8th Biennial Scientific Conference on the Greater Yellowstone Ecosystem

Greater Yellowstone Public Lands

A Century of Discovery, Hard Lessons, and Bright Prospects

Proceedings

Edited by
Alice Wondrak Biel

Greater Yellowstone Public Lands

8th Biennial Scientific Conference on the Greater Yellowstone Ecosystem

Greater Yellowstone Public Lands

A Century of Discovery, Hard Lessons, and Bright Prospects

Proceedings

Edited by Alice Wondrak Biel

Yellowstone Center for Resources
Yellowstone National Park, Wyoming
2006

Design: Alice Wondrak Biel

Suggested citation: Name of author(s). 2006. Paper title. Page(s) __ *in* A. Wondrak Biel, ed., *Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects.* Proceedings of the 8th Biennial Scientific Conference on the Greater Yellowstone Ecosystem. October 17–19, 2005, Mammoth Hot Springs Hotel, Yellowstone National Park. Yellowstone National Park, Wyo.: Yellowstone Center for Resources.

For ordering information, contact: Resource Information Office, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190; (307) 344-2203.

Greater Yellowstone Public Lands Program Committee

Charles Preston, Draper Museum of Natural History, chair
Hank Harlow, University of Wyoming
Kathy Tonnessen, National Park Service
Rocky Mountains Cooperative Ecosystem Studies Unit
Mary Maj, Greater Yellowstone Coordinating Committee
John P. Allen, U.S. Forest Service, Gallatin National Forest

Cover and frontispiece photos courtesy National Park Service.

This document was produced by the Resource Information Team, Yellowstone Center for Resources.

Contents

Foreword

Since Yellowstone National Park's establishment, its extraordinary resources have been protected largely through the efforts of generation after generation of park managers and friends. The challenges facing park managers have grown increasingly complex, and today, effective protection of the parks' natural and cultural treasures requires active, informed management based on good science—science conducted by researchers outside, as well as inside the National Park Service. It also requires partnerships of the sort exemplified by the Greater Yellowstone Coordinating Committee (GYCC), a sponsor, subject, and major participant in this event.

The purpose of the Greater Yellowstone conference series, instituted in 1991, is to encourage awareness and application of wide-ranging, high-caliber scientific work on the region's natural and cultural resources. The wealth of subjects and issues to be explored in Yellowstone National Park provides an unbounded font of research possibilities, as well as an unflagging need for their results. This biennial conference series provides a much-needed forum for knowledge sharing among park managers, the general public, and the hundreds of researchers doing work here.

The Eighth Biennial Scientific Conference, *Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects,* reached across agency boundaries to focus on the mandates, "cultures," relationships, and accomplishments of the numerous local, state, and federal management agencies responsible for Greater Yellowstone's public lands. The conference's featured speakers were interagency (U.S. Forest Service Chief Dale Bosworth, former chief Jack Ward Thomas, former National Park Service Intermountain Region Director Karen Wade), interdisciplinary (fire ecologist Monica Turner, conservation biologist Rick Knight, art historian Sarah Boehme), and international (Harvey Locke of the Yellowstone-to-Yukon Conservation Initiative). Other conference highlights included a panel of current and former GYCC members, an extensive poster session, and 48 additional presenters who participated in panels and sessions on history, mammals, biocomplexity, water resources, fire, human values, native plants, and trophic cascade questions, all with a cross-agency or cross-boundary perspective.

Greater Yellowstone Public Lands attracted the highest number of registrants (209) of any biennial conference to date. They included members of the public as well as scientists, authors, media representatives, and individuals from a number of government agencies. We hope these conferences and their proceedings continue to contribute to professional knowledge and debate on the many aspects of this extraordinary area.

S. Thomas Olliff
Chief, Yellowstone Center for Resources

Opening Welcome

Suzanne Lewis

Superintendent, Yellowstone National Park

Conference mission

The 8th Biennial Conference on the Greater Yellowstone Ecosystem was perhaps the most immediately pragmatic of them all, and the one of most direct use to public land managers. Conference participants focused on the mandates, "cultures," relationships, and accomplishments of the numerous local, state, and federal management agencies responsible for Greater Yellowstone's public lands. The hundredth anniversary of the U.S. Forest Service, in 2005, was a fitting time to reflect on the evolution of all of Greater Yellowstone's land management agencies. Are the "conflicting mandates" of these agencies really the problem they've been portrayed to be? Do past or future opportunities provide a context for examining the direction of critical ecological issues, such as threatened and endangered species, ecosystem integrity, alien species invasions, migration corridor protection, and fire management? As important, what are the prospects for long-term planning, scientific information exchange, sustainable recreation, and community prosperity? What new social and ecologic paradigms and perspectives may serve the needs of the region?

Ladies and gentlemen, my name is Suzanne Lewis, and I am superintendent of Yellowstone National Park. It is my pleasure and honor to welcome you to the Eighth Biennial Scientific Conference on the Greater Yellowstone Ecosystem. I bring you this welcome not only on behalf of all of us who work in the park, but on behalf of our many co-sponsors throughout Greater Yellowstone.

I hope that many of you were here for the showing of *The Greatest Good,* the magnificent new film about the history of the U.S. Forest Service. We in Yellowstone take special pride in the role this region played in the development of the national forests. Historian Aubrey Haines has said that the creation of the original timber reserves to the east and south of Yellowstone National Park in the 1890s, which later became the first national forests, stands as "the finest achievement of the Yellowstone crusade." This thought, of Yellowstone not as a park but as part of a broader movement, gives us a new slant on Wallace Stegner's famous statement that the national parks are the best idea America ever had. In fact, the parks were just part of the best idea. The national forests, the wildlife refuges, *and* the national parks that share sponsorship of this conference are all part of the same *greater* best idea. And as everyone here knows, every day the management of the public lands in the Greater Yellowstone Ecosystem provides us with both a grand showcase and a stern test of that best idea.

Back when we sent out the call for papers for this conference, we were excited at the prospect of a conference that offered an in-depth examination of public land management in Greater Yellowstone. We had our moments of uncertainty—of wondering if we could really put such an ambitious thing together. But the agenda fulfills our hopes. More than any previous gathering in this very productive conference series, the meetings we begin today have engaged the managers of public lands throughout the Greater Yellowstone Ecosystem. Though you will hear plenty of the latest and finest science, you will also hear from some of the most thoughtful and influential managers in the recent history of our region. The long, complicated conversation over Greater Yellowstone that we initiated with the first of these conferences 14 years ago has never been so essential, so challenging, or so full of hope.

I don't want to stand in the way of that conversation, so let me close with a few thank you's and housekeeping notes.

The major players who put this conference together are all listed in the front of your agenda booklet, but on behalf of the conference co-sponsors I simply must thank some people. The planning committee are the logistics soldiers—the people who take care of the thousand details that just have to be remembered. Virginia Warner, Roger Anderson, Tami Blackford, Paul Schullery, Alice Wondrak Biel, Tom Olliff, Joy Perius, and John Varley have handled those responsibilities this time, and I know that the entire team would agree that Virginia Warner deserves special recognition for coordinating all this planning so smoothly.

The program committee are the scientific organizers. They review all the abstracts, make the tough decisions, and create the agenda for the sessions you are about to enjoy. Chairman Chuck Preston, Hank Harlow, Kathy Tonnessen, Mary Maj, and John Allen have done their job superbly. A special thanks to Chuck and Hank, who are veterans of previous program committees and yet were still willing to come back and do it again.

Our friends at Xanterra Parks and Resorts have come through as they always do. Tracy Diem, Brad Harbach, Debbie Fellows, and all the folks who are taking care of us at the hotel and dining room are a big reason this conference series has flourished.

These conferences might still be a little too big for us to pull off if it weren't for a great many enthusiastic volunteers—all the people who ensure that lights go on and off at the right moment during sessions, that microphones get handed to the right person at the right time, and take care of many other small but essential chores.

Please join me in thanking all of these folks for their hard work getting ready for today [*applause*].

During your stay, please remember that we in the National Park Service are at your service. If we can help you in any way, please let us know. The team of park staff and volunteers who are hosting this conference are easily identified, but you should consider any of us wearing the grey and green of the National Park Service to be available to answer your questions or provide you with other assistance.

Finally, for those of you who are new to Yellowstone, one very important thing does distinguish this conference venue from most others. That one thing is the wildlife. Please—be very careful out there. Our neighborhood elk are preoccupied and unpredictable this time of year, and they demand your attention whenever you step outside. We who live here learn to keep our heads up and not go barging thoughtlessly around corners. Make caution a habit, and give these big, beautiful, distracted animals, both the bulls *and* the cows, plenty of room.

With that, I declare this meeting convened, I thank you all for joining us here, and I wish you success and wisdom in your exploration of Greater Yellowstone's Public Lands.

The Greater Yellowstone Coordinating Committee: Challenges of Today

Robert Barbee

Former Superintendent, Yellowstone National Park

Jack Troyer

Regional Forester, U.S. Forest Service Intermountain Region

Barry Reiswig

Refuge Manager, National Elk Refuge

Rebecca Aus

Forest Supervisor, Shoshone National Forest

Mary Gibson Scott

Superintendent, Grand Teton National Park

Note: The text that follows is an edited transcription of the panelists' remarks at the conference.

Remarks of Bob Barbee

Well, it's great to see a lot of old friends here, and familiar faces, still as youthful and vigorous as they were when I left here 10 years ago. At any rate, [Assistant Superintendent] Frank [Walker] and [Superintendent] Suzanne [Lewis], you know, if you hang around long enough and keep some of your marbles, you get invited to participate on panels to give an historical perspective. I never thought that that would ever happen [to me], but it does. And so here I am, and I'd rather do historical perspective than what some of these other folks are going to do, because they're looking into crystal balls and the future. I always thought that if you hang around crystal balls long enough, you end up with glass in your mouth. [But] I don't have to worry about that.

In preparing for my few remarks here, I went back and read all sorts of documents, including the infamous Vision Statement of the Greater Yellowstone. And all the controversy, the newspaper articles and stuff, it all came flooding back . . . like it just happened yesterday. It was quite a time.

Well, let me share just a few historical tidbits. Let's start with "Greater Yellowstone." When did that terminology get recognized? It so happens that it was coined a long time ago by Emerson Hough, who wrote an article in the *Saturday Evening Post* in 1917, sort of answering the State of Wyoming, because Wyoming was protesting the expansion of Yellowstone. So that's where the words were first used. [As far as we know], John Craighead, one of the two Craighead brothers, the famous bear researchers, was the first person to use the words, "Yellowstone ecosystem." And so that became, and continues to be the watchword du jour, so to speak, for the Greater Yellowstone.

Now the GYCC. I know that people—superintendents, forest supervisors—communicated about things, probably way back. We know that. But by the 1960s, [it became more and more apparent that] some of these cross-boundary issues needed to be dealt with, and so . . . the GYCC was formed to address a lot of these cross-boundary issues and, sort of for the first time, to begin to deal with the Greater Yellowstone on kind of a landscape basis. Although those words weren't used. In 1984, I was over in my office [at Mammoth Hot Springs], and I got a call from a guy who said, there are a couple of us that want to come up and talk to you and your staff about a new organization that's forming. One, his name was Bob Anderson, and the other was Rick Reese. And those two individuals came and presented us with their new notion of forming the Greater Yellow-

stone Coalition. And they had no money, you know, it was all-volunteer, and so that was the start of the first real environmental special interest group, so to speak, that exclusively concentrated on the Greater Yellowstone. And of course we all know how that organization has evolved.

So the point here is [there was] lots and lots of interest in what was going on in the Greater Yellowstone, to the point that in 1985, the House Committee on Public Lands and National Parks and Recreation held a subcommittee meeting in Washington [D.C.] about the Greater Yellowstone Area. I testified there, along with a lot of other people. And at one point—it is somewhat intimidating as you sit there at the table and there's all these stellar figures up there, firing questions at you, but—I think [it] might have been Congressman [Mo] Udall [of Arizona, who] . . . asked me to define the word, "ecosystem." And I thought, oh my God, I can think of a thousand places I'd rather be right now than here [*laughter*]. But anyway, I said, "You know, I think I can probably do that, but there's somebody here (John Varley, who was with me, sitting out there in the audience) who can do a better job at it that I can." And to this day—there he sits over there—John Varley has not forgiven me. [Asks John:] Is that true? But as he always does, he rose to the occasion.

So the hearings were held, and more and more interest was developing about this. There was a lot of testimony, and the result was that the GYCC decided that we . . . needed to do something about all of this, and so Steve Mealey, the supervisor on the Shoshone [National Forest], hosted a meeting at a guest ranch called Blackrock over there on the way to Cody [Wyoming], and we had a little hermitage there. And so the GYCC and all kinds of bright staff people holed up there for several days deliberating on what we should do. And it was decided that we would aggregate all the . . . forest plans and park plans, . . . critically examine them, and put them side by side and see what we had. And so we did that. It took a tremendous amount of staff time, [but] there they all were. And [we saw], for the first time, [that] the emperor had no clothes. Because there were all kinds of little inconsistencies and that kind of stuff. It was a tremendously helpful and introspective exercise. [And] so . . . we . . . produced this big document, this plan aggregation document.

Well, all this sounds like kind of a yawn—ho hum, you know—but it was actually a very bold step. And then, well, what do you do next? [We thought] maybe we'd better get a statement of principles [out there] that we all [could] buy into. So we had more meetings ad nauseum about statements of principles, and then we had a big argument about what to call this. And the faction that wanted to call it the Vision for the Future won. And I don't even remember what I argued. I probably did [argue], but I don't remember. So anyway, out comes the notion that we're going to develop, out of all this, a statement of principles called the Vision for the Future: A Framework for Coordination in the Greater Yellowstone. And then enter Jack Troyer from the forest service and Sandra Key from the park service, who are going to shepherd this whole thing and be staff to the GYCC. And you know, Jack Troyer in those days was a vigorous, young guy with black hair, and now look at him [*laughter*]. [A]ctually, the only thing that's different is that his hair isn't black. Anyway, they set about this incredible exercise of developing the Vision, which was going to be . . . something not too extensive . . . and they helped the staff develop a document that turned out to be, after it was pared down, [about] 60 pages, I think it might have been, and we thought we had done some really good work.

Well. The reaction was swift, the reaction was emotional, and [it was] intense. It caught us completely off guard. And right away, there was opposition developing because of some of the wording in there. [People were saying], ". . . what they said is one thing, but what they really mean is that this is going to be a big federal lock-up." A land grab. And so the governors of the three states [Idaho, Montana, and Wyoming] signed a letter protesting [the document], and every organization you can imagine on the commodities side, including the Bankers' Association of Wyoming, all protested. We had support, but it was tepid. At least in my opinion. And so . . . of course you have to have public involvement. Lots of public involvement all over the place. And the momentum, and the opposition built. We had a meeting I can recall well—Jack [Troyer] can too, and others—in Bozeman [Montana]. There were 700 people there, and the opposition bused people in from all around. It was during the first Iraq war, and you know, yellow ribbons meant you supported the troops or whatever. But they all wore yellow armbands, the opposition. And the meeting turned into just the most incredible—we've all been to lots of public meetings, but this was unbelievable. We were "Nazis." We were "Communists." One guy got up, I still remember, and he said, "now, I haven't read this . . ." and I thought, well— ". . . but I have a lot of friends that I respect that have. And from what they say, this is bad." And

then another woman got up after that and she used her time to recite the Pledge of Allegiance. So it took on kind of a patriotic sort of thing . . . almost evangelical. And I thought, this thing—regardless of how honorable the effort and how incredibly professional the staff were—this thing is headed for the shoals. And . . . that's eventually where it ended up. And the nut of it all is that the politicians jumped into it, [and] the political appointees in Washington jumped into it, and we ended up with a little 10-page pamphlet [that] was sort of a watered-down, diluted version.

And so what did we learn about all this? Well, we learned that adventurism by the bureaucracy is not rewarded. You know, organizations, according to Peter Drucker, are set up to police the status quo. [W]e were clearly being adventurous, but it sounded . . . pretty bureaucratic . . . and all that. [W]e learned that technical correctness may not be politically expedient. And we learned that the media is not necessarily a window to the world. We learned that . . . a plausible explanation doesn't necessarily yield understanding. And we learned that virtue was not its own reward. And we probably should have done a better job [of] preparing . . . the various publics that we had to deal with.

So we learned a lot of things. But in the final analysis, it took casualties. One regrettable casualty was our regional director, Lorraine Mintzmyer. [S]he's a very principled woman, and I tried to say well, look . . . let's not fall on our swords here, because you know you win some and you lose some, and we'll still be here. There'll still be flowers in the rubble, and we can kind of pull this thing together and exchange a lot of relatively innocuous interagency memorandums and do a lot of stuff, and we can accomplish a lot of these things, and . . . that's really pretty much what happened. And so the process was not a failure. And the original Vision is still around. A lot of things that are in there happened—are happening today. The GYCC is still there, is still a very collegial group. I'm sure they, as well as we, talk with each other about things and focus on landscape-scope issues, and so life, you know, life is OK. And the sky really didn't fall. So anyway, that's sort of my historical summary of the GYCC. That's . . . the beginning. OK? Thank you.

Remarks of Jack Troyer

Well, Bob, since you came up here [to the podium], I guess I will come up here as well. It's been a pleasure to be here and [to] think about what we've learned and how this entire event can benefit the Greater Yellowstone and the Greater Yellowstone Coordinating Committee. [A] lot of thank-yous . . . could be made here, but I really want to thank Suzanne for [her] leadership role in kind of making this happen, and [for] including the forest service and our centennial celebration as part of this. Last night was so fun—Bob Barbee and I had a chance to reminisce a few stories, and we actually could have gone on for hours had there been time.

