from Kissui (in review).

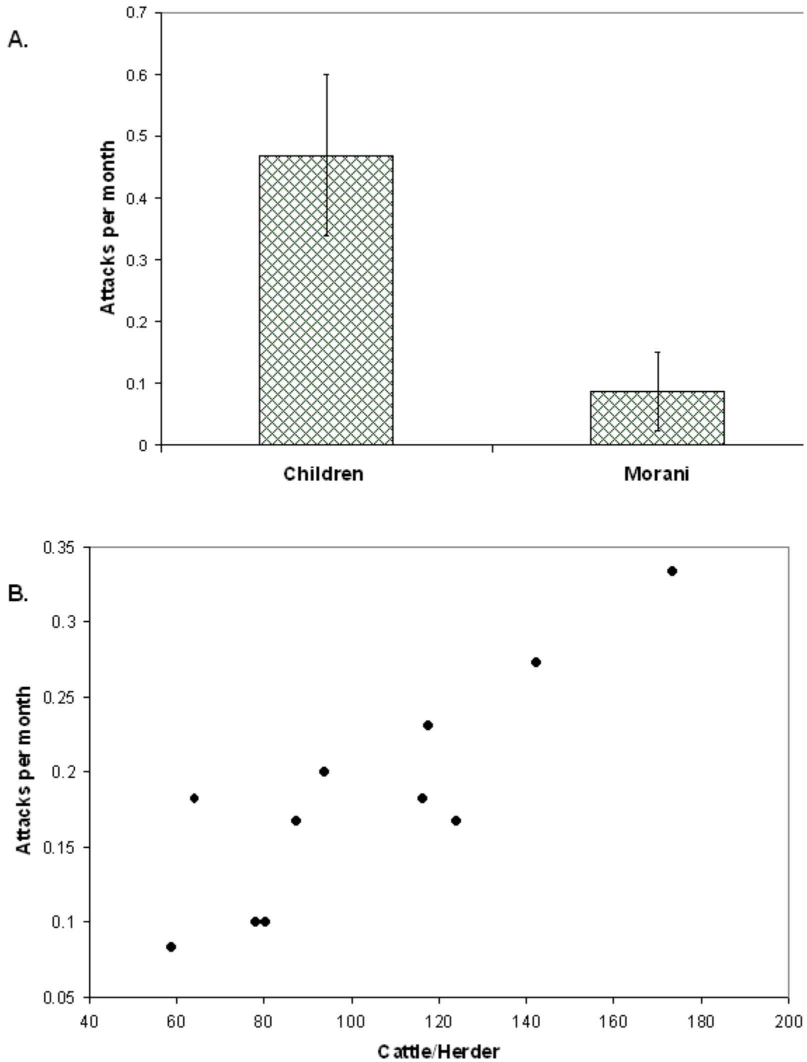


Figure 2. Monthly risk of depredation on grazing herds of cattle in the NCA. (**A**) Herds tended solely by herdboys suffered higher rates of

depredation than herds tended solely by *Moranis* ($p = 0.05$); vertical bars indicate standard errors. (**B**) Risk of attack increased with the average number of cattle tended per herdsman ($p = 0.0006$). Taken from Ikanda & Packer (in review).