So . . . since Bob and I and the panel didn't rehearse, I'm going to delete the part of my talk that Bob already covered. He did a great job of it, and I'm going to try to add a little bit of historical perspective from more where I fit in[to] the process, add a few thoughts about today, and then [about] the GYCC for the future. So the first point I wanted to make was to reinforce what the chief [U.S. Forest Service Chief Dale Bosworth] said last night at that wonderfully memorable lights-out deal [Chief Bosworth spoke in the Mammoth Hotel Map Room during a power failure] that I think is better than if it would have been here [in the Mammoth Rec Hall], because we'll all remember it. But you remember, Dale talked about his personal appreciation of the role of the GYCC for 40 years, and it's important to remember that—that it really was a pioneer [organization]. That a lot of things did happen here first. And there's a lot of value in that. That first MOU [interagency Memorandum of Understanding] was signed in 1964. Clear back in 1979 . . . grizzly bear guidelines were published. Back in 1983, the bald eagle working group came in, so there were all of these very, very important things. Bob mentioned the Congressional Research Service report and the subcommittee hearings, and from my perspective, one of the key outcomes of that hearing process was the idea that there was a need for better coordination in the Greater Yellowstone, and there really was. The GYCC recognized that, and that's what led to the entire process of the aggregation that Bob so well described.

Another thing that happened about that time was the chief of the forest service, Max Peterson at the time, designated the regional forester in Denver (that's region 2 for the forest service), and then the director of the park service [designated] the park service regional director, [to be] the co-chairs of the Greater Yellowstone Coordinating Committee. During those years it was Gary Cargill and Lorraine Mintzmyer. So that kind of bumped the level of tension at the national level and in the Greater Yellowstone. Of course, we all know the process that happened.

I entered the picture in June of 1988. I remember my first day on the job, going from kind of a fast-paced life as a staff boss on the forest to wondering, OK, I was picked for this job. Now what am I going to do? I just remember having a couple of hours there thinking, oh, my God, what have I done by saying yes, I would do this job? One of the things that I remember thinking about was how to build support for the idea that issues did cross boundaries. We all knew that, but still, this was 20 years ago. The idea of interagency workings, and working across boundaries, and the forest service working outside the green lines so to speak, was not like it is today, and I think we kind of forget that. So as I was thinking about that, some fires were burning, and I remember a couple weeks later calling each of the eight fire management officers on the eight [USFS] units and asking them a series of questions about what they were doing. And then I just compiled the results and sent it all out to them. It was kind of obvious that we were coordinating OK on some cases and not on other cases. But . . . as the '88 fires moved ahead, they made the case that obviously fire, but also a lot of other things—[for instance] the noxious weed issue that followed the fires—truly crossed boundaries. And so there was really a very small job to do to build that case. That [case] was absolutely made.

[A] couple of the things that I think that are important to add to Bob's remarks are [one, that] unlike the GYCC meetings of today, which are what I think they should be, for three or four years there you couldn't have one without anywhere from 25–100 people from the public and the press being there. And that made the dynamics of how you worked together across boundaries—and the frank conversations that sometimes need to take place—this made that different. And after the Vision and the Framework documents were over, one of the things we hoped we could accomplish was to restructure the GYCC back to [having] the focus truly be on the supervisors and the superintendents, and then the fish and wildlife service as well. And that all happened, and that's a good thing. So I think the . . . regional foresters and the regional directors of the park service are . . . called ex-officio members, so to speak.

But anyhow, of the three regional foresters, I'm the forest service contact, and one of the roles that I do try to play is to be a resource for the GYCC managers. One of the things that I looked forward to by being up here and being able to talk today was to truly build support for the tremendous work that they are doing. . . . [R]egarding the Vision document and the Framework document, after 15 years you kind of get a perspective on what happened. There were three main goals in that first document. The first one was called Conserve the Sense of Naturalness and Maintain Ecosystem Integrity, and I believe a lot of the consternation that Bob talked about was caused by our inability, collectively, to articulate what we meant by "a sense of naturalness." And I think that was—speaking for myself—the key word in that whole process. And what the managers meant—I know it because Sandra [Key] and I remembered the eight of them debating this for hours—was not that nature would be taking its course on the national forests, but rather that the vision for the future was that there was a sense that this was really a wild place. I think it's maybe the most wonderful place in North America, when you think of the Greater Yellowstone as a whole. So that was a key goal, but it was also a key part of the communication issue that we had.

The second goal was to encourage opportunities that are economically and biologically sustainable, and the third was to improve coordination. There was a whole series of coordinating criteria that went under each one of those that were put together through an ID [interdisciplinary] team that we assembled, and I went through the six forest supervisors and the two park superintendents. So that's kind of how the process went. Bob described very accurately what happened between draft and final. . . . [A]s I look back . . . I think that it was a huge success that we were able to get that Vision document, the 60-pager, to a final [draft]. Because there were a lot of folks out there saying that we should not have a final—that [it] was a bad idea that two agencies with different missions would publish something like this. So we published it.

In hindsight, I think that the Vision document was of a lot more depth [than the Framework document], but there are very important things left in that 10-page Framework document. It was fun for me to go back and read those and look at what's happening now, and I really commend the GYCC for getting that stuff done. And if you look at some of the principles and guidelines in that Framework document, you'll see some things that were not exactly talked about in 1989 and '90, one of them being that there wouldn't be a net increase in open road mileage on the national forests. And the National Park Service said no net increase in roads.

At the same time this was all going on, there was a program the forest service called New Perspectives. But this was before we, the forest service, adopted

ecosystem management as our policy, and so talking about using the word “ecosystem” the way we were using it then was two or three years ahead of its time. So there were a lot of communication challenges, and I [wasn’t aware of] Bob’s story about trying to describe “ecosystem” in front of the congressional subcommittee, which would have been interesting in 1985. So we did get that to a final document, and I think that’s an important thing to recognize. Then . . . we sort of tried to disband the office that was known as the team leaders’ office, get it back to implementing the document, and I think that’s what happened. . . .

I watched with some interest because by this time I was in Wisconsin as a forest supervisor. There was a veritable growth industry here for a year or two [in] people writing stories about what went right and what went wrong with this process. A lot of folks said what we really needed at the time was a regional plan: “GYCC, what you should have done was collect about $20 million and done this right. Have a regional plan for the entire Greater Yellowstone, the whole 11 million acres.” They [argued] . . . that case. The GYCC did not believe then, and I certainly didn’t and don’t now, that that would have worked. I’m convinced it would not have worked. The reason I say this is that about three years later, we [tried that with the] forest service and the BLM [Bureau of Land Management] with the Interior Columbia Basin Ecosystem Management Project. Some of you know about ICBEMP, or CRB as it was known. Chief Bosworth was the regional forester at the time, and he’ll tell you a lot of stories about those six or seven years when we spent tens of millions of dollars trying to do that. The net result of that was that I don’t believe you can really come up with a one-size-fits-all, detailed plan for a huge area. I don’t think that’s the nature of things. So some good science came out of the ICBEMP project, but in the long run it ended up more with a statement of principles, similar to what happened with the Yellowstone project.

So with that little bit of history, I wanted to talk just for a couple of minutes about . . . four or five thoughts that I have. One thought is that (and I must have given 100 speeches about this in that job, but) I believe passionately today, like I did then, that the complementarity of the missions—[U.S.] Fish and Wildlife Service, [U.S.] Forest Service, National Park Service—in the Greater Yellowstone works well. And I think that you only need to take a drive through the Greater Yellowstone even today, in this busy world, and see the great resources that are there [to be convinced of that]. I think that that works well, and that I believe it’s a model for the future. I wanted to reinforce that I think that the four threats that the chief talked about last night absolutely apply in the Greater Yellowstone, and they’re going to get worse rather than better. I learned when I came on this job, and I believe it today, that [Greater Yellowstone] is a national and world treasure, and when things go wrong here in some manner, it’s going to make national headlines or world headlines because this place is so special.

In my view, the biggest threat for the future is absolutely not federal coordination here. I think it’s what’s going to happen to those five million acres of private lands in the Greater Yellowstone. It’s the [threat to] open space that Dale talked about last night. I think there’s been something like a 300% increase in private land development in the last 30 years, and that’s accelerating. So that to me is the challenge: working across boundaries with state governments and tribes in an interagency way, [with] NGOs, environmental groups, everybody. That, I think, is going to be key to the kind of Yellowstone that we have 100 years from now. . . .

I think the last thing that I wanted to say [was that] in terms of the six national forests here, . . . the day-to-day challenges . . . are very similar to [those faced by] typical national forests across the country. And that is there is so much work to do. There are so many trails to take here, so many more people visiting the forests, and we’re struggling to stay even and having fewer people on the ground than we used to. It doesn’t matter whether it’s owage fees or administering grazing allotments. The way the GYCC leverages partnerships to get more work done with fewer people is the way it has to be done; that’s the key to our future, and that . . . is a key point.

So I want to close by . . . saying that when I go back to the conversations that took place 15 or 20 years ago, a lot of the things that I think those six supervisors and two superintendents were hoping for the future have come to pass in terms of the way our forests and parks—and now the fish and wildlife service and others—work together. There are some wonderful examples that are part of this conference. There are posters about noxious weeds, for example—about what’s happening in the Greater Yellowstone, [which] was kind of an incubator for what’s happened around the country with noxious weeds. There’s the group of fire management planners and operations people that work together in the Greater Yellowstone to coordinate things, and their pub-

lished guidelines [from] the year 2000, I think, are a model. There's . . . the 2000 Watershed Management Strategy for the GYA [Greater Yellowstone Area], and I think Mark Story is here; he's probably going to talk about that at some point in time. I've got a list of about 10 of these, but I'm not going to go through all of them. You kind of get the point.

The GYCC is working with the Yellowstone Business Partnership to make sure that economic opportunities are part of the things that we're doing. I think that there was a wonderful western water law conference held last week in Cody that the GYCC was part of, and I've already heard great things about that from our national director of watersheds and wildlife in the forest service, Dan Zimmerman. So like I say, I could go on, but I won't because there's more examples. But if you take these examples that I'm talking about, then you go back to that Vision document and that Framework document, and look at those coordinating criteria, these are the kind of things that we hoped would happen those many years ago. So I think I would close by saying that very quietly, and I think efficiently, and in a competent manner . . . a very solid group of dedicated resource professionals have been in charge here [in] the last 15 years, and they keep moving us in the right direction. . . . This is my pep talk part of this, but the chief's here, he's got to listen to me, he's trapped here. The GYCC, as you heard last night, in his mind is very, very important. You're all here, so the more support we can give to that interagency working group is going to be better for us all. So I'm glad I had a chance to come up here and publicly say that. Again, Suzanne, thank you for the opportunity to be here. Thanks very much.

Remarks of Barry Reiswig

I was out on the lawn this morning looking at a band of elk out here, and John Varley came by, and he said, "You know, I'd expect you [to be] the last of all people standing out here looking at a herd of elk. Don't you ever get enough of that?" And I told him that I think in Jackson Hole right now there are five golf courses being planned. I don't know why anyone would build a golf course in a town that's buried in ice and snow for six months a year, but that's not my deal. But one of those courses is built across a migration route for elk, and the [Wyoming] Game and Fish Department warned the developers that of course elk would be attracted to this area. And they were ignored, and of course the course was built, and now the elk are on the golf course, and the owners are complaining that they're damaging their facility. So it kind of makes you wonder, you know, are we slow learners, or what? But so these issues—we just seem to keep doing them over and over.

Some folks have called this [area] the cradle of conservation. Yellowstone in 1872, the Yellowstone Timberland Preserve in 1891, the elk refuge in 1912, the Jackson Hole National Monument in 1929; it truly is one of the birthplaces of conservation in this nation. My own experience with this area started in 1974, I think, when I was driving through here. I was a college student heading back to my junior year in school, and I stopped here; I have a picture, in fact, that I took up at a lake on the plateau here of a trumpeter swan on a beautiful day with the mountains in the background. Little did I know how important that would become as part of my life later on. But there was something special about this place. And it's hard to describe. I've been to the Sierra Nevada, the Cascades, central Idaho, the Bob Marshall [Wilderness], Alaska, British Columbia, the Northwest Territories, the Yukon, but there's something special about this place that I don't feel in any other place I've ever been. Even though there are many other spectacular, wonderful places in North America. I don't know what that is. Is it the geyser basins? Is it the bears? What is it about this place that makes it so special? But I felt that when I was here just passing through here that time.

And I was fortunate enough, in 1983, to come back from Alaska to become the manager at Red Rock Lakes [National Wildlife Refuge]. And for a person like myself, that was really an ideal job. It was a very remote area, it was pretty wild country, it was stocked with some very interesting people. I think the chief last night talked about local people and their values and their importance. And I remember there were three Bill Joneses in the Centennial Valley, and so they gave them nicknames to tell them apart. There was a Whiskey Bill, a One-Eyed Bill, and a Horse Thief Bill. That not only . . . separated the three, it also gave you a little insight into these people's characters. And there were the Miller brothers. There was Bill and Link, and Bill was called Coke-Bottle Bill, because he had very poor eyesight and his glasses were so thick they looked like the bottoms of Coke bottles. And his brother Link was the mailman, and he delivered the mail in the Centennial Valley for 56 years. And he did it originally with a snowplane, because in the 1930s, when he started, there were no fences in the Centennial Valley, and he could run his snowplane up from Monida [Idaho], where they lived, up Monida Pass, up and down the valley, and

deliver the mail to all 11 different folks that lived up there. These folks are part of the character of the country; there are people like this all over this ecosystem. And the people have great concern and care about the land, and are very much a part of the fabric of this country.

I was also fortunate to be able to do a trumpeter swan survey. We did that twice a year. We did it in September, and then we did it again in February. We started at Ennis Lake [near Ennis, Montana] and we worked our way south, and I think we flew for anywhere from 35 to 40 hours, and we ended up at Green River Lakes [near Pinedale, Wyoming]. We did that in September, and then we'd come back and do it again in February. And it was just an awesome opportunity to see this, a snapshot of this country from the air. And it's something I've never forgotten. It is truly magnificent country. It is truly awesome country. And I was so fortunate to be able to participate in those surveys, and to be able to see this country. Trumpeter swans were easy to survey. You know—they weren't brown, they didn't hide in the trees, we didn't have any of those issues. They were white dots, and we could see them easily, we knew the ponds they were going to be in. So it was pretty easy to do that survey and still go out and look at the countryside and admire it.

And then in 1996, I came back as the manager of the National Elk Refuge, just about the time the GYCC was kind of going through a renewal. The agencies agreed to hire an executive director, there was funding set aside for projects, and at that time the [U.S.] Fish and Wildlife Service joined the organization. So we're the Johnnies-come-lately of the GYCC. But a friend of mine who is a professor at Yale, Tim Clark, and I know some of you folks may know Tim, he chides me all the time. He says, you guys really aren't doing much. And he envisions the GYCC as some kind of supermanagement team. His notion is that we should throw off the shackles of agency management and become kind of a supernova of management for this area. And I said, Tim, I don't think it works that way. I think most of the folks in GYCC obviously are tied to their agencies and their agency missions. And for us to kind of shake ourselves loose of that and go our own way probably is going to meet with some consternation.

People are concerned when agencies get together and start collaborating. It makes them nervous. And I think we've seen that here. I think they think we're planning some kind of nasty revolution or something, or some dastardly thing is going to come out of [collaboration] that's going to impact them negatively. So any time we get together and start planning and scheming, I think a lot of people kind of get scared of that. So we've tried in this current atmosphere to do things that achieve the coordination and collaboration necessary, without raising the fears of people in these communities, and conversely to try to draw people in and make them partners of some of the things we're doing. And that's not a very glamorous thing; it's not a thing that makes headlines in the papers. But I think it's an approach that does, over time, build a cooperative spirit and increase understanding that we're here for the benefit not only of the ecosystem, but also of the people who live here. We don't always agree. But that's just the nature of the game.

I think that in the future, these coordinated and collaborative efforts are going to become even more important. We heard last night [from Chief Bosworth that] there are probably going to be a billion people in the United States at the end of this century. That is truly a sobering thought. Can you imagine what kind of pressure is going to be brought to bear on the land when we have this many people? With all of their dreams and aspirations? We're starting to see significant pressures here now. I just need to look to the southeast of Jackson to the tremendous gas boom that's going on in the Pinedale [Wyoming] area. Where they're drilling probably in the vicinity of 6,000 gas wells. It's just a tremendous pressure. We're seeing the increase in recreational pressure here. A group of agency recreation managers got together, came to the GYCC, and said, we would like to do an assessment of recreation. There was some back and forth negotiating, and these folks have put together kind of a snapshot of summer recreation in the GYA. [It's] not quite done yet—they're still putting the final touches on—but . . . it's very interesting to be able to look at recreation in the whole of the GYA, when you look at all of the units put together. There are some very interesting patterns developing from this.

But to think about the pressure that we're going to face on the land, and the products that people are going to expect us to deliver, we're going to need all the coordination and collaboration we can get. And so I think that the role of the GYCC, along with others, is going to become increasingly important, and it's going to become increasingly important for us to work together as federal managers with the states [and] with local governments to try to continue to maintain the outstanding resources that this area

has, and at the same time provide some of the products and the things that people will want from this magnificent region.

I guess my final thought is one of the field people. In as many or more cases, it is the people in the field who come to us with ideas about projects that they would like to do, or collaborations that they would like to be involved in. And I would like to thank and commend those folks in the field—the rangers, the foresters, the range people, recreation staff, wilderness managers, maintenance staffs, archeologists—the whole gamut of professionals in these agencies who are working on the ground to maintain the resources that we enjoy. In more cases than not, they come to us with ideas, they come to us with collaborations, and they put those together. They're the folks who really make the wheels turn. I just wanted to commend you folks out there for the job you're doing, and I also want to thank you scientists who are raising the knowledge base of the ecosystem. Something that's very, very important. We're seeing some of this research being portrayed here today and tomorrow, and I wanted to commend you folks for what you're doing. We're headed for some very challenging times, and I think it's going to take every bit of scientific knowledge and cooperation that we can [muster] to maintain what we have. But I think it's worth the effort. I only have to get on my horse and head into the mountains or take a drive through this country to realize what's at stake here and how valuable what we're looking at is to this nation and to the world. So I think we're planning to do our part to try to maintain that and to continue it into the future. Thanks.

Remarks of Rebecca Aus

Thank you for the opportunity to be here and visit with you today. It has been my privilege to serve as forest supervisor on the Shoshone National Forest for the past nine years, and my only regret in being here is that I had fully expected that the person speaking on behalf of the forest service would have been my good friend Jerry Reese, who up until his very recent retirement, was the senior forest supervisor in the Greater Yellowstone Ecosystem [GYE] . . . and frankly, I would have preferred to hear his comments today rather than be espousing, myself!

The fact that this panel is on this agenda, in part, emphasizes the centennial celebration of the forest service, and is a very tangible symbol of what the Greater Yellowstone Coordinating Committee is all about. Suzanne's kindness and generosity, and I might add wisdom, in including us in this forum is a testimony to the quality of the partnership and the relationships we share. So thank you, Suzanne.

One of the events that the Shoshone National Forest held this past year in recognition of 100 years of service, was to invite our retirees back to the forest for our traditional Fourth of July picnic and parade. As part of that, we made a special effort to invite the past forest supervisors for the Shoshone, and the five who are still alive actually showed up. It was a remarkable experience to visit with Jack Lavin, who was the supervisor of the forest in 1967, three years after the GYCC MOU was developed. John Mumma, Steve Mealey, Ray Hall, and Barry Davis all had fascinating stories related to the issues and concerns that have been dealt with in this ecosystem over time, and it was a wonderful reminder that while many of the important issues we deal with seem to take an agonizingly long time to resolve, actual real, concrete progress can be made when folks work together with a common goal in mind.

My conversations with these supervisors and the need to be prepared for this panel inspired me to dig through the tomes of historical information related to this ecosystem in a more aggressive way than I have in the past. The records and the oral history revealed bumps along the road toward achieving the common goal of coordinating our work to conserve this important ecosystem. Those bumps, those growing pains, and that rich experience helped pave the path for many of the GYCC successes we see today. Some of the lessons I think we've learned over the years have been incorporated into our operating principles and practices and are regularly used today.

For example, while we have a set public meeting agenda, we also have committed to one "strategic thinking" retreat each year. The primary goals of the retreat are to confirm the committee's priorities and take some thoughtful time to look into the future and strategize about how to be prepared for new issues. It is also an opportunity to reconnect, to discuss what went well over the past year and, equally important, what didn't go well. We talk about how we can help each other; conversely, we talk about situations where we may not have done our best to be partners. It's an opportunity not only to describe our aspirations for the coming years, but also to critique our current work. These retreats have been hugely beneficial in helping us to maintain quality working relationships and produce quality, coordinated products that meet our ecosystem priorities.

A second tool we've grown fond of over the years is the use of subcommittees. The GYCC currently works with over a dozen committees, each with its own specific resource charter. Much of the really great work that we often get credit for is a result of the interagency effort of the folks assigned to these tasks. A recent example that I am particularly excited about is the establishment of our new GYCC Subcommittee for Sustainable Operations. The parks have been working on sustainability issues such as use of biofuel, environmentally friendly cleaning products, energy-saving infrastructure design, and recycling of such odd, but voluminous products as camp stove propane canisters. The parks are light years ahead of the national forests with this effort; recognizing that, the national forests and [wildlife] refuges agreed that we could more efficiently bring ourselves up to the parks' higher standard with a subcommittee that focuses on that specific challenge. Just this year, such a committee was formed; it is now actively working toward improving our energy footprint across the ecosystem. Our goal is to partner with each other to optimize recycling, use of green products, and energy efficiency in this important ecosystem. And that is one of the beauties of working with the GYCC: if one of our three agencies has solved, or made progress in a key area, the rest of us can easily just "hook our wagons to the rising star" and draw from that success.

Although all of the subcommittees deserve recognition, another that I would specifically like to mention today is the invasive species team. This interagency group addresses the serious threat of the introduction and spread of more than 200 non-native, invasive plant species. To address this threat, more than 100 private, county, state, and federal land managers in the GYE have been collaborating to protect our native plant communities. This is a critical partnership that has been developing over the past 20 years and continues to strengthen and grow as a key emphasis item. The subcommittee provides a unique venue that brings together communities, counties, universities, the NRCS [USDA Natural Resources Conservation Service], the parks, the refuges and six national forests, [local] weed and pest departments, and citizens interested in working on weeds together. This group works on inventory and mapping, education of both our own employees and the public, and weed prevention programs (such as weed-free hay, equipment washing stations, and sand and gravel certification programs). In my view, a key focus area for the subcommittee has been the development of Cooperative Weed Management Areas; their goal being to have the entire ecosystem "covered" by groups of folks who are "taking care of their own backyards." The work of this subcommittee provides a regional platform with a pool of expertise and resources that is, to my knowledge, unmatched elsewhere in the country.

In addition to the use of subcommittees, the GYCC also often uses the tool of chartered initiatives to make quick progress on an issue. Our most recent assignment went to the recreation managers across the ecosystem. Their task was to develop a current inventory of our summer recreation use, opportunities, and predictions for the future. This document is still in draft form, but once complete, it should provide information for understanding what the trends and uses are, and how each of our units collectively and uniquely contributes to the public's recreational interest. The assessment also helps identify where particular public recreational uses are most compatible with resources and management objectives. This is baseline information, and will eventually help inform decisions on recreation infrastructure, public information, and education needs, and help us to be more effective and integrated in our management of public lands for recreation purposes. A similar effort, the GYA Winter Use Assessment, was completed years ago and has been a useful document in both the parks' [Yellowstone and Grand Teton] Winter Use EIS [environmental impact statement] and in helping to focus the monitoring of winter uses on the adjacent national forests.

I'm going to digress for a second and mention that the above two initiatives—the recreation assessments and the subcommittee on invasives—as most of you might know, fit nicely into the forest service's [list of] top priorities, commonly referred to as the Chief's Four Threats. If you add, to the two I've mentioned in detail, the GYCC's Priority Land Project, which focuses on the public–private land interface and prioritizes areas for Land and Water Conservation funding or conservation easements, and the fact that our fuel- and fire managers have one of the longest-standing partnerships within the ecosystem and have collaborated on such things as the FARSITE fuel model layer across the ecosystem, you can conclude that our GYCC effort is very compatible with that of my particular agency.

I will just quickly mention one additional tool that the GYCC is absolutely dependent upon: the position of the executive coordinator. I recall that when I first joined the GYCC, we were operating without

a coordinator. I don't know how long that had been going on, but I do know that as we were attempting to transition the role of the chairperson, it became an issue. Understandably, none of the members wanted to take on the role of being the chairperson without the assistance of an individual who could help coordinate meetings, monitor the progress of subcommittees, assist with partnerships, and ensure quality communication for the GYCC as a whole. As we negotiated to transition [former Yellowstone superintendent] Mike Finley into the chairmanship of the committee, we also agreed that the executive coordinator was essential to our success, and have subsequently been blessed with extremely talented folks who help us get our work done.

I think you can take from my comments that I believe things are running fairly smoothly with the GYCC these days. And while there is always room for improvement, I think there is also room for celebration. I know that the accomplishments we've been able to make on the Shoshone National Forest over the recent past would not have been possible had people like Jack Lavin not laid the groundwork in 1968. I also know that many of our major accomplishments in the GYCC couldn't have been achieved without the efforts of our predecessors. A timely example would relate to grizzly bear habitat management within the ecosystem. While there is a separate committee that is solely responsible for the recovery of the grizzly bear, I think it would be a major mistake not to include a short comment on the success story that the imminent delisting of that species in this ecosystem represents. While the GYCC includes only the land management agencies that were involved in this effort, and the state game and fish departments and the U.S. Fish and Wildlife Service also play essential roles, one of the GYCC's persistent goals has been to ensure coordinated management of threatened, endangered, and sensitive species. Intense cooperation, coordination, and conversation about specific land- and people-management issues related to threatened and endangered species regularly occurs, and actions result from those conversations. The recovery of the Yellowstone grizzly bear is remarkable and irrefutable testimony to the commitment of the GYCC to work together. And as I said in the beginning, the important issues we deal with seem to take an agonizingly long time to address—decades in this instance—but we are capable of actual, concrete, meaningful progress. And that, we can all celebrate!

Remarks of Mary Gibson Scott

As a relative newcomer to the Greater Yellowstone Coordinating Committee—I arrived in May of last year—I was pleased to find that federal land managers in the ecosystem had such a sustained commitment to meeting and working with each other.

It's not hard for me to imagine that one might *think* that at least two big national parks immediately adjacent to each other would have always worked closely together, or at least tell the same story to the public who visit them, usually in the same trip. Of course, the parks share a common set of management policies, along with 388 other [there are 390 total] national park areas. Yet the history of the two parks is considerably different, and provides for a fair amount of difference in how we've managed some of our most visible resources and still do today. You know—Grand Teton is the one with the dam, an elk reduction program, commercial airport, livestock grazing, private and state lands within the park boundary. Talk about administratively complex!

I see the GYCC, however, as focusing not on the differences between our two national parks or even between us and the six national forests, but on the commonalities among us. An incredible amount of coordination seems to be occurring, on everything from wildland fire management to land exchanges. The GYCC promoted partnerships "before their time," long before the concept of "cooperative conservation." Now, it's all about relationships, and using them to benefit our joint goals and objectives—things like conservation of the bighorn sheep herd that ranges atop the Teton Range, and maintaining good air quality over Jackson Hole in the face of increasing energy development in the Upper Green River Basin. My staff tells me it wasn't always that way, and I can believe it. It's so easy to get caught up in our own day-to-day business and lose sight of the greater good. I'm sure the same is true for all of us.

The GYCC, I'm told, really got a boost in the 1980s, and it took a few years before the relationship-building at my level trickled down to staff. But since then it's produced growing success in how we provide a landscape approach to resource management, and in maximizing our results—helping us to maintain functional ecosystems, a main principle of the GYCC. Here are a few examples:

- A tri-state bald eagle working group started by writing a management plan (in 1983), and has today helped achieve biological recovery of our national bird.

- Grand Teton National Park hosts an interagency dispatch center shared with the Bridger-Teton National Forest that also assists Teton County [Wyoming] law enforcement, fire, and rescue personnel.

- The GYCC provided project funds for us to work with the National Elk Refuge and the Bridger-Teton on controlling spotted knapweed in the Gros Ventre River corridor, and we believe we are winning the battle in this important riparian zone.

- The GYCC also recently provided funding, and the Bridger-Teton shared their fisheries biologist, for a project that surveyed park and forest streams and documented native cutthroat trout populations. When he identified, in my park, that an old road bridge was blocking native fish passage up a spawning tributary of Bailey Creek, our park hydrologist spearheaded an effort this past season—jointly funded by Grand Teton and the forest—to rebuild the bridge for better visitor access and fish passage.

- My chief of resources [Sue Consolo Murphy] tells me that she remembers when, as a result of "trickle-down effect" from both the GYCC and our sister group, the Yellowstone Ecosystem Grizzly Bear Managers' Subcommittee, grizzly bears in the ecosystem were first translocated from Yellowstone National Park to adjacent federal lands, including the John D. Rockefeller, Jr., Memorial Parkway, which we administer and which lies between Grand Teton and our big "north district" neighbor. For two decades before that, all the "problem" bears had been moved from outside the parks back *in*, and even into the late 1980s and early 1990s, too many people thought there was only one park where grizzlies did or should live (and it wasn't mine). But it was with great excitement (and some noticeable agency nervousness) that, in the fall of 1989, biologists from Grand Teton and Yellowstone parks and the Targhee and Bridger-Teton national forests—along with the game and fish departments of both Idaho and Wyoming—cooperated to relocate a female grizzly bear and her two yearlings from the northern end of Yellowstone to beyond its south gate. The relationships forged by managers and their staff in meeting rooms (and perhaps social time afterward) from Bozeman [Montana] to Cody [Wyoming] gradually resulted in employees' breaking their typical patterns of action and broadening the possibilities for a resource we all share. After that, true cross-boundary translocations quickly became commonplace, which contributed to the incredible recovery we see today in the ecosystem's grizzly bear population numbers and distribution.

So where do we go from here? I'm quite sure that, given these tight times for federal budgets, we'll need to continue and expand our efforts to build and maintain partnerships and leverage funding, between our own staff and volunteers as well as with external organizations and private individuals.

We can benefit and demonstrate efficiency by sharing expertise and research results through conferences such as this one. Grand Teton is also interested in expanding its efforts at sharing research results and implications to the public through the concept of a research learning center and improved virtual information transfer. We encourage the participation of our fellow GYCC members and other interested partners in this effort.

We should celebrate our successes, and keep them coming. We all face similar pressures—an ecosystem that continues to grow in popularity as a place to visit and to live, a need for more and better science to help us make the best possible decisions, and expectations that we agencies and our staffs will collaborate both with each other and with our citizenry.

As I mentioned above, I think Grand Teton has participated in numerous interagency efforts that contribute to the GYCC's main principles. One of our continuing challenges is to encourage opportunities that are economically and environmentally sustainable. Defining and monitoring limits of acceptable change and assuring that such thresholds are not crossed—within units and across agency boundaries—has turned out to be a much easier goal to articulate than to flesh out and achieve. If we reaffirm its importance, then we should renew a GYCC commitment to indeed make progress in that direction; otherwise, we should reframe this goal in keeping with what we believe to be possible and of primary importance in today's circumstances.

I think we should revisit the GYCC priorities and reaffirm or revise them to meet our priority

needs for the next five or ten years. I'm particularly interested in the GYCC including the ecosystem's cultural heritage resources in its strategic plans as appropriate. And I look forward to working with my friends and colleagues around the ecosystem on goals of mutual interest.

Carnivore Conservation and Search Dogs: The Value of a Novel, Non-invasive Technique in the Greater Yellowstone Ecosystem

Jon P. Beckmann

North American Program, Wildlife Conservation Society, 2023 Stadium Drive, Suite 1A, Bozeman, MT 59715 (316-992-2927, jbeckmann@wcs.org)

Abstract

In the Greater Yellowstone Ecosystem (GYE), habitat connectivity is a concern because large carnivores have difficulty dispersing successfully between protected areas. One area of high conservation value is the Centennial Mountains and surrounding valleys (1,500 km^2) along the Idaho–Montana border. They have been deemed important to connecting central Idaho with the GYE, and the range anchors the southern Yellowstone-to-Yukon system. The Centennials have also been identified as a peripheral sink area within the GYE. Despite the geographical appeal of the Centennials as a linkage zone, empirical investigation of their importance for large carnivores has received scant attention. This is due in part to the complex arrangement of public lands within the range, steep topography, and the difficulties associated with conducting research on large carnivores in the region. The aim of this project was to utilize a novel, non-invasive DNA sampling technique to examine the relative abundance of a suite of large carnivores in the Centennials and surrounding valleys. Search dogs specifically trained to locate the scat of four target species (black bears, grizzly bears, cougars, and gray wolves) were used to sample the study area. From DNA extractions, I can identify the samples not only to species, but also to gender and to individual animals, and can estimate sex ratios, densities, and (possibly) home ranges. I will discuss how search dogs are being used to examine various carnivore species' use of the landscape with respect to habitat parameters, public land management, and changes in land use patterns over time to examine human impacts on species distributions and movements. Finally, I will discuss the merits and limitations of this novel, non-invasive method for carnivore conservation research inside the GYE using preliminary data from this study.

Introduction

As the human population continues to boom in the Intermountain West, new subdivisions and increasing human density are occurring at accelerated rates. For example, areas adjacent to public lands are being sold and subdivided across western North America (Knight and Mitchell 1997). In fact, the fastest-growing region in the U.S. is the Intermountain West, with growth rates rivaling those of several African nations and exceeding that of Mexico (Knight and Mitchell 1997). Concentrated growth in limited areas raises serious conflicts among traditional agriculture, unprecedented urban expansion, and wildlife conservation. Of particular concern are wide-ranging carnivores, especially at the interface of wildland and urban or suburban areas. Little is known about how carnivores live in and move through these interface areas (Beckmann and Berger 2003b). Such gaps in knowledge impede prudent management, a situation that will likely be exacerbated in the future. Currently, the potential for loss of livestock, consumption of pets, property damage, and even injury or death to humans due to free-ranging large carnivores exists or has been documented (Herrero 1985; Beier 1991; Herrero and Higgins 1999). For these reasons, large carnivores both capture the public's imagination and inspire calls for carnivore control, protection, and translocation.