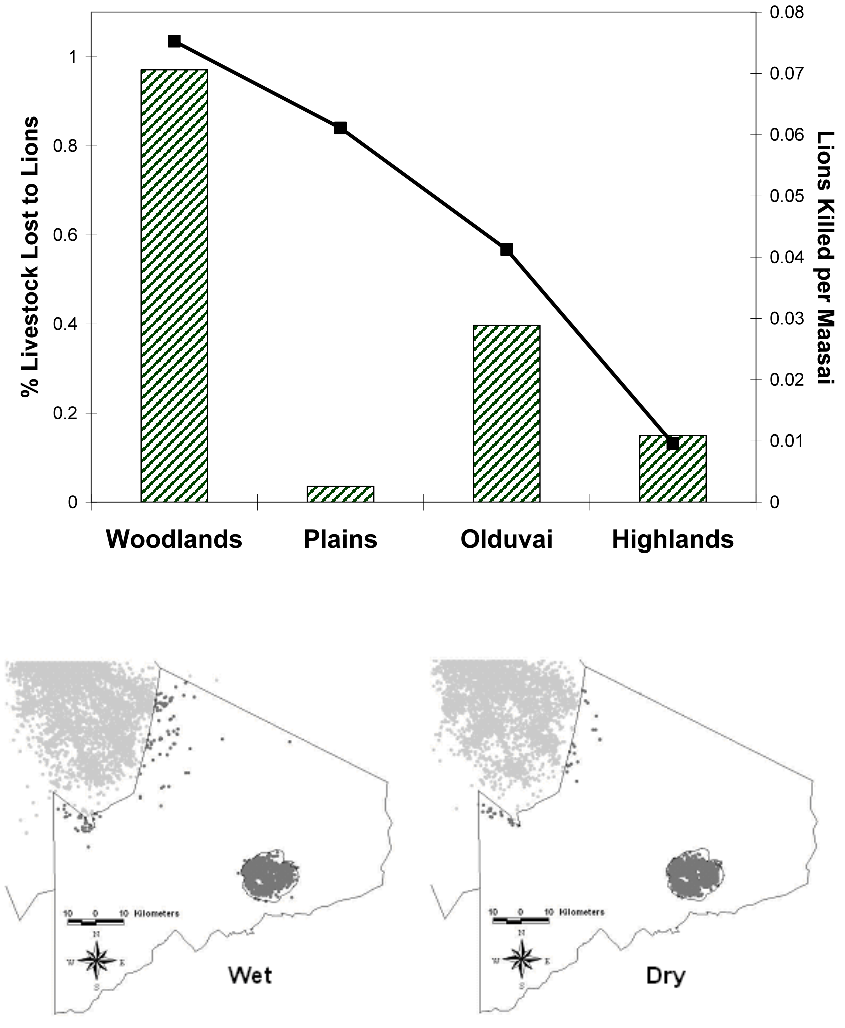


Figure 3. Spatial pattern of lion attacks and lion sightings in the NCA. **A.** Percentage of livestock lost to lions (hatched bars) vs. lions killed per Maasai (black line) across four broad geographical areas in the

NCA. **B.** Lion sightings by the Serengeti lion project 1984-2004 inside Serengeti National Park (grey) and in the NCA (black), as well as of Ngorongoro Crater lions (also black; all of which were in/near the Crater) during the Wet and Dry seasons. The northern-most part of the NCA includes Angata Kiti. Taken from Ikanda & Packer (in review).