Knight and Mitchell (1997) point out that as population-driven, landscape-level changes occur, there are other associated changes, such as an increase in the number of pets, more vehicles and road-killed wildlife, and increasing human–carnivore interactions, leading the public to categorize those carnivores as "nuisance wildlife" (Knight and Mitchell 1997; Beckmann and Berger 2003a). Although our understanding of the impacts of these changes is limited, Knight and Mitchell (1997) state that several studies suggest that these types of changes result in an accumulation of human-adapted species (e.g., raccoons [*Procyon lotor*]) and a decline of species sensitive to human activities, such as large carnivores (Tyser and Worley 1992; Knight and Mitchell 1997; Beier 1995). In addition, these changes contribute to habitat fragmentation and species isolation. In

the Greater Yellowstone Ecosystem (GYE), isolation is of particular concern for the large carnivore species that currently occur inside both the Yellowstone National Park and the Grand Teton National Park core areas. Such core areas are of fundamental importance because they not only harbor populations of rare and sensitive species, but also could become completely isolated from other northern Rockies systems due to human activities in peripheral lands over the next few decades.

One area of high conservation value is the Centennial Mountains along the Idaho–Montana border west of Yellowstone National Park (Figure 1). They have been deemed important to connecting central Idaho with the GYE, and the range anchors the southern Yellowstone-to-Yukon (Y2Y) system. The Centennials have also been identified as a peripheral sink area within the GYE (Noss et al. 2002). Lower levels of connectivity, higher road densities, and fewer refugia in the southern Y2Y region make this link particularly important. North–south connections through the Canadian and U.S. Rocky Mountains have received a fair amount of attention, but east–west corridors, such as the Centennial area, have not been intensively examined. The idea of connecting the GYE not only to the Yukon, but also to the Cascade Range and other areas to the west, has placed a new emphasis on these corridors. Noss et al. (2002) point out that for most "mega" species (e.g., grizzly bears [*Ursus arctos*], wolves [*Canis lupus*], and wolverines [*Gulo gulo*]) in the GYE, modeling predicts that core areas will remain strong sources of individuals over the next 25 years. However, because of human perturbations, namely road construction, these core areas may no longer be able to support populations of these "mega" species in the peripheral distribution (surrounding sink habitat) in the next 25 years (Noss et al. 2002). Because the Centennials have been not only delineated as an area of possible linkage within GYE, but also identified as a possible peripheral sink area, it is critical to examine whether the range is currently functioning as a linkage zone for large carnivores. This is particularly true given that more than half of the Centennial range falls outside the grizzly bear recovery zone, where mortality rates are often higher for bears than in more protected regions (M. Haroldson, pers. comm.). As Servheen et al. (2001) point out, linkage zones are different than corridors in that they are areas that could support carnivores at low densities over time, rather than areas that are strictly used just as travel lanes.

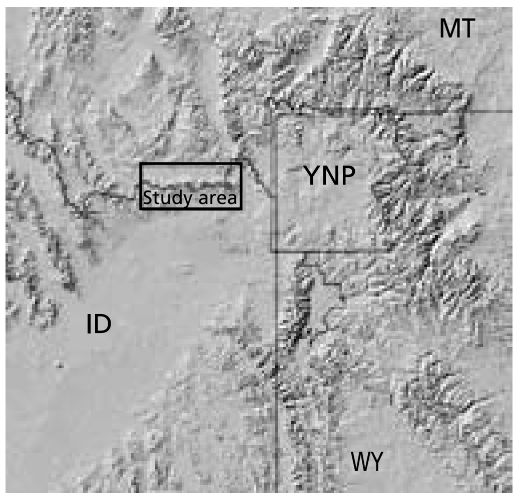


Figure 1. Location of the Centennial Mountains study area (black box) in the Greater Yellowstone Ecosystem (GYE). The Centennials form the Continental Divide between Idaho and Montana directly west of Yellowstone National Park. The Centennials have been identified as a potential linkage area for large carnivore populations in the GYE with central Idaho wilderness areas.

The primary species driving the interest in the Centennials are the federally protected grizzly bear and gray wolf. However, to a lesser degree there is also interest in more common species of large carnivores, such as black bears (*U. americanus*) and cougars (*Puma concolor*), as relatively no data are available concerning these two species in the Centennials despite the fact that both are hunted in the range. Increasing the significance of the issue of connectivity is the fact that portions of both U.S. Interstate 15 and U.S. Highway 20 bisect the area. In addition to potentially increasing the mortality risk of carnivores, human-altered landscapes may increase habitat fragmentation. The primary causes of habitat fragmentation, especially for bears, are human activities, including road building (Servheen et al. 2001). Habitat fragmentation isolates populations, potentially leading to losses of genetic diversity as well as population decline, and may result in the eventual extinction of a species or local population. Maintaining linkage opportunities between bear populations in the GYE and Salmon–Selway area could enhance grizzly bear recovery in the United States (Servheen et al. 2001). Therefore, if the Centennials are a significant impediment for grizzly bear dispersal from the GYE into the wilderness areas of central Idaho, there could be serious impacts on the population viability of grizzly bears within this ecosystem. Conversely, movement across the area is essential to prevent further fragmentation and isolation of bear populations inside the GYE.

A major concern associated with focusing issues of connectivity on a single, "mega" species, such as grizzly bears, is that successfully documenting whether a species is able to use an area as a linkage zone may only be tenable at longer temporal scales (e.g., several decades). If ecologists and conservationists want to understand the importance of the Centennial Mountains to connectivity within the Y2Y, then research should also focus on species that may generate data useful for determining the effectiveness of the range for connectivity at shorter time intervals. Thus, this project has taken a suite approach to examining connectivity for large carnivores in the Centennial Mountains. This suite approach allows examination of the region for species that use the landscape differently and thus have different habitat requirements for linking isolated populations, such as those found inside the GYE. By examining species such as black bears and cougars, rather than focusing solely on grizzly bears, it may be possible to generate data useful for determining the effectiveness of the range in connecting populations at shorter time intervals.

Effective management and conservation of carnivores requires that ecologists have reliable and detailed demographic information. However, for most species of carnivores, especially threatened and endangered (T&E) species, such data are often difficult to obtain. The causes of difficulty in data acquisition include low population densities, wide home ranges for individuals, and, in some cases, issues associated with trapping and marking rare species (Smith et al. 2003). Although the Centennial Mountains and two surrounding valleys only cover approximately 1,500 km^2, they are a microcosm of the entire GYE in that they contain Bureau of Land Management wilderness study areas, a U.S. Fish and Wildlife Service refuge, two national forests, and the U.S. Department of Agriculture Sheep Experiment Station, as well as Bureau of Reclamation lands, Idaho and Montana state lands, and private lands. This complex arrangement of public and private lands creates challenges when researchers attempt to address landscape-scale questions or conservation concerns such as long-distance migrations (LDMs) of ungulates, or connectivity issues for large carnivores. It can often be difficult to align all entities in order to conduct invasive (capture/handle) scientific studies. Acquiring permits to capture and handle animals from each agency can be challenging and, in many instances, logistical and monetary challenges can arise, making invasive studies difficult. In this research, for instance, using a suite approach to addressing connectivity issues for several large carnivore species would have made a capture study extremely expensive and impractical. Finally, when T&E species are involved, and because large carnivores can often be controversial with the general public, a non-invasive approach may often be a better option for certain research questions. Most methods of live capture and marking individuals to obtain demographic data have biases associated with them. For example, data can be biased by behaviors of target species (e.g., sex-biased trapping; see Smith et al. 2003). Capturing and marking also have associated risks of injury to both the study animal and researchers. Thus, as Smith et al. (2003) point out, non-invasive techniques to gather population demographic data have found recent favor among ecologists. For these reasons, a new, alternative method to sampling in a complex political landscape with rugged terrain, at a huge scale, and for a suite of relatively rare species of carnivores, was needed for this study.

Recent advances in molecular genetics have made fecal DNA technology a promising, viable option for researchers working on species that are difficult to capture and mark due to biological and political factors; for detecting species presence or absence; for identifying the sex of each individual; and for determining the identity of each individual (Smith et al. 2003). Fecal analyses have been used in the past to examine food habits, determine relative abundance of animals, infer habitat use, and estimate home range size, as well as in parasitology studies (Smith et al. 2003). DNA technology has advanced such that a well-designed study can use fecal DNA sampling to determine species, sex ratio, home range, paternity, and kinship, and even to produce population estimates for carnivores (Smith et al. 2003; Boulanger et al. 2004; McKelvey and Schwartz 2004a and 2004b; Paetkau 2004).

Acquiring data from feces (scats) of rare carnivores requires sampling across a large area on the landscape. Obtaining samples for populations with low densities and/or cryptic scats, in addition to human error in identifying the scat, may influence the reliability of demographic data (Smith et al. 2003). Because human limitations also prevent locating sufficient scats for such species, a more effective method of scat recovery was needed for this project (Smith et al. 2003). We employed a novel DNA sampling technique that has only been used intensively in the last several years (see Smith et al. 2003; Wasser et al. 2004). We used dogs specifically trained to locate

the scat of four target species (black bears, grizzly bears, cougars, and gray wolves) to sample the Centennial range and surrounding valleys. This method was used in conjunction with fecal DNA analyses on black bear and grizzly bear populations as early as 1998 (Wasser et al. 2004). Dogs have also been used to locate scat of species such as San Joaquin kit foxes (*Vulpes macrotis mutica*), black-footed ferrets (*Mustela nigripes*), coyotes (*Canis latrans*), and lynx (*Lynx canadensis*) (Smith et al. 2003). In fact, in one study, dogs were used to detect the presence or absence of a target species, kit fox, with 100% accuracy despite the presence of sympatric striped skunks (*Mephitis mephitis*) and American badgers (*Taxidea taxus*) (Smith et al. 2001; Smith et al. 2003). In this paper, I describe this novel, non-invasive sampling technique using preliminary data from the Centennial Mountains study area as an example of its utility inside the GYE, and I discuss the merits and limitations of this technique.

Sampling with dogs

Four dogs (two Labrador retrievers, two German shepherds) were trained to detect scat of black bears, grizzly bears, cougars, and gray wolves using the techniques described in Smith et al. (2003). In order to sample the Centennials in a block design, a 5 × 5-km grid was overlaid onto the 1,500 km^2 study area, resulting in 60 grid cells (25 km^2 each). Using this grid size enabled us to detect the smallest home range of the four target species (i.e., that of female black bears) using data reported in the literature for similar systems (e.g., see Nagy and Haroldson 1990; Beier 1995; Logan and Sweanor 2001; Beckmann and Berger 2003a). The 60 cells were then individually numbered and stratified into five blocks of 12 cells each. Employing a random number generator, we then selected four grids per block, resulting in 20 cells being sampled using transects in 2004. In 2005, we sampled the remaining 40 grid cells. Because grid cells were eliminated after they were searched, each of the 60 cells has been sampled with a transect once at this point in the study. Each triangle-shaped transect was six kilometers long, meaning that a total of 360 kilometers have been searched by dogs and their two-person handling teams (one handler and one orienter). These random-direction transects were triangular so that the dogs could return to the starting point without ever having to retrace their route, as occurs in straight-line transects. This avoided unnecessary energy expenditure by the dogs and kept them fresh for successive days during this intensive search work.

Each transect was recorded with a GPS unit on both the dog and the human handler, and the resulting transects were mapped using GIS software (ArcView 3.2, ArcMap). Each dog carried a GPS unit in order to map the distance covered off of the human-walked transect, to accurately estimate the total area sampled, and to estimate densities based on scat hit rates. Scats were collected in 95% ethanol in the field for transport to the DNA lab. For each scat collected, we recorded distance off the transect, altitude, slope aspect, quality of sample (degree of freshness), habitat, land management agency responsible for the site, fire history, logging history, ATV/snowmobile use level, presence of livestock (type and number), and distance to road, trail, building, fence, or any other anthropogenic structure. These covariates will later be included in spatial analyses models using multiple logistic regression and hierarchical partitioning analyses to examine the impacts of human activities in the Centennials on their ability to function as a linkage zone for carnivores.

DNA analyses

Species identification

The DNA isolation procedure involved freeze-drying the samples and then pulverizing them in order to uniformly distribute DNA in the samples. DNA was extracted from every sample using a QIAGEN Dneasy DNA extraction kit following the manufacturer's protocol. Extractions were carried out in a separate room under quasi-clean conditions to prevent contamination. Each sample was isolated a minimum of two times and tested. Negative controls (no scat added to extraction) were used with each set of extractions to test for contamination. After DNA was extracted, polymerase chain reaction (PCR) amplification and restriction enzyme analyses were performed. Scat samples that failed to produce PCR amplification after the second extraction were removed from the analyses.

Two methods were used for species identification, both involving mitochondrial (mt) DNA analysis. The first used a size difference between black bears and grizzly bears (Woods et al. 1999). A region of mtDNA was amplified via PCR, using primers that targeted a region of the cytochrome B gene of the mt genome. Black bears yielded a fragment approximately 15 bases larger than grizzly bears. One primer was fluorescently labeled, allowing visualization on an automated DNA sequencer for precise size

comparisons. Positive and negative controls, in addition to the DNA isolation blanks, were included for each amplification. The second method of species identification used sequence analysis of a region of the cytochrome B gene. Samples were amplified using primers that target this region (Farrell et al. 2000), and sequence analysis was then performed (using Big Dye terminator chemistry on an ABI Prism 377 automated DNA sequencer). DNA sequences were edited and aligned using Sequencer (Genecodes). Sample sequences were compared with known sequences and with entries in GenBank using the megaBLAST program (National Center for Biotechnology Information) to identify species that possess sequences of high similarity. Sequence analysis was attempted on all samples that failed using the size-based method.

Individual and sex identification

Microsatellite genotyping was used to determine individual genotypes for the samples. Samples were genotyped in quadruplicate at seven microsatellite loci (G10A, G10B, G10C, G10J, G10L, CXX.20, and G10D) using 2–3 locus multiplexes, with one primer of each pair fluorescently labeled. Positive and negative controls were included in each amplification. Genotypes were determined following electrophoresis on an ABI Prism 377 using Genescan and Gentoyper software (ABI) and an internal size standard. Alleles were scored if they were detected at least twice across the four replicate amplifications. Multilocus genotypes were determined for the samples that met the scoring criteria at four or more loci.

Sex was determined using Sry and ZFX/ZFY coamplifications, with one primer of each pair fluorescently labeled. Electrophoresis and scoring of fragments was as described for the microsatellite amplifications, although gender amplifications were performed in duplicate. Six known bears (three males, three females) were included, as was an amplification blank, to assist gender determinations for bears.

Preliminary results

To date, 60 transects have been sampled in the Centennial study area. Humans have walked 365.5 kilometers, and dogs have sampled 767.7 kilometers, covering 2.1 times the total distance of humans. The number of scats/km varied between dogs ($\bar{X}_{\text{scats/km}}$ = 0.376, range 0.242–0.746). A total of 289 scats have been located, of which only four are non-target species based on both field identification (2005 samples) and DNA analyses (2004 samples). To date, dogs have been 98.6% accurate in identifying only target species of carnivores. The four non-target scats identified by DNA analyses were all from red fox (*Vulpes vulpes*). Because some DNA analyses are still pending for samples collected in 2005, a preliminary breakdown of scat samples based only on field identification reveals that all taxa (ursids, canids, and felids) have been sampled using this technique: bears (n = 269), cougars (n = 11), and wolves (n = 5). In addition to data collected from scat, dogs have located den sites for carnivores, potential rendezvous sites, and kill sites in the Centennials. High-quality DNA samples (hair) were collected from carnivores at bed sites and kill sites.

Discussion

Dogs have been used by humans for millennia for a multitude of purposes including hunting, serving, rescuing, herding, protecting, leading, capturing and tracking wildlife, and even aversive conditioning of "nuisance" carnivores (e.g., Beckmann et al. 2004). More recently, dogs have been used as a conservation tool, as search dogs have been trained specifically to locate scat of target species of interest in order to obtain DNA samples. This novel sampling technique has merit as a useful tool for ecologists addressing landscape-scale conservation issues such as connectivity for populations of large carnivores via linkage zones. Yet, as with any technique, limitations exist. One limitation of the technique is that costs can be prohibitive at some level, as few people are expert at handling dogs for this type of work. However, for studies such as the one described here—examining a complex, landscape-scale phenomenon such as long distance movements for several wide-ranging species simultaneously—an invasive capture study would most likely be many orders of magnitude higher in cost than the use of search dogs.

One of the largest drawbacks of this sampling technique is that the dogs often outwork the DNA lab, finding many scat samples that are too old and degraded to be suitable for DNA amplification. This was especially true during the first year of this study as the lab attempted to obtain individual DNA fingerprints. Because of cost constraints, it was difficult to use dogs to walk transects prior to actual sampling bouts to clear old scats; thus, dogs located some very degraded scats during sampling. In many cases, dogs located scats that were little more than crumbs or were old enough to be covered by mold, both of which contribute to the breakdown and/or

contamination of DNA (Wasser et al. 2004). In addition, because bears are only out of their dens for a relatively short period of time in the Centennials, clearing transects in spring or early summer after the snow was gone would not give animals much time to deposit new samples prior to the first snows of the following winter. Another limitation to this sampling technique is that because DNA from scat is considered low-quality DNA, lab expenses are generally higher than they are for higher-quality sources of DNA (e.g., tissue, blood, or hair).