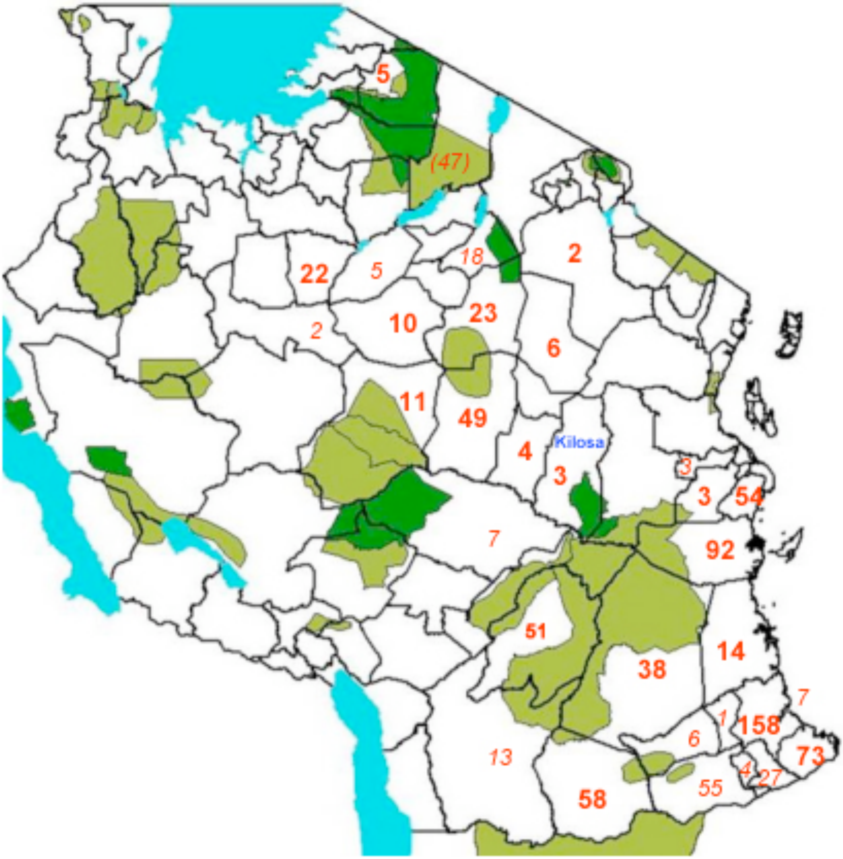
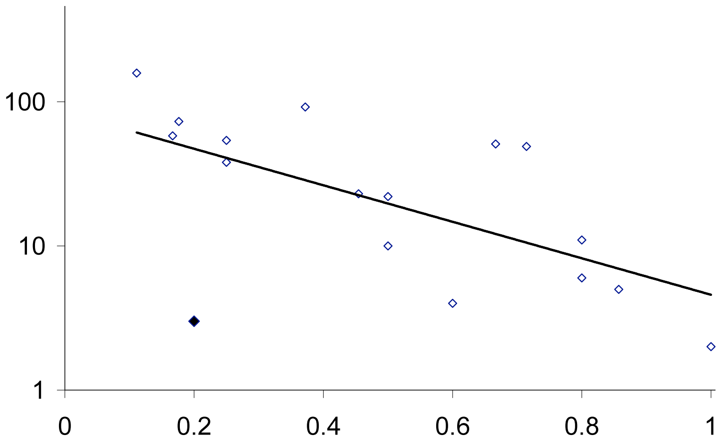


Figure 4. Map of Tanzania showing the number of lion attacks on humans Jan. 1990 - Sep. 2004. Bold numbers show districts surveyed directly; italicized numbers rely solely on reports to the Wildlife Division. Number in brackets indicates data collected by D.I. Dark green areas are National Parks; light green areas are Game Reserves. Taken from Packer et al. 2007.



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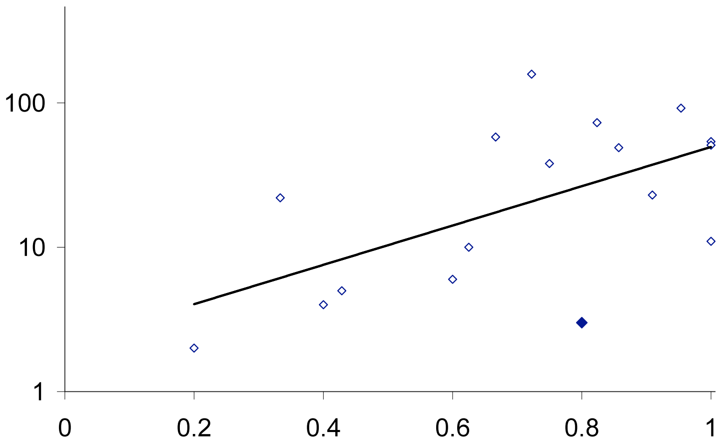