In addition to these limitations, the technique is so new that relatively little is known about several of its methodological aspects. For example, little is known about differences in detection rates as environmental variables change. Wind speed, relative humidity, topography, age of sample, and temperature all influence the scent cones left by scat samples (Wasser et al. 2004), yet models do not currently exist for predicting the shape and size that scent cones take under various environmental conditions. Thus, accurately predicting the likelihood of detection by dogs under various conditions is currently impossible. Other methodological questions still to be worked out include: What happens to detection rates as more species are added to a dog's repertoire? Do dogs begin to lose the ability to detect the first species added to their scent search as more species are added? Do they start to generalize to all carnivores on the landscape at some point in time? Do different breeds of dogs and different individuals within a breed have various success rates at locating scats? All of these puzzles currently remain unanswered and are limitations to the usefulness of this technique, because ultimately, these variables affect the validity of using search dogs as a carnivore research tool.

There are several benefits to using dogs as a research technique for addressing certain conservation questions. Because search dogs are capable of covering extremely large areas on the landscape, they are useful for addressing landscape-scale questions. Dogs also have the ability to sample for multiple species simultaneously, as demonstrated in this project (although as acknowledged above, the effects of adding multiple species to a dog's search repertoire are unknown at this time). Because dogs have been shown to be up to four times more effective at locating scats than trained human observers, they are useful in sampling for rare or low-density species, such as most large carnivores (Smith et al. 2003; A. Whitelaw, pers. comm.). As with any non-invasive technique, search dogs present no risk to the carnivore species being studied, which is a large benefit when addressing research or conservation issues for T&E species. Non-invasive methods of data collection also eliminate potential trap biases that occur in capture studies, especially the sex-biased trapping often found in carnivore studies (see Smith et al. 2003). Search dogs are also useful in extremely rough terrain, such as that of the Centennial Mountains, where capturing species such as grizzly bears in leg snares would be a big challenge and would present risks to both bears and researchers. Finally, search dogs may be helpful during attempts to locate areas with higher densities of target species before an invasive capture study is begun. This may reduce costs associated with low trap success by increasing the probability of successful trap sets.

As demonstrated here, search dogs are a useful technique for sampling complex matrices of public lands for carnivores. Not only can they reduce the difficulty in acquiring permits and decrease some costs, they can also help sample multiple, rare species simultaneously to address certain conservation questions. However, many questions remain. Most notably, the effect on detection rates as more species are added to a dog's repertoire, whether different breeds of dogs and different individuals within a breed have various success rates at locating scats, and how environmental factors affect scent cones and detection abilities of dogs. Future research should address all of these questions to increase our understanding of the effectiveness of using search dogs as a carnivore conservation tool.

Acknowledgements

I wish to thank A. Whitelaw, A. Hurt, and M. Parker with Working Dogs for Conservation for their expertise in handling search dogs. I appreciate their efforts in working the dogs in the extreme terrain of the Centennials. Without their help and support, none of these data would be possible. I thank the Wilburforce Foundation for funding support of this project. Thanks to the Bureau of Land Management, the Caribou-Targhee National Forest, Idaho Fish and Game, and Red Rock Lakes National Wildlife Refuge for support of this project. I thank B. Weber, J. Hilty, and C. Groves, colleagues of mine at the Wildlife Conservation Society, for the time they invested in discussing options for conducting this research, and for their support. Thanks to A. Toivola and B. Brock for their help in producing GIS maps and spatial analyses. Finally, I thank C. Williams and L. Waits for running the DNA analyses.

References

Beckmann, J. P., and J. Berger. 2003a. Using black bears to test ideal-free distribution models experimentally. *Journal of Mammalogy* 84:594–606.

Beckmann, J. P., and J. Berger. 2003b. Rapid ecological and behavioural changes in carnivores: the responses of black bears (*Ursus americanus*) to altered food. *Journal of Zoology* (London) 261:207–212.

Beckmann, J. P., C. W. Lackey, and J. Berger. 2004. Evaluation of deterrent techniques and dogs to alter behavior of 'nuisance' black bears (*Ursus americanus*). *Wildlife Society Bulletin* 32:1141–1146.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. *Journal of Wildlife Management* 59:228–237.

Beier, P. 1991. Cougar attacks on humans in the United States and Canada. *Wildlife Society Bulletin* 19:403–412.

Boulanger, J., B. N. McLellan, J. G. Woods, M. F. Proctor, and C. Strobeck. 2004. Sampling design and bias in DNA-based capture–mark–recapture population and density estimates of grizzly bears. *Journal of Wildlife Management* 68:457–469.

Farrell L. E., J. Roman, and M. E. Sunquist. 2000. Dietary separation of sympatric carnivores identified by molecular analysis of scats. *Molecular Ecology* 9:1583–1590.

Herrero, S. 1985. *Bear attacks: their causes and avoidance*. New York: Nick Lyons Books.

Herrero, S., and A. Higgins. 1999. Human injuries inflicted by bears in British Columbia: 1960–97. *Ursus* 11:209–218.

Knight, R. L., and J. Mitchell. 1997. Subdividing the West. Pages 272–274 *in* G. K. Meffe and C. R. Carroll, eds., *Principles of conservation biology*. Second edition. Sunderland, Mass.: Sinauer Associates, Inc.

Logan, K. A., and L. L. Sweanor. 2001. *Desert puma: evolutionary ecology and conservation of an enduring carnivore*. Washington, D.C.: Island Press.

McKelvey, K. S., and M. K. Schwartz. 2004a. Genetic errors associated with population estimation using non-invasive molecular tagging: problems and new solutions. *Journal of Wildlife Management* 68:439–448.

McKelvey, K. S., and M. K. Schwartz. 2004b. Providing reliable and accurate genetic capture–mark–recapture estimates in a cost-effective way. *Journal of Wildlife Management* 68:453–456.

Nagy, J., and M. A. Haroldson. 1990. Comparisons of some home range and population parameters among four grizzly bear populations in Canada. *International Conference on Bear Research and Management* 8:227–235.

Noss, R. F., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the greater Yellowstone ecosystem. *Conservation Biology* 16:895–908.

Paetkau, D. 2004. The optimal number of markers in genetic capture–mark–recapture studies. *Journal of Wildlife Management* 68:449–452.

Servheen, C., J. S. Waller, and P. Sandstrom. 2002. Identification and management of linkage zones for grizzly bears between large blocks of public land in the northern Rocky Mountains. *Proceedings of the International Conference on Ecology and Transportation*, Keystone, Colo., September 24–28, 2001. Raleigh, N.C.: Center for Transportation and the Environment, North Carolina State University (March):161–198.

Smith, D. A., K. Ralls, B. Davenport, B. Adams, and J. E. Maldonado. 2001. Canine assistants for conservationists. *Science* 291:435.

Smith, D. A., K. Ralls, A. Hurt, B. Adams, M. Parker, B. Davenport, M. C. Smith, and J. E. Maldonado. 2003. Detection and accuracy rate of dogs trained to find scats of San Joaquin kit foxes (*Vulpes macrotis mutica*). *Animal Conservation* 6:339–346.

Tyser, R. W., and C. A. Worley. 1992. Alien flora in grasslands adjacent to road and trail corridors in Glacier National Park (U.S.A.). *Conservation Biology* 6:253–262.

Wasser, S. K., B. Davenport, E. R. Ramage, K. E. Hunt, M. Parker, C. Clarke, and G. Stenhouse. 2004. Scat detection dogs in wildlife research and management: application to grizzly and black bears in the Yellowhead Ecosystem, Alberta, Canada. *Canadian Journal of Zoology* 82:475–492.

Woods, J. G., D. Paetkau, D. Lewis, B. N. McClellan, M. Proctor, and C. Strobeck. 1999. Genetic tagging of free-ranging black and brown bears. *Wildlife Society Bulletin* 27:616–627.

Watershed Management Strategy for the Greater Yellowstone Area

Greg Bevenger

Shoshone National Forest, 808 Meadow Lane, Cody, WY 82414
(307-578-1263, gbevenger@fs.fed.us)

Mark Story

Gallatin National Forest, P.O. Box 130, Bozeman, MT 59771 (406-522-8573, mtstory@fs.fed.us)

Pete Bengeyfield

Beaverhead-Deerlodge National Forest, 420 Barrett Street, Dillon, MT 59725
(406-683-3966, pbengeyfield@fs.fed.us)

Brad Higginson

Caribou-Targhee National Forest, 1405 Hollipark Drive, Idaho Falls, ID 83401
(208-557-5786, bhigginson@fs.fed.us)

Abstract

The Greater Yellowstone Area (GYA) is the headwaters of several rivers with national significance, including the Yellowstone, Madison, Gallatin, Snake, Wind, Clarks Fork, and Shoshone. Not only are these headwaters important for fish, wildlife, and recreation in their upper reaches, but communities downstream also depend upon their clean, abundant flows for recreation, domestic, agriculture, and industrial uses. From an economic standpoint, water may be the most valuable resource produced in the GYA. National direction for federal agencies is clear, consistent, and direct in emphasizing watershed protection and restoration in policy and decisionmaking. Federal land managers in the GYA, through the Greater Yellowstone Coordinating Committee (GYCC), have identified watershed management as one of their top priorities. In 2001, the GYCC collaborated to produce a watershed management strategy for the GYA that will better position the agencies to provide effective stewardship of watersheds and aquatic systems into the twenty-first century. The strategy was developed through a watershed reconnaissance that identified watershed vulnerability, crucial and damaged stream segments, and overall watershed and aquatic system condition. The reconnaissance led to the development of eight specific strategies. Each strategy contains objectives and recommendations for successful implementation. For example, one strategy is to "provide research results and tools to support sustainable management, protection, and restoration of watersheds." To that end, the GYCC recently funded hydrologists in the GYA to conduct field inventories of reference aquatic conditions on a variety of functioning landscapes throughout the GYA. An updated summary of the watershed management strategy will be presented.

Introduction

The Greater Yellowstone Area (GYA) is the headwaters to several of America's most prominent rivers, including the Missouri, Yellowstone, Snake, and Green. Waters of the GYA are renowned for their excellent fishing in superlative settings. Legendary rivers such as the Henry's Fork, Firehole, and Madison (as well as the Missouri, Yellowstone, Snake, and Green) attract anglers from around the world. These headwaters are important not only for fish, wildlife, and recreation, but also for communities within and downstream of the GYA that depend upon the clean, abundant flows for domestic, agricultural, and industrial uses. From an economic standpoint, water may very well be the most valuable resource produced in the GYA. A vital function of GYA federal land management administrative units is to ensure the integrity of these important waters.

Federal land managers within the GYA have identified watershed management as one of the top

management priorities for the Greater Yellowstone Coordinating Committee (GYCC). This management is directed and guided by numerous laws, rules, regulations, and policies. One guiding document of recent significance is the Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management, published in the Federal Register on October 18, 2000. This policy is one outcome of the *Clean Water Action Plan: Restoring and Protecting America's Waters,* released in 1998 to "provide a blueprint for restoring and protecting the nation's precious water resources."

The Unified Federal Policy provides a framework for a watershed approach to federal land and resource management activities by:

- using a consistent and scientific approach to manage federal lands and resources and to assess, protect, and restore watersheds;
- identifying specific watersheds in which to focus funding and personnel for accelerating improvements in water quality, aquatic habitat, and watershed conditions;
- using the results of watershed assessments to guide planning and management activities in accordance with applicable authorities and procedures;
- working closely with states, tribes, local governments, private landowners, and stakeholders to implement this policy;
- meeting Clean Water Act responsibilities to comply with applicable federal, state, tribal, interstate, and local water quality requirements to the same extent as non-governmental entities; and
- taking steps to ensure that federal land and resource management actions are consistent with applicable federal, state, tribal, and local government water quality management programs.

In adoption of the Unified Federal Policy, members of the GYCC collaborated to produce a watershed management strategy for the GYA (Greater Yellowstone Hydrologists 2002). This paper summarizes that strategy. The strategy was prepared to better position the GYCC to provide effective stewardship of watersheds and aquatic systems into the twenty-first century. The strategy is consistent with the USDA Forest Service Natural Resource Agenda and USDI National Park Service Natural Resource Challenge, as well as with strategic plans recently developed by both agencies in response to the Government Performance and Results Act (GPRA). The strategy utilizes information available from the Inland West Water Initiative.

Inland West Water Initiative

Background

A few years prior to the release of the Unified Federal Policy, national forests in the interior west states of Montana, Idaho, Utah, Nevada, Arizona, New Mexico, Colorado, Wyoming, and South Dakota completed a project that parallels the framework of the Unified Federal Policy. Dubbed the Inland West Water Initiative (IWWI), the project was created as a proactive strategic step for protecting vital water-related resources on national forest lands. The primary initial task, completion of a rapid watershed reconnaissance through the use of existing information, resulted in a database that identifies:

- watershed vulnerability (the inherent risk of conducting activities within a watershed);
- crucial stream segments (locations of critical water-dependent resource values at risk and in need of priority protection);
- damaged stream segments (locations of damaged soil, riparian, and aquatic resource values in need of restoration); and
- geomorphic integrity and water quality integrity (probable condition of watersheds and aquatic systems, respectively, at a consistent scale of resolution).

This initial task was completed between 1998 and 1999. In 2000, U.S. Forest Service (USFS) staff in the GYA worked cooperatively with staff from Yellowstone National Park to produce comparable information specific to the park. The GYCC is presently pursuing similar efforts for Grand Teton National Park, the National Elk Refuge, Red Rock Lakes National Wildlife Refuge, and Gray's Lake National Wildlife Refuge.

Reconnaissance basics

The IWWI database is structured by sixth-field hydrologic unit boundaries (HUB), which are watersheds that generally range in size from 5,000 to 50,000 acres. The project also utilized a common stream network layer. Watershed vulnerability data reflect the inherent risk for watershed conditions to become degraded if certain sensitive lands are disturbed. Sensitive lands are defined as having highly dissected slopes, highly erodable soils, or landslide deposits and potential for landslides. Watersheds rated as high vulnerability have more than 50% of

their area in sensitive lands; watersheds rated with moderate vulnerability have 20–50% of their area in sensitive lands; and watersheds rated low vulnerability have less than 20% of their area in sensitive lands.

Stream segments identified as crucial have especially high resource values. They can include reaches that possess any of the following characteristics:

- being classified as an outstanding fishery;
- having an instream flow water right;
- having a public water supply diversion;
- providing outstanding recreation value;
- having a water-based cultural use;
- being in a water-based Research Natural or Special Interest Area; or
- having a self-propagating population of, or potential to support any designated endangered, threatened, or sensitive species.

Stream segments identified as damaged are those in which physical, chemical, or biological impacts have caused any water-related resource value to be seriously degraded. They can include segments exhibiting any of the following impacts:

- bank damage;
- sediment loading;
- channel modification;
- flow disruption;
- thermal change;
- chemical contamination; or
- biological stress.

Geomorphic integrity data provide information on soil–hydrologic function as a sponge-and-filter system to absorb and store water, and on geomorphic resilience of streams. Watersheds with high integrity are those in which the following criteria occur:

- soil–hydrologic function is judged to be excellent or good throughout the watershed;
- all streams are judged to be in dynamic equilibrium relative to their potential; and
- all riparian areas are judged to be in properly functioning condition.

Watersheds with moderate integrity are those in which any of the following are apparent:

- soil–hydrologic function is judged to be degraded in isolated areas (less than 20%) of the watershed;
- a minor percentage of the stream miles (less than 20%) are judged not to be in dynamic equilibrium; or
- a minor percentage of the riparian miles (less than 20%) are judged to be functioning at-risk or non-functioning.

Watersheds with low integrity are those of which any of the following is true:

- soil–hydrologic function is judged to be degraded over much (more than 20%) of the watershed;
- a major percentage of the stream miles (more than 20%) is judged not to be in dynamic equilibrium; or
- a major percentage of the riparian miles (more than 20%) are judged to be functioning at-risk or non-functioning.

Water quality integrity data provide information on whether designated beneficial uses are being supported or water-related resource values are being protected. Watersheds with high integrity are those in which no stream segment is damaged by physical, chemical, or biological impacts. Watersheds with moderate integrity are those in which only a minor percentage (less than 20%) of stream segment miles are damaged. Watersheds with low integrity are those in which a major percentage (more than 20%) of stream segment miles are damaged.

For both the geomorphic and water quality integrity data sets, the premise is that watersheds of high integrity are relatively pristine; watersheds of moderate integrity can recover in the short term, either naturally or through revised management with minimal capital investment; and watersheds of low integrity cannot recover without major capital investment and revised management that complements the recovery.

Reconnaissance limitations

The IWWI work was conducted in a very short timeframe to provide a reconnaissance-level estimate of geomorphic and water quality conditions. Protocols for conducting the assessment were developed; however, they were imprecise. Thus, the ratings are subjective and should be recognized by the user as such. To that end, it is assumed that the protocols were applied consistently within an administrative unit; it is probable they were applied inconsistently across units. Furthermore, the ratings apply to vast areas of land, using existing, readily available information that varied in detail both within and across administrative units. Therefore, comparison between units may be tenuous at best.

Inland West Water Initiative summary of ratings for the GYA

Summary ratings for the national forests in the GYA were originally completed in the spring of

1998, and updated in November 2000. Yellowstone National Park ratings were completed during April 2000. The watershed vulnerability GIS layer was then updated in December 2001, in order to account for the several major cross-administrative boundaries (Shovic and Urie 2001). The update required development of a consistent stream dissection coverage for the GYA, integration of new land type data, and linkage of results to the spatial data using 53 structured queries to make results repeatable and upgradeable when the base data change. Maps displaying geomorphic integrity, watershed vulnerability, water quality integrity, crucial segments, and damaged segments were prepared during the assessment but are not displayed in this paper due to scale issues.

Though individual units varied, the proportion of highly sensitive watersheds in the GYA was reduced by the watershed vulnerability update from 47% to 27%. This was likely due to a combination of more detailed data, more land area included, and more consistent application of criteria used for defining sensitivity, but could also be from the conservative application of the rather general criteria given in the IWWI documentation.

The Shoshone National Forest had the highest amount (55%) of highly sensitive watersheds. Yellowstone National Park had the lowest, with 9%. The Shoshone National Forest contained the most highly dissected land area (30%), while the Beaverhead-Deerlodge and Caribou-Targhee national forests had the highest percent of watersheds with landslides (14% and 12%, respectively). The Custer National Forest and the National Elk Refuge had the highest proportion of highly erodable soils (46%), primarily due to large areas of shallow soils and silty, erodable soils.

Landscape data were missing from only about 2% of the entire GYA. Watershed data were missing from the Caribou-Targhee National Forest (46%) because they were unavailable at publication time. However, Grand Teton National Park and the National Elk Refuge were added. This model can be reprogrammed to include these missing data at a later date. The new watershed data are highly consistent across administrative boundaries.

Only 34% of the watersheds in the GYA had a high geomorphic integrity rating. This low percentage was primarily a function of the stringent high geomorphic integrity rating criteria, which required excellent soil–hydrologic function throughout a watershed; that all streams be in dynamic equilibrium; and that all riparian areas be in properly functioning condition. Most watersheds in which multiple use activities occur will have at least some soil–hydrologic function degradation, some stream segments not in dynamic equilibrium, or some riparian areas not properly functioning; hence, the preponderance of moderate geomorphic integrity ratings. Yellowstone National Park had a high percentage (75%) of high geomorphic integrity watersheds due to the relatively undeveloped and undisturbed nature of the park.

The 6% of GYA watersheds with low geomorphic integrity ratings were areas with considerable watershed disturbance and/or function disruption. They comprise some of the highest priority areas for watershed rehabilitation and management improvement. Watersheds with ratings of moderate geomorphic integrity also have considerable potential for watershed rehabilitation.

Range and road impacts were the most frequent cause of low or moderate watershed geomorphic integrity ratings. Grazing was the predominant cause on the Madison Ranger District of the Beaverhead National Forest, on the Bridger-Teton and Caribou national forests, and on the Beartooth Ranger District of the Custer National Forest. Roads were the primary cause on the Gallatin and Shoshone national forests. In Yellowstone National Park, fire was the primary cause of downgraded geomorphic integrity ratings due to several watersheds in the eastern part of the park (Absaroka Range) with high watershed vulnerability ratings and a significant amount of 1988 canopy burn.

Water quality integrity ratings are a direct function of the damaged stream GIS layer, which includes stream segments with one or more human-caused damaging factors including bank damage, sediment loading, channel modification, flow disruption, thermal change, chemical contamination, or biological stress. Damaged streams are frequently listed on state 303(d) lists. The IWWI damaged stream layer displays damaged stream segments by cause. The highest percentages of damaged streams occur on the Madison Ranger District of the Beaverhead National Forest, on the Bridger-Teton and Caribou national forests, and on the Beartooth Ranger District of the Custer National Forest. They also have the highest percentages of impaired watershed conditions, with grazing as the primary cause.

Sediment and channel modification are the primary causes of low-to-moderate water quality

integrity ratings in the GYA. This is reflective of grazing and roads as the primary causes of adverse GYA watershed impacts. Yellowstone National Park is different than the GYA national forests in that several stream segments have lowered moderate water quality integrity ratings due to biological causes—primarily, non-native fish invasion. The chemical cause shown for the Beartooth Ranger District of the Custer National Forest, the Gallatin National Forest, and Yellowstone National Park is historical mining impacts in the Cooke City area.

Crucial streams have especially high resource values, including outstanding fishery, instream flow water rights, public supply diversions, outstanding recreation, Research Natural Areas, or threatened and endangered species reaches. About 10% of the streams in the GYA were rated as crucial. The Bridger-Teton National Forest has the highest percentage of crucial streams, due primarily to a large number of stream segments with outstanding recreation values in the Bridger and Teton wilderness areas.

Strategic approach to watershed management in the GYA

Broad-level strategic direction for watershed management within the USFS and National Park Service (NPS) is both clear and direct. Documents such as the Clean Water Action Plan and the Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management provide national direction to land managers to emphasize watershed protection and restoration in policy and decision-making. At the agency level, the Natural Resource Agenda (USFS) and the Natural Resource Initiative (NPS) provide further direction to emphasize the protection and restoration of watersheds.

The Government Performance Results Act directs that agency missions be carried out in a businesslike manner. In response to that act, the USFS revised its Strategic Plan (i.e., USDA Forest Service strategic plan, 2000 Revision) to outline long-term goals and objectives for future management. Under the broad goal of ecosystem health, Objective 1a of the strategic plan states, "Improve and protect watershed conditions to provide the water quality and quantity and soil productivity necessary to support ecological functions and intended beneficial water uses." This objective further outlines eight strategies to achieve the desired results. One goal of the GYA watershed management strategy is to further define the national objective and its strategies to be specific to the GYA.

The information provided by the IWWI analysis is important in localizing the objective. This analysis provides a common-scale, GYA-wide assessment of watershed condition, and focuses on important areas for strategic planning. The following recommendations for addressing the eight strategies of the national objective are based on the IWWI analysis. The eight strategies and their associated recommendations are presented below in a priority ranking reflecting their importance to the GYA.

Strategy 1. Use cooperative techniques in planning and stewardship of the national forests and grasslands, national parks, and wildlife refuges to resolve natural resource issues.

Implicit in this strategy is an emphasis on communication at all levels. The GYA contains a number of agencies with a variety of missions, as well as a diverse public with a variety of interests and values. Effective communication among these entities is essential to achieving the understanding necessary for resolving issues.

The GYCC provides a forum for interagency communication. Similar efforts between federal agencies and tribes, states, and private interest groups (e.g., Greater Yellowstone Coalition, Henry's Fork Foundation, Bozeman Watershed Council, Bear Canyon Task Force, Bear River Advisory Group, and Red Canyon Coordinated Resource Management) should be fostered. IWWI data can serve as a useful source of information to identify opportunities for additional partnerships as well as cooperative watershed planning and restoration.

Education is an integral part of communication. The GYA contains people with a vast amount of cultural and scientific knowledge concerning the history and workings of the ecosystem. Federal agencies should foster technical transfer of information both internally and externally.

Strategy 2. Design projects to achieve soil and water quality protection and watershed restoration with emphasis on transportation and livestock grazing systems.

This strategy is especially applicable to the GYA. The IWWI analysis showed that where watersheds were identified as having low or moderate geomorphic and water quality integrity, the major causes were either livestock grazing, roads, or both. Following are some specific recommendations to address these two causes:

Livestock grazing

- Forest plans within the GYA generally provide vague direction for standards dealing with livestock management. Thus, develop a common process for determining allowable use standards, stream bank alteration, forage utilization, woody browse, and stubble height that would further define existing direction. Include these standards in Allotment Management Plans (AMPs).
- Increase the level of range administration.
- Review allotment reauthorization schedules. Where possible, elevate to high priority for AMP development those sixth-code HUBs identified in the IWWI as having a geomorphic integrity rating of moderate or low with grazing as the primary cause.
- Increase range condition and trend surveys to assess upland condition.

Transportation system

- Identify where road drainage is allowing sediment to enter streams and then disconnect these roads from streams. Prioritize these areas according to HUBs identified in the IWWI analysis as having water quality integrity of moderate or low, with the cause being roads.
- Decommission excess roads. Prioritize roads for decommissioning according to HUBs identified in the IWWI analysis as having water quality integrity of moderate or low, with the cause being roads.
- Relocate roads that encroach on stream channels. Work with engineers to design adequate relocations.
- Identify fish barriers caused by stream crossings. Work with fish biologists to prioritize and initiate a process to replace the barriers.
- Identify front- and backcountry trails that are an appreciable source of sediment delivery to streams. Work with recreation specialists to disconnect these trails from streams.

The IWWI provides important information on watershed conditions that is useful for developing integrated resource programs. Sharing this information with other functional or program areas can assist with the identification of projects that would contribute to addressing critical watershed needs. For example, establishing priorities for trail and road maintenance and reconstruction; abandoned mine reclamation; developed site restoration; and fisheries, range, and wildlife improvement projects would be made easier with the benefit of this information.

Strategy 3. Provide research results and tools to support sustainable management, protection, and restoration of watersheds.

This strategy is especially applicable to the GYA because of its large numbers of streams in good condition. The IWWI analysis showed that 34% of the watersheds within the GYA function at high levels of integrity for water quality and geomorphic integrity. These areas can provide references for acceptable watershed conditions both within the GYA and for many other locations in the Rocky Mountain West.

Recent methodologies for analyzing watershed condition (i.e., the Federal Agency Guide for Pilot Watershed Analysis & Ecosystem Analysis at the Watershed Scale) recommend the use of reference reaches as a means for comparing watershed attributes. However, little work has been done to establish reference reaches for the variety of stream types that exist in wildland watersheds. Therefore, this strategy calls for creating and funding a team to conduct field inventories of reference aquatic conditions on a variety of functioning landscapes throughout the GYA, then developing relationships using field data to describe reference conditions for physical and biological components of the aquatic system. The information should be provided in a format that can be disseminated nationwide.

Strategy 4. Complete assessments, plans, and projects for watersheds identified as "priority" for treatment through Clean Water Action Plan cooperation with federal, tribal, state, and private landowners.

This strategy calls for compiling a list of the watersheds within the GYA that have already been identified through various regional efforts or are on state 303(d) lists, and using GYA influence to help obtain funding to complete work in these watersheds.

Strategy 5. Increase the number of abandoned mines and contaminated sites treated.

This strategy calls for providing a comprehensive, GYA-wide, inventory of prioritized sites, and working with state abandoned mine agencies to complete projects.

Strategy 6. Ensure the continued availability of water to meet purposes for which public lands

were established and to sustain ecological functions.

Currently, federal agencies work through individual states' water rights processes to obtain "favorable conditions of water flow" as directed by the U.S. Forest Service Organic Act and the establishment acts for the national parks and national wildlife refuges in the GYA. Administrative units within the GYA will continue to be a part of this process.

Strategy 7. Implement a system of national standards for assessing watersheds by the end of 2001.

This process has already been established through the use of "A Framework for Analyzing the Hydrologic Condition of Watersheds." GYA forests will use this process in determining the condition of fifth-level HUBs.

Strategy 8. Maintain the integrity of roadless areas through implementation of a roadless area conservation policy.

The USFS roadless area policy will be followed within the GYA. Recommendations for trail restoration in roadless watersheds (see above) will be applied.

Conclusion

Along with the privilege of administering landscapes within one of the nation's most spectacular settings, federal land managers in the GYA also share the responsibility for ensuring the integrity of one of the area's most valuable resources: water. Prompted by the Unified Federal Policy for a Watershed Approach to Federal Land and Resource Management, the GYCC has demonstrated a commitment to establishing watershed management as a top priority by preparing a watershed management strategy for the GYA. The strategy may be found at <http://mpin.nbii.org/gycc/committees/index.html>.

The multi-agency (and within an agency, multi-unit) approach to the strategy expands upon existing data to produce watershed information that provides consistency across administrative boundaries. Watershed and waterbody characteristics and conditions are identified and rated across the GYA. Managers and decisionmakers use this information to assist them in prioritizing watersheds and waterbodies in terms of protection, management, and restoration opportunities.

The management strategy provides a useful tool that when utilized on a particular unit, or across various units, will further the GYCC's commitment to watershed management. The specific guidance provided in the strategy provides management direction that will ensure that the GYA continues to perform its vital function as "America's headwaters."

References

Greater Yellowstone Hydrologists. 2002. *Watershed management strategy for the Greater Yellowstone Area*. Prepared for the Greater Yellowstone Coordinating Committee.

Shovic, H. F., and W. Urie. 2001. *The Greater Yellowstone Area watershed vulnerability modeling project.* Sponsored by the Greater Yellowstone Coordinating Committee and the Greater Yellowstone Area Hydrologists. Interagency Spatial Analysis Center.

Yellowstone Paintings: Artistic Discoveries, Hard Rides, and Golden Vistas

Sarah E. Boehme

John S. Bugas Curator, Whitney Gallery of Western Art

Aubrey L. Haines Lecture, October 19, 2005

Sarah E. Boehme has served as the John S. Bugas Curator, Whitney Gallery of Western Art, at the Buffalo Bill Historical Center in Cody, Wyoming, since 1986. She was curator and co-author of the exhibition catalogue for the national touring exhibition, *John James Audubon in the West,* and was co-curator and contributed an essay to the exhibition catalogue for the Museums West exhibition, *Powerful Images: Portrayals of Native America.* She also wrote the exhibition catalogues, *Whitney Gallery of Western Art; Absakoree Hut: The Joseph Henry Sharp Cabin; Buckeye Blake: Art on the Western Front;* and *Rendezvous to Roundup: The First 100 Years of Art in Wyoming.* She was co-author of *Seth Eastman: A Portfolio of North American Indians,* and *Frontier America: Art and Treasures of the Old West from the Buffalo Bill Historical Center.* She earned her BA from Sarah Lawrence College and holds an MA and PhD in history of art from Bryn Mawr College. Dr. Boehme has lectured extensively on topics in western art and artists including Thomas Moran, Frederic Remington, and Charles M. Russell. She serves on the Frederic Remington examination committee.

Artists who portray the Yellowstone region often create visions of a pristine wilderness in which the wonders of the region appear with no inference of outside human influence. We see that approach in Thomas Moran's chromolithograph, *Yellowstone Lake*, published in 1876 (Figure 1). In this landscape, Moran features a rocky foreground, jutting forcefully and signifying the wildness of the land. In the middle ground, we see the serene placidity of the lake. In the distance, the sky reiterates this tension of fierceness and beauty with dark and swirling clouds balanced by stunning rays of beatific light and a glowing rainbow—a symbol of divine presence and blessing. Avian life swirls, but the land appears as if no human has witnessed this scene, as if the artist has happened upon this moment for the first time.

This portrayal of the landscape of the American West, including Yellowstone, as an untouched land creates a powerful ideal both for the viewer and for the artist. The artist assumes a heroic role, sometimes even a spiritual role, as a creator of beauty. Yet the interests of government agencies, private businesses, and individual agendas often paved the paths that brought artists to Yellowstone. Examination of the historic context of Yellowstone's art provides perspective on the interrelationships of artistic creation and pragmatic functions. We will look today primarily at two artists, Thomas Moran (1837–1926) and Albert Bierstadt (1830–1902), whose works of art portrayed the wonders of Yellowstone to the public.

The idea of the artist intertwined with government and economic interests clashes with our romantic notions of the solitary genius toiling alone in a garret. The solitary artist works only the ideas from his mind, with no assistance other than the maulstick that steadies his hand. Yet reality is quite different. Issues of access, patronage, and marketing affect artistic outcomes, as seen especially in the example of artist Thomas Moran. Thomas Moran was an artist who took a very active role in his career, and his art is uniquely linked with the history of Yellowstone National Park. In fact, rarely is an artist so identified with a place that it becomes part of his name. Yellowstone was the experience that changed him; it provided him with a pivotal moment in his career, when he transformed himself from a journeyman engraver to a fine arts painter. Moran also had an effect on Yellowstone. Rarely do we find an artist who has a direct effect on public policy.

The paintings and other prints created by Thomas Moran spurred an appreciation for both the landscape and its preservation and encouraged the utilization of the land and its resources. His stunning watercolor, *Great Blue Spring of the Lower Geyser Basin*, 1872 (Figure 2), resulted from his groundbreaking journey into the Yellowstone region in 1871. This painting does not present a totally pristine wilderness, because we see human figures on the edge of the springs. They give scale for the viewer of the work of art, who is looking at a

Figure 1. Thomas Moran, artist; Louis Prang, publisher. *Yellowstone Lake,* 1875, published 1876, chromolithograph. Buffalo Bill Historical Center, Cody, Wyoming. Gift of Clara S. Peck; 18.71.5.

Figure 2. Thomas Moran. *Great Blue Spring of the Lower Geyser Basin, Firehole River,* Yellowstone, 1872, watercolor on paper. Buffalo Bill Historical Center, Cody, Wyoming. Purchased with funds from the William E. Weiss Fund, Mrs. J. Maxwell Moran, Wiley Buchanan, III, Nancy-Carroll Draper, Nancy and Nick Petry, Steve and Sue Ellen Klein, William C. Foxley, John F. Eulich, Mary Lou and Willis McDonald IV, and D. Harold Byrd, Jr.; 24.91.

Figure 3. Charles Moore. *Upper Falls, Yellowstone,* 1870, pencil on paper. National Park Service, Yellowstone National Park. NPS photo.

Figure 4. Walter Trumbull. *Upper Falls, Yellowstone, 115 feet.* 1870, pencil on paper. National Park Service, Yellowstone National Park. NPS photo.

mysterious landscape. In this case, they certify that humans have entered this landscape and are observers of its features. There are four figures; one appears to have a headdress with feathers, signifying an Indian. Both the Indian and the other men are observers in this wonderland. Although this specific watercolor was probably painted for a private patron, it is one of a group that resulted from Moran's trip association with governmental support. He traveled to the Yellowstone region with the expedition of Ferdinand V. Hayden. It was an extraordinary moment for the region and for the artist.