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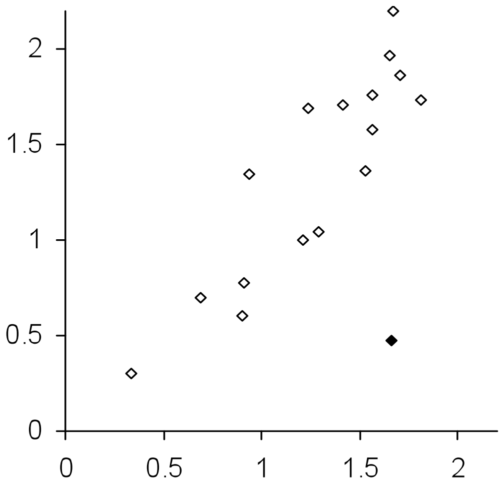

Figure 6: Ecological factors influencing number of lion attacks in 17 districts. **A.** Abundance of mid-sized prey, P=0.0091, n=17. **B.** Abundance of bush pigs, P=0.0129. **C.** Predicted number of attacks from multivariate regression model including both factors, adjusted r^2= 0.45, P=0.0059, n=17. Solid diamond refers to Kilosa district where villagers were relocated out of problem-animal areas in 1992. Taken from Packer et al. 2007.

Managing Predator-Prey Systems: Summary Discussion

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Introduction

Managing predator-prey systems involves complex challenges for resource managers. Inherently dynamic population fluctuations, multi-species interactions, and trophic cascades make it difficult to anticipate the outcome of wildlife management activities and decisions. When combined with the economic-socio-political dimensions of predator control, identifying optimal management policies can frustrate the most-seasoned wildlife biologist.

We have enlisted a diversity of case studies and perspectives for this workshop spanning a spectrum of issues concerning wildlife managers attempting to manage both predator and prey. Wildlife managers are increasingly being challenged to accommodate a broader perspective of ecosystem management (Boyce and Haney 1997). Many studies have demonstrated population consequences of predators on prey populations, but how managers should use this information is not easy to decide. Predator control can be effective at enhancing survival and recruitment in populations of prey, but certain methods for controlling predators sometimes meet with fierce resistance from the public. Society demands that wildlife managers take a broader perspective on predator management than focusing solely on enhancing populations of those species preferred for hunting.

Accommodations can be made to allow predators to coexist with humans. In some instances this might entail reduced or altered hunting yields for prey species (Nilsen et al. 2005), and compensation for livestock raisers. Still, predators are appreciated in their own right (Weiss et al. 2007), and can offer opportunities for hunters and trappers to become part of the solution (Hammill 2007).

Ecosystem role of predators

Conservation focused at top predators can be justified ecologically because of the benefits to biodiversity (Sergio et al. 2005, 2006). The potential role of predators in structuring ecological communities has been recognized for some time (Errington 1967). For example, overexploitation of sea otter (Enhydra lutris) populations resulted in increases in sea urchins that subsequently destroyed kelp beds that provided habitats for fish and other marine organisms (Estes et al. 1998). Because of such complexity of food webs in ecological communities, it is difficult to anticipate the full ramifications of eliminating or restoring predators. For example, reducing predator numbers to increase abundance of prey can have counter-productive results such as increasing disease and parasite infections in prey (Packer et al. 2003).

Predators appear to have top-down influences in many ecological communities, resulting in trophic cascades, i.e., predators reduce herbivore abundance releasing vegetation (Terborgh et al. 2006). Several studies have documented trophic cascades associated with wolf

(Canis lupus) recovery in Yellowstone National Park, meaning that wolves have changed the distribution of habitats used by elk (Cervus elaphus), which has released aspen (Populus tremuloides; Ripple and Beschta 2004) and willow (Salix spp.; Beyer et al. 2007) from herbivory (Fortin et al. 2005). Subsequent increases in aspen and willow have provided habitats for a diversity of other species including songbirds and beavers (Castor canadensis), thus wolves influence many levels of the ecosystem (Hebblewhite 2007). Likewise, human activity associated with tourism has displaced cougars (Puma concolor) in portions of Zion National Park resulting in concentrations of mule deer (Odocoileus hemionus) that suppress vegetation, i.e., a trophic cascade (Ripple and Beschta 2006). Maintaining top-level predators is viewed to be an essential component of maintaining natural ecological processes in national parks (Boyce 1998).