Before his trip to Yellowstone, Moran was an artist seeking to establish a career as a landscape painter. He had created some masterful depictions, drawn from his imagination and his close study of nature, such as *Children of the Mountain,* 1869, oil on canvas, private collection. But he still needed to work as an engraver for magazines to support himself and his family. Thomas Moran was born in Bolton, England, in 1837; he immigrated to the United States as a boy of seven with his family. As a schoolboy in Philadelphia, he visited art galleries, and at the age of 16, he went to work as a wood engraver. He sketched and painted Pennsylvania landscapes, and in 1862, he and his brother, Edward, also an artist, traveled to England to study paintings of artists they admired—especially those by J. M. W. Turner—as well as to sketch the European landscape. Upon returning to the United States, Moran married his fiancée, Mary Nimmo, and launched his career as a painter, supplemented by work as an illustrator for magazines. Through his illustration work, he first learned of the Yellowstone region.

Scribner's magazine commissioned Moran to illustrate a two-part article, "The Wonders of the Yellowstone," written by Nathaniel P. Langford, who would later become the first superintendent of Yellowstone National Park (Langford 1871). Langford, a businessman and then a tax collector in Montana, traveled through Yellowstone in 1870, as part of the Washburn–Doane expedition. He wrote an account of the trip and gave lectures in the East about the Yellowstone, publicizing the region. The article he wrote about the fantastic features of Yellowstone cried to be illustrated. Moran had, as resources, Langford's text and some rough pencil sketches by two members of the party, neither of whom was a trained artist.

Army Private Charles Moore (1846–1921), who

Figure 5. Thomas Moran. *Upper Falls,* 1871, wood engraving. NPS photo.

was part of the military contingent on the Washburn–Doane expedition, blocked out an image of the Upper Falls of the Yellowstone River (Figure 3). A civilian also drew the upper falls (Figure 4); Walter Trumbull, a journalist on the expedition, sketched out a rudimentary outline. (Trumbull's father was Senator Lyman Trumbull of Illinois, who would later be an important figure in the congressional consideration of making Yellowstone into a park.) These awkward sketches provided working material and inspiration for Moran. He redrew the scene to give a sense of three dimensions, volume, and variety to the landscape features (Figure 5).

Moran reworked other sketches by Moore and Washburn for the publication, and the task convinced him that Yellowstone was a site he wanted to visit. He obtained permission to join the official governmental expedition into Yellowstone planned for the summer of 1871. Ferdinand V. Hayden, a medical doctor who had become a geologist working in explorations for the government, obtained an appropriation from Congress to organize an expedition to study the Yellowstone region. Hayden assembled a party of scientists and included an artist, Henry Wood Elliot (1846–1940), and a photographer, William Henry Jackson (1843–1942). Moran was approved to join the party, but did so with his own financing, backed by business interests—*Scribner's* magazine and Jay Cooke of the Northern Pacific Railroad. Moran seems actually to have borrowed money from both, although he redeemed his loans with art—so essentially, he sold art to finance his trip. He placed his painting, *Children of the Mountain,* with Roswell Smith, publisher of *Scribner's*, for a loan of $500, and he never redeemed the painting. He likewise obtained $500 from Jay Cooke, and later seems to have given him watercolors of Yellowstone in exchange. Representatives of Cooke associated with the Northern Pacific Railroad wrote to Hayden on Moran's behalf, so interrelationship was significant. The Northern Pacific was seeking attractive destinations for future extensions of its tracks, and an accomplished artist's depictions were potentially useful.

Thomas Moran took the Union Pacific Railroad west and made his first sketch of the West at Green River, Wyoming. Then he traveled on into Utah, and to Virginia City, Montana, where he joined the expedition. Moran and photographer William Henry Jackson became friends and comrades, sketching and photographing together and influencing each other with ideas on composition and views. Jackson photographed the formations at Mammoth Hot Springs with Thomas Moran in the image to give scale and to serve as a romantic figure looking into the landscape (Figure 6). He joined the group in early July, and stayed through August. Moran was not a seasoned explorer as many others on the party were. He had little experience in riding horseback, and often had to use a pillow on his saddle. The

Figure 6. William Henry Jackson. *Hot Springs on Gardner River,* 1871, photograph. NPS photo.

Figure 7. Thomas Moran. *Great Springs of the Firehole River,* 1871, watercolor. National Park Service, Yellowstone National Park. NPS photo.

Figure 8. Thomas Moran. *Hot Springs, Yellowstone,* 1871, watercolor. National Park Service, Yellowstone National Park. NPS photo.

bacon and fried foods were upsetting to his digestion, but he endured them for the experience.

As he traveled, Moran made sketches; some were rough pencil sketches with simple contour lines for geologic features. In other sketches, such as his study of the springs of the Firehole River (Figure 7), he applied watercolor washes to build volume and indicate the extraordinary colors of the landscape. As in this work, he would also jot down notations of color names for future reference. Later in his studio in the East, he used the sketches to paint finished watercolors such as the one of Great Blue Spring (Figure 2). These works had the fluid, fresh look of watercolor, but were carefully constructed with layers of color, accented by opaque white.

Just as the two artists, Moran and Jackson, worked together in Yellowstone, their watercolors and photographs also served complementary pur-

poses. Hayden had employed Jackson previously, and he knew instinctively that photography gave a sense of reality to visual imagery. In its short history, photography had become accepted as a mirror of nature providing truth—the perfect tool for the scientist. Yet Moran's watercolors provided an element that was lacking in photography at that time—color. Not just color, but a vividness that brought the landscape to life (Figure 8).

Moran, of course, was never an official member of the expedition, so his drawings remained his own property, not the government's. He had obligations to satisfy—watercolors for Jay Cooke and illustrations for *Scribner's* magazine—and his own ambitions to further. Therefore, there is a caution in assuming too much for his role in publicizing the Yellowstone region, but Moran's watercolors clearly played a role. Ferdinand Hayden lobbied Congress for the continued funding of his scientific expedition and for protection of the land. He went to a public forum, as well. Hayden expressed his sentiments to a popular audience through an article for *Scribner's*, again illustrated by Moran, but this time from the artist's own experience viewing the park (Figure 9). In his article, Hayden chastised the national legislators, saying, "Why will not Congress at once pass a law setting it (the Yellowstone) apart as a great public park for all time to come, as has been done with that far inferior wonder, the Yosemite Valley?" (Hayden 1872, 396). In his lobbying, it seems that Hayden used every available tool, including the watercolors by Moran.

William Henry Jackson later wrote, "in the proceedings before Congress for the creation of the Yellowstone National Park, the watercolors of Moran and the photographs of the Geological Survey were the most important exhibits brought before the Committee" (Jackson 1936, 157). An article in *Harper's Weekly* in March 1872 discussed the bill that had been pending before Congress and then said, "those who had been so fortunate as to see the original sketches by the artists who accompanied Dr. Hayden know how beautiful as well as interesting the phenomena of the region are." Other anecdotal evidence from Moran's family supports the view that Hayden personally borrowed works by Moran to convince Congress of the importance of Yellowstone (Kinsey 1992, 60). After Congress approved a bill, Ulysses S. Grant signed into law the act that set aside Yellowstone lands as a public park on March 1, 1872.

In the meantime, Moran was at work on his masterpiece, a painting of the Grand Canyon of the Yellowstone River, a monumental work. He explained his belief about subjects for art in a letter to Hayden: "But I have always held that the grandest, most beautiful, or wonderful in nature would, in capable hands, make the grandest, most beautiful, or wonderful pictures; & that the business of a great painter, should be the representation of great scenes in nature" (Anderson et al. 1997, 89). In creating his great masterwork, *Grand Canyon of the Yellowstone* (Figure 10), Moran based his composition on nature, but it was always an artistic interpretation of nature. The artist sought Hayden's approval of the painting, but he later described his manipulation of elements. He stated that he did not value literal translations of nature, and that his primary motive for *Grand Canyon* was the display of color. Moran was quoted as saying,

Figure 9. Thomas Moran. *The Great Cañon and Lower Falls of the Yellowstone,* 1872, wood engraving. NPS photo.

Figure 10. Thomas Moran. *The Grand Canyon of the Yellowstone, 1872,* oil on canvas, 84 × 144.25 inches. The U.S. Department of the Interior Museum, Washington, D.C.

> The forms are extremely wonderful and pictorial, and while I desired to tell truly of Nature, I did not wish to realize the scene literally, but to preserve and convey a true impression. Every form introduced into the picture is within view from a given point, but the relations of the separate parts to one another are not always preserved. For instance, the precipitous rocks on the right were really at my back when I stood at that point, yet in their present position they are strictly true to pictorial nature; and so correct is the whole representation that every member of the expedition with which I was connected declared, when he saw the painting, that he knew the exact spot which had been reproduced" (Sheldon 1972).

Like the finished watercolor of *Great Blue Spring,* Moran's masterwork of *Grand Canyon of the Yellowstone* did include a human presence. Two small figures, an explorer and an Indian, face the chasm of the Canyon. Moran acknowledged the native inhabitants of the region and placed the explorer in a companion role.

Moran exhibited his masterwork to great acclaim. *Scribner's* magazine, which of course had supported Moran, was a logical source for praise, finding the painting "the most remarkable work of art which has been exhibited in this country for a long time." But other critics chimed in as well, saying "Moran . . . will stand henceforth in the front rank of American paintings," and "Mr. Moran's 'Great Canyon of the Yellowstone' will, we are sure, be received by the best judges in America as the finest historical landscape yet painted in this country" (Anderson et al. 1997, 91–92).

Moran exhibited the painting in Washington, D.C., at the Smithsonian and at the Hall of Representatives. In an unusual act of patronage, Congress purchased it for $10,000, for the Capitol building. Congress's prior purchases and commissions had primarily sponsored decoration of the Capitol building with scenes from history. Purchasing, outright, a landscape painting signaled a new direction, a new appreciation for the landscape itself, as well as an embracing of Moran's accomplishments as an artist. After being supported by private business and his own initiative, to have government patronage brought Moran to a new level of achievement.

Moran continued to paint scenes of Yellowstone based on his sketches. His other significant project was the production of a portfolio of 15 chromolithographs, including nine scenes of Yellowstone for publisher Louis Prang (Figure 1). This publishing venture translated the beauty of his watercolors into theoretically more available prints. Moran also cre-

ated a unique monogram, superimposing the initial M of his last name over the T of his first name to make a Y, signifying "Thomas Yellowstone Moran." His experiences united the identity of the artist with the identity of his most important subject. Yellowstone had made his career; he had helped to make Yellowstone a national park and bring it to the attention of the public.

Yet it would be another 20 years before Moran returned to Yellowstone. In 1873, he traveled to the Grand Canyon of the Colorado with John Wesley Powell. In future summers he would paint in the Arizona region and other sites, primarily in the Southwest. Moran would return, quite dramatically, to Yellowstone in 1892, but in the meantime, his rival as a painter of the American Western landscape, Albert Bierstadt, would try his hand at portraying the wonders of Yellowstone.

Albert Bierstadt was born in Germany on January 7, 1830, and immigrated to New England with his family as a young child. Determined to be an artist, he traveled to Düsseldorf in 1853 to receive painting instruction. While abroad, he sketched along the Rhine, and in the Alps, quickly absorbing the fundamentals of drawing and painting. He returned to the United States in 1857. He came west in 1859, accompanying engineer Frederick Lander's survey along the Overland Trail. The surveying and road-building party provided Bierstadt with the ability to travel to the Rocky Mountains, although it appears that his expenses were Bierstadt's own responsibility.

This trip ignited the most productive phase of his career. In the following decades, Bierstadt made several excursions west and achieved great fame and financial success for his depictions of the Rocky Mountains and of the Yosemite in 1863. Albert Bierstadt did not venture to Yellowstone until 1881. His career was waning somewhat at this point. He was not experiencing the success of his early period either in critical acclaim or in the prices for his paintings. The trip to Yellowstone may have been one effort to revive his career. He traveled in the company of John Sherman and his brother General William T. Sherman, who had traveled through the park previously.

Bierstadt's description of his journey was mostly idyllic, but he did refer to being lonely. In an unidentified newspaper clipping, "An Artist's Rambles: Albert Bierstadt's Wanderings in Search of the Picturesque in the Rocky Mountains," the artist described his trip to Yellowstone:

> While I was in the Park we lived in tents almost exclusively. There are no houses anywhere near the geysers, and hence we found it sometimes very lonely. I say lonely because I did not find people to converse with; but, ah, how can one be lonely when one is surrounded by all the glories of a most glorious nature, and overhung by a sky unequaled by any in the world (Brooklyn Museum Archives).

Ironically, in this solitude, William Wylie, who would later go on to operate the Wylie Tent camps in Yellowstone, and who would be responsible for bringing scores of visitors to the park, observed Bierstadt painting. He mentioned the artist in the important early guidebook he wrote, somewhat like a celebrity sighting:

> The author had the pleasure of sitting beside and conversing with the famous American artist, Bierstadt, as he was seated on a point in the Grand Canyon about 400 feet below the surface—engaged in reproducing in oil, upon canvas, the Grand Canyon and Falls. It was indeed marvelous to see with what rapidity and accuracy these scenes were by him transferred to the canvas. He then remarked to me that a different picture could be taken at almost every hour in the day, since a difference in the direction of the sun's rays made a difference in the appearance of the colors in the Canyon (Wylie 1882, 61).

Bierstadt's views of the park were primarily visions of an untouched wilderness, a view of the park that he stressed in his interview. Stylistically and pictorially, Bierstadt's depiction of the Lower Falls is quite different from Moran's approach. Bierstadt portrays the Falls as darkly romantic, with the Germanic influence in the composition (Figure 11).

Yet in his presentation of himself to the public, he took great pains to be specific and to provide scientific information in relation to his art. In a clipping from an unidentified newspaper, Bierstadt was quoted about his trip to Yellowstone:

> But I have never been so impressed with the infinite divinity of the types of nature as I was by these same geysers. I went West with the fixed intention of spending the greater part of my time about the geysers, and also to study them as thoroughly as I could in the protracted period I had allotted to myself. . . . We encamped near the geysers, and hence the heat of the boiling water warmed the atmosphere about us. . . . The 'Old

Figure 11. Albert Bierstadt. *Yellowstone Falls,* ca. 1881, oil on canvas. Buffalo Bill Historical Center, Cody, Wyoming. Gift of Mr. and Mrs. Lloyd Taggart; 2.63.

> Faithful' geyser is only a short distance from the 'Beehive,' and is much the more popular as the stream of water bursts forth at intervals of fifty-five minutes. This ascends to a height of two hundred and fifty feet, and the stream of water is as large in circumference as a hogshead.

In other statements, he referred to the sedimentary deposits of silica, iron and sulfur crystals, and to the volcanic origin of Yellowstone.

Bierstadt added human interest to his comments on the beauty and science of Yellowstone. He complained about trying to eat the fish from Yellowstone Lake. Describing the fish as ruined by parasitic worms, he said, "It is seldom very appetizing when one finds a worm eighteen inches long in the sauce."

After his return from Yellowstone, the artist turned to producing larger versions of the sketches he made on site. He did not paint an immense Yellowstone landscape as Moran had done. Instead, his canvases were of more moderate size. Bierstadt did not seek a Capitol setting for his paintings of western scenery; rather, he sought placement in another national building: the White House, the residence of the president. Bierstadt loaned five paintings to President Chester A. Arthur (1881–1885). An article in the *Kansas City Times* on April 13, 1884, reported that "Mr. Bierstadt is a personal friend of the president's and on one of his visits here he was forced to

notice the bare walls of the upper part of the house. . . . In consequence, Mr. Bierstadt sent these pictures down from his studio, lending them to the president for as long a time as he chooses to keep them."

Bierstadt had a more permanent arrangement in mind. The *Congressional Record* indicates that Bierstadt was attempting to sell the group. A Senate resolution in May 1886 (after Arthur had left office and the president was now Grover Cleveland) included an inquiry into the "propriety and expediency of purchasing the paintings of 'The Yellowstone Falls,' 'The Giant Geyser,' 'Yosemite in Winter,' and 'General View of Yellowstone Park.'" The architect of the Capitol had no hesitation in recommending their purchase. In 1890, the House of Representatives considered an appropriation of $65,000, then $50,000, and it was said that the paintings at the White House "were placed there by the artist at request of President Arthur, in the year 1882 under the verbal agreement that they were to be purchased by the Government. They are illustrative of the grandest scenery in the country, and have been pronounced by competent critics splendid specimens of Bierstadt's genius." As late as 1893, another bill was introduced for the purchase of the paintings. Congress took no action, and eventually the paintings were returned to the artist (Buffalo Bill Historical Center Curatorial Files).

The paintings did have a significant effect. The newspaper clipping that discussed the paintings Bierstadt loaned to the White House concluded, "They were hung in their present places just two years ago, and after a twelvemonth's contemplation of the painted semblance of the 'Yellowstone Falls,' the 'Yellowstone Canyon' and the 'Giant Geyser,' President Arthur made up his mind to go out and see the originals." With an entourage including a cavalry escort, a journalist, and photographer Frank Jay Haynes, President Arthur visited Yellowstone Park in 1883. In that year, the Northern Pacific Railroad reached the northern border of the park, opening up the park to increased tourism. The visit of a sitting president added to the publicity, and brought the park to the attention of many potential visitors.