Conflicts with predators

Although society recognizes values associated with maintaining predators (Weiss et al. 2007), there are many circumstances when predators can come in conflict with human interests. For as long as humans have maintained domestic animals we have had conflicts with large predators that kill livestock. Public reaction is often intense when predators kill pets, and cougar and wolf predation on dogs is relatively common and apparently increasing (Treves et al. 2002; Beck et al. 2005). Likewise, humans themselves are occasionally killed by large carnivores, triggering fear and resentment towards offending animals (Packer and Kissui 2007).

Mesocarnivores, including red fox (Vulpes vulpes), raccoon (Procyon lotor), striped skunks (Mephitis mephitis), and coyotes (Canis latrans), can have substantial consequences to waterfowl nesting success (Rohwer and Fisher 2007), and likewise have been shown to suppress populations of bobwhite (Colinus virginianus; Carroll et al. 2007) and ring-necked pheasants (Phasianus colchicus; Hollevoet amd Dixon 2007). Predator control has been practiced by game keepers in Europe for many decades (Redpath et al. 2004), and is increasingly used to support gamebird production in North America (Rohwer and Fischer 2007).

With expansion of cougar and wolf populations in North America during the past decade, wildlife managers are faced with a new dimension in trying to manage big game populations in the face of predation levels that did not exist in previous decades. In Alaska and Canada, managing ungulate populations in the face of wolf predation has been a continuing source of debate and controversy (National Research Council 1997). Wolf control is used to reduce predation on moose (Alces alces) in Alaska and the Yukon (Hayes et al. 2003; Titus 2007). Cougars and bears can be a substantial source of mortality on ungulate populations (Munro et al. 2006; Harris 2007; Knopff and Boyce 2007), but these species are less often targeted for predator control.

Lethal predator control often attempts to target offending individuals. This is particularly well justified in the case of cougars because of the high levels of prey specialization that have been documented among individuals of this species (Knopff and Boyce 2007).

Methods used for managing predators, and associated public perception, are a crucial consideration in developing effective systems of management for predators and prey. Wolf control by aerial gunning, poisoning, or killing pups at the den meets strong public opposition. Even though the great majority of wolves killed by humans in Alaska are taken by hunting and trapping, it is the relatively few wolves killed by aerial gunning of wolves that evokes such bitter controversy over wolf control programs (National Research Council 1997).

Predators can sometimes be a serious threat to species at risk of extinction. For example, control of exotic red fox has been used to increase reproductive success and survival of greater sage-grouse (Centrocercus urophasianus) in Utah (Baxter et al. 2007), and California clapper rails (Rallus longirostris obsoletus) in California (Harding et al. 2004). Predator control can be a crucial element in protecting threatened or endangered species. Wolf control is being practiced in Alberta to protect dwindling populations of woodland caribou (Rangifer tarandus tarandus). And cougar culling is used to protect endangered populations of desert bighorns (Ovis canadensis) in New Mexico (Rominger 2007).

Coexisting with predators

Managing game populations for hunter harvest becomes more complex when predators are competing with humans for the same prey. Adjustments to harvest regimes may be necessary, but certainly we can have sustainable harvest of populations under predation (Nilsen et al. 2005). Elk on the northern range of Yellowstone National Park are harvested by hunters when they move into Montana during winter. The sustainability of this harvest is ensured because the Montana Department of Fish, Wildlife and Parks has density-dependent harvest guidelines so that the number of tags issued for the late-Gardiner elk hunt increases with the number of elk censused on the northern range (Varley and Boyce 2006). This helps to balance the hunter harvest with wolf predation ensuring that the elk population is not driven to low levels by excessive hunter harvest. Models have been developed that permit harvest guidelines while accommodating predators (Nilsen et al.

2005; Varley and Boyce 2006) and these can be used to achieve sustainable yields. Clearly, however, application of such models will require data on ungulate herds and predator populations.

We believe that predator management requires ecosystem management and this must include careful consideration of habitats as well as the particular predator and prey populations (Boyce and Haney 1997). Hollevoet and Dixon (2007) provided a conceptual framework whereby predators are managed in a manner similar to their prey. Management and population goals are determined and a potential suite of management activities are implemented based on desired outcomes. Management actions include adjusting season length and bag limits for hunters and trappers, but must also include other activities such as management of habitats that provide secure areas for prey. Ecosystem management acknowledges the value of predators in the environment and may reduce the need to engage more Draconian management activities.

Conclusions

Lethal control of predators is a highly controversial wildlife management practice (Niemeyer 2007). The practice appears to be more accepted when it is used to protect a threatened or endangered species (Dekker 2006), especially when control targets an exotic species of predator (Harding et al. 2001; Baxter and Bunnell 2007). Public resistance to lethal control of predators is most severe when predator populations are low, or when the sole justification is competition between predators and humans for the same prey.

Controlling predator populations to reduce predation on a threatened or endangered species may be difficult to achieve. Keeping wolf and cougar populations in check might require reducing alternate prey (Gibson 2006; Wielgus 2007). Control of abundant mule deer populations in the Sierra Nevada mountains of California might be required in addition to reductions in cougar numbers to prevent extirpation of Sierra Nevada bighorn sheep populations (Gibson 2006). Industrial development in areas occupied by the Little Smoky caribou herd in western Alberta has increased the abundance of moose and deer. Consequently, the Alberta government has issued additional hunting permits for moose and deer in an attempt to reduce alternate prey for wolves, hoping to reduce wolf numbers and thereby predation pressure on caribou. Yet, the ultimate cause for the decline in caribou is habitat alteration due to industrial development (McLoughlin et al. 2003; James et al. 2004). The only long-term solution must involve habitat management (see Hollevoet and Dixon 2007).

Human harvest of prey can be in competition with predators. This has resulted in political pressure on state and provincial governments to reduce predator numbers. One approach is to do this with recreational hunting and trapping of predators. Predator hunting is increasingly popular in many areas, and fur trapping also can be used to help control predator populations. In Alaska, for example, the majority of wolf removals are by recreational hunting and trapping with aerial wolf control contributing a relatively small proportion of total wolf removals (see Figure 1 in Titus 2007). In other areas, however, harvest of predators is low because there are few hunters or trappers skilled in removing predators (Zager et al. 2007). Also, in recent years low fur prices have reduced the incentive to trap predators.

We believe that wildlife managers have not fully taken advantage of the opportunity to involve hunters and trappers in harvesting predators, and we need to understand how to use these people more effectively in predator management (Hammill 2007).

Even though large numbers of predators are taken by hunters and trappers, they often are not very effective at achieving predator control (Zager et al. 2007) because predators are not removed from populations where predator control is most needed. However, bounties are viewed negatively by the public, and bounty systems are easily abused, e.g., claiming bounties for animals taken from non-target areas. Other incentives should be considered for focusing the efforts of hunters and trappers.

Non-lethal methods for deterring predators sometimes can be effective at reducing wildlife and livestock depredation on a local scale (Musiani et al. 2003; Shivak 2006). These include fladry, electronic guards, and radio-activated guards. Although expensive, invasive, and labor intensive, contraceptives can be effective at limiting wolf numbers, at least temporarily (Hayes et al. 2003). Finding effective ways to manage predator-prey systems in ways that are effective while remaining sensitive to public opinion will continue to be a challenge for wildlife managers. Several speakers in this workshop have indicated the importance of engaging human dimensions research to understand public responses to predator management (Mansfield 2007). We need to know which forms of predator management are most acceptable to the public and when predator control is justified.

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