Although Bierstadt continued to try to sell his Yellowstone paintings to the government as late as 1893, he never returned to Yellowstone itself, and turned to different subjects for his last great paintings. When Thomas Moran did finally return to Yellowstone in 1892, his trip took him through the northern part of the state of Wyoming. The circumstances influenced one of his most important Yellowstone paintings.

Moran's return trip was again in the company of photographer William Henry Jackson. In the initial planning, Jackson was the official member of the party, as he had been in 1871. Jackson was commissioned to make photographs of Wyoming for its state building at the World's Columbian Exposition, to take place in Chicago in 1893. Wyoming had just become a state in 1890, so the exposition would be, in some ways, a debut for the state on the world stage. Jackson's instructions came from Elwood Mead, the state engineer who was also secretary of Wyoming's exposition committee. In March 1892, Mead wrote Jackson about the planned expedition to obtain photographs of the mountain scenery of Wyoming. He proposed that they go first to Crook County, to secure views of Devils Tower. Then they would cross the state to Yellowstone Park. Mead wrote, "We shall be greatly pleased to have Mr. Moran become a member of the party." He asked if Moran would definitely come, and if so, what pack animals Moran would need. By June, it was confirmed that Moran was coming on the trip. Mead wrote to the general manager of the railroad that was furnishing transportation that there would be two additional members of the party, one being Moran. He said, "Mr. Moran expects to obtain sketches for a painting to be made a part of the Wyoming exhibit." Therefore, both Jackson and Moran were planning to produce works from this trip for the Wyoming State Building (Wyoming State Archives).

Moran documented the first part of the trip in an article published in *Century Magazine*. "A Journey to the Devils Tower in Wyoming" was a rare instance when Moran wrote of and published his experiences. Moran reported that the party consisted of Jackson; Jackson's assistant, Millet; and himself. Misadventures filled the journey. They received bad directions and got lost. They encountered inhospitable ranchers and then a hailstorm. According to Moran, they suffered from an "awful fusillade of iceballs that struck us with a force as if coming from a sling. . . . How long would it last? How long could we stand it?" The horses almost stampeded, and then they became stuck in the "gumbo mud" (Moran 1894).

Moran and Jackson finally reached Devils Tower, and it seems to have been worth the trip. Moran said it was a "grand and imposing sight, and one of the remarkable physical features of this country." Because Moran had previously seen many extraordinary landscapes and had not written about them, it may have been the rigors of this trip that

Figure 12. Thomas Moran. *Golden Gate, Yellowstone National Park,* 1893, oil on canvas. Buffalo Bill Historical Center, Cody, Wyoming; 4.75.

singled it out for literary attention.

After Devils Tower, Moran and Jackson joined other members of the state expedition organized by Elwood Mead and traveled across the Bighorn Mountains, entering Yellowstone from its northeast corner (Bassford 1967). They visited a site they had not previously seen together, and it resulted in one of Moran's major paintings.

Moran made a series of pencil sketches of Golden Gate pass, which is about four miles south of Mammoth Hot Springs. Later, in his studio, he used these as aids in painting *Golden Gate, Yellowstone National Park* (Figure 12). Yet when he created the painting, he manipulated, as he always did, to make the best pictorial truth, placing elements in the composition that would not be visible from one viewpoint. What is especially significant in *Golden Gate* is that Moran portrayed not only the beauty of nature, but also the handiwork of humans. He depicted the trestled road built by the Army Corps of Engineers. Traveling at the behest of the state engineer of Wyoming, he was likely to appreciate the fine points of road building. Having suffered through a miserable wagon ride in northeast Wyoming, he was probably grateful for the smooth ride the road promised. Yet it is a remarkable element to have celebrated in his painting, especially because so few Yellowstone landscape paintings contain any suggestion of human alteration of the natural setting. Moran's painting was especially successful because he made the road seem to be an integral part of nature.

A painting celebrating the beauty of Yellowstone and the engineering feat of road building along a mountain pass would have been a very appropriate image for the State Building of Wyoming at the Columbian Exposition. Alas, it did not happen. Wyoming never constructed a state building; the exposition commission did not have sufficient appropriations from the state legislature to pay the costs of a separate building. Wyoming did have a state mineral exhibit in the Mining Exhibit Hall, and Jackson's photographs were exhibited there. Moran's painting of *Golden Gate* does not seem to have been shown at the World's Columbian Exposition, where it would have been a wonderful example of nature and progress, consistent with the theme of

the exposition. Moran did show, in the fine arts exhibit at the Columbian Exposition, his second great painting of *The Grand Canyon of the Yellowstone* (1893, oil on canvas, Smithsonian Museum of American Art). Moran's 1893 painting is more romantic and dramatic than his 1872 version. The landscape seems more mysterious and unapproachable. Moran created that vision even as he knew that the park was being changed by human presence. The ideals of wilderness and the emotive possibilities of the landscape inspired the artist.

Moran exhibited *Golden Gate* at the 1894 exhibition of the National Academy of Design in New York. There it caught the attention of artist Frederic Remington, who remembered Moran's painting when he visited Yellowstone and traveled over the road. Remington wrote about it in his article, "Policing the Yellowstone" for *Harper's Weekly* in 1895. Remington, struck by the beauty of the Golden Gate pass, wrote, "Mr. Thomas Moran made a famous stagger at this pass in his painting, and great as is the painting, when I contemplated the pass itself I marveled at the courage of the man who dared the deed" (Samuels 1979, 169).

The interests of business, the government, private citizens, and even artists trying to make a living are all intertwined with complicated motives in the creation of art about Yellowstone. Yet the art endures, and the park endures, and we return to each for inspiration and joy.

References

Anderson, N. K., T. P. Bruhn, J. L. Kinsey, and A. Morand. 1997. *Thomas Moran*. Washington, New Haven and London: National Gallery of Art, Yale University Press.

Bassford, A. O., ed. 1967. *Home-thoughts from afar: letters of Thomas Moran to Mary Nimmo Moran*. East Hampton, N.Y.: East Hampton Free Library.

Brooklyn Museum Archives. Bierstadt Collection.

Buffalo Bill Historical Center Curatorial Files. Typescripts. Records of the Senate (Sen 50A-F13). Records of the House of Representatives (Report 3961).

Hayden, F. V. 1872. Wonders of the West II: more about the Yellowstone. *Scribner's Monthly* 3 (February):388–396.

Jackson, W. H. 1936. With Moran in the Yellowstone: a story of exploration, photography and art. *Appalachia* (82):149–158.

Kinsey, J. L. 1992. *Thomas Moran and the surveying of the American West*. Washington and London: Smithsonian Institution Press.

Langford, N. P. 1871. The wonders of the Yellowstone. *Scribner's Monthly* 2 (May):1–17 and (June):113–128.

Moran, T. 1894. A journey to the Devils Tower in Wyoming. *Century Magazine* 47 (January):450–455.

Samuels, H., and Samuels, P. 1979. *The collected writings of Frederic Remington*. Garden City, N.Y.: Doubleday & Co., Inc.

Sheldon, G. W. 1972. *American painters: with one hundred and four examples of their work engraved on wood*. Reissued edition. New York: Benjamin Blom, Inc.

Wylie, W. W. 1882. *The Yellowstone National Park, or, The Great American Wonderland*. Kansas City, Mo.: Publishing House of Ramsey, Millett & Hudson.

Wyoming State Archives. Report on the Wyoming World's Fair Commission.

A Tribute to Partnership in the Greater Yellowstone Area

Dale Bosworth

Chief, U.S. Forest Service

Opening Keynote, October 17, 2005

Dale N. Bosworth became the fifteenth chief of the U.S. Forest Service on April 12, 2001. Mr. Bosworth was born in Altadena, California, and grew up there in a forest service family. He began his career in 1966, as a forester. He served as a line officer on several national forests and in planning positions in the West, and worked in the Washington Office as deputy director of forest management from 1990 through 1992 before being assigned to the field as a deputy regional forester. He was also the regional forester for the Intermountain Region headquartered in Ogden, Utah, and prior to his selection as chief, served as regional forester for the Northern Region, headquartered in Missoula, Montana.

It's a real privilege to be here tonight to give the opening keynote address. It's an honor for the forest service, particularly this year, when we are celebrating our centennial. I understand the centennial film, *The Greatest Good*, about the history of the forest service, was screened earlier today, and I hope you got a chance to see it, because I think it goes beyond our own history to issues that affect us all in federal land stewardship, such as managing fire and fuels, sustaining habitat for wildlife and fish, and, above all, working together through partnerships.

One reason it's such a privilege to be here during our centennial year is that the Greater Yellowstone Area [GYA] is where our first national park is located—and one of our first national forests—[both created] even before our agencies were created.

Interagency partnership

I see my presence up here tonight as a tribute to the strength of our interagency partnership through the Greater Yellowstone Coordinating Committee [GYCC]. We started working together here in the GYA about 40 years ago. That's pretty amazing, because it was a time when interagency collaboration was not encouraged, and not much of it was happening anywhere.

But we were starting to understand that ecological processes cross borders and boundaries, and we gradually came to realize that if we were truly interested in sustainable land management, then we had better start working together. And we've been doing so ever since through the GYCC. I understand that our partnership is now stronger than ever, thanks to the leaders who are on the committee and the strong relationships between them.

I had the honor of being associated with the GYCC in the 1990s, when I was regional forester for the forest service in the Intermountain Region and later the Northern Region. I was also on the Interagency Grizzly Bear Committee [IGBC], and chaired that committee for a couple of years. Our success on the IGBC wouldn't have been possible without strong support from the GYCC.

As a result, we've seen the grizzly go through a remarkable recovery in the GYA. By working together across the landscape, we've made some real progress. We've met all our recovery goals since 1998, and the grizzly population in the GYA has tripled over the last 30 years or so. We've been so successful that the U.S. Fish and Wildlife Service is nearing a delisting proposal. The forest service is in the process of amending forest plans to incorporate the conservation strategy.

Four threats

Strong federal partnerships like this set an example for the nation. We need partnerships like this now more than ever, because we face some very serious threats on the nation's forests and grasslands. At the forest service, we've been focusing on four threats in particular. One threat comes from fire and fuels. The 1988 Yellowstone fires signaled a period of growing fire seasons and increasing fire danger nationwide, particularly in the WUI [wildland–urban interface]. Our goal is to restore the dynamic ecological processes that our forested landscapes evolved with, including disturbances such as fire. But the issue is very complex. Restoring fire to the landscape might not always work where there's a threat to the WUI or other things to consider, so we need sound mitigation strategies that address the social and ecological complexities of the situation.

A second threat comes from invasive species. Following the [1988] Yellowstone fires, there was a

huge threat from invasive weeds, and we formed interagency teams to deal with it. These teams were a model for the Cooperative Weed Management Areas that then spread across the country. Our strategy now is to take a collaborative, all-taxa approach to prevention, response, control, and restoration.

Another enormous threat comes from loss of open space. I spent most of my career in the northern Rockies and the Intermountain Region, and I've seen a lot of changes in and around the GYA. Rural areas are disappearing and the WUI is growing, and not just here. Nationwide, we lose more than 4,000 acres of working farms, ranches, and forests to development every day. We have got to find collaborative ways of stopping the loss.

A fourth threat comes from unmanaged outdoor recreation. Recreation has become by far the biggest use of national forest land, and the biggest economic contributor. That's especially true here in the GYA, and as the WUI expands, recreational use will only grow. We have got to get to a point where visitors get the high-quality experiences they want without compromising the health of the land or the ability of future visitors to get those same high-quality experiences. That goes especially for the use of off-highway vehicles, both in this region and nationwide.

I believe these are the greatest threats facing the nation's forests and grasslands—fire and fuels, invasive species, loss of open space, and unmanaged outdoor recreation. Yet our national focus is on other issues—like whether too much timber is coming off national forest land or whether we're building too many roads. My biggest fear is that these other, lesser issues are absorbing all our energy while more important things are falling by the way. I think we need to change the national dialogue to focus on the things that really count the most.

The GYCC is helping us do that by setting a national example of partnership to address the most serious threats. For example, for more than a decade now, a central coordinating principle for the GYCC has been to maintain functional ecosystems, partly by focusing on the ecological processes needed by fire-dependent species like aspen and whitebark pine—partly by controlling invasive weeds, and partly by other means. This is where our focus should be, and I commend the GYCC for leading the way.

Future challenges

So these are the four main threats we're dealing with—fire and fuels, invasive species, loss of open space, and unmanaged outdoor recreation. But there are other, longer-term challenges, as well, and in the next few minutes, I'd like to outline some of them:

- *Dealing with a growing population.* By the turn of the next century, we are projected to have more than half a *billion* Americans. Think about what that means for our water resources alone. Think about the additional pressures that will put on the GYA as people move into the WUI around here, and as they demand more opportunities for outdoor recreation.

- *Expressing the changing face of America.* Most of our population increase over the next century will come from immigration. That means Americans are going to get even more urban and ethnically diverse. Conservation belongs to all of our citizens, yet the face of conservation has traditionally been rural and white. We need to broaden the circle of conservation. We need to give Americans from every background more opportunities to participate in conservation.

- *Restoring the health of our watersheds, along with our deteriorating infrastructure.* The forest service has a huge backlog of watershed restoration projects, including here in the GYA. We've got thousands of deteriorating culverts to replace. We've got roads to restore, abandoned mines to reclaim, vegetation to treat, and all kinds of deferred maintenance and ecological restoration to catch up on.

- *Supporting our land ethic with a sound, well-focused consumption ethic.* Americans want it all—recreation opportunities, access, clean water, wildlife, and scenery, plus inexpensive two-by-fours and printer paper. Last year, Americans consumed wood products at record levels, and we remain the largest wood-consuming nation on earth. Yet we don't want any changes in the landscape or any commercial operations on public land. If we truly believe in a land ethic, then we as a nation must also demonstrate a sound consumption ethic.

- *Understanding and coping with long-term and large-scale climate changes.* Climate change at various scales is undeniable. For example,

> we're in a much drier period in parts of the West than we were 30 years ago. This has huge social, economic, and ecological implications, including here in the GYA.

New collaborative models

Taken together with the Four Threats, these challenges are on a scale seldom seen in the last hundred years. And if there's one thing we've learned over the last few decades, it's that our way of dealing with challenges through top-down approaches and through conflict and gridlock doesn't work. We need to find new models for dealing with the issues we face today and the ones we'll face 20 years from now, whatever those issues might be.

At the beginning of this year, the forest service held a Centennial Congress to celebrate our past and to look to the future. We invited partners and collaborators from all over the country to help us address the challenges to conservation in the century ahead. I was interested in hearing not only what folks thought the major challenges were, but also how they thought we ought to address them. How we approach each other is key. Do folks from outside federal agencies like the forest service come to us and want us to give them the solutions? Or do they come to us to help them work out the solutions for themselves?

The Centennial Congress was a model of the latter. The participants focused on major issues that will matter for years to come, like ecosystem services and the need for more conservation education. But the way the Congress framed these issues was particularly important. The participants focused on building our role at the forest service as a convener and facilitator instead of a top-down director of everything that happens. They focused on the need for engaging folks in finding solutions for themselves, because they are the ones who are out there on the land and can truly make a difference. They focused on community-based stewardship.

I believe that our role as federal land stewards in the twenty-first century will be to facilitate a collective commitment to conservation. The possibilities for collaboration are endless, but the only way to resolve the issues that truly matter in the long term will be through a collective commitment to conservation. The best way we can care for the land and serve people today is to build more capacity for community-based stewardship.

In all of this, science will have a strong role to play, as the agenda for this conference clearly shows. Community-based stewardship, social values, outdoor recreation, fire and fuels, invasive species, watershed restoration—a lot of the challenges I just mentioned have been or will be specifically addressed at this conference. We welcome that; I believe that our land management and our science are at their best when we share ideas and experiences, tackle issues jointly, and come up with the solutions that work best all across the landscape.

Spirit of conservation

In closing, this being the centennial year of the forest service, I want to invoke the spirit of conservation from a century ago. A century ago, President Theodore Roosevelt and other conservationists warned against wasting timber, wildlife, and other natural resources. They warned of the need to conserve America's spectacular wild landscapes.

At the time, there was a widespread sense that America's resources were limitless, so why worry about conservation? There's a similar prideful sense today that our technological capacity is limitless, so why worry about conservation? If we run out of a resource, we can always find a substitute.

Unfortunately, that's not necessarily so. Just like a century ago, I think we need to guard against complacency—against the blithe assumption that our natural resources will be there forever, no matter how much we waste, neglect, and abuse them. Taken together, the threats and the challenges we face today are as great as any we've ever seen. But we can't address them by acting alone; we need to work together across the landscape.

For 40 years, the Greater Yellowstone Coordinating Committee has led the way. The GYCC embodies the collaborative spirit that I think is at the heart of conservation: of suspending distrust, of finding common ground, and of acting together to achieve a common purpose. Strong federal partnerships like this set an example for the nation. They bring out the best in all of us. I am proud of our history of working together here in the GYA in the spirit of conservation, and I look forward to the next 40 years of collaboration.

Multi-Park Invasive Plant Monitoring Protocols with Applications to the Greater Yellowstone Ecosystem

Elizabeth Crowe

NPS Greater Yellowstone Inventory and Monitoring Network, 106 AJM Johnson Hall, Bozeman, MT 59771 (406-994-7202, elizabeth_a_crowe@contractor.nps.gov)

Abstract

The second-greatest cause of biodiversity loss throughout the world is invasion by exotic plants, animals, and other species. Invasive plant infestations create a tremendous economic and environmental burden on landowners and managers, and have been increasing and expanding rapidly over the last few decades throughout the U.S. Increasing global trade and travel, more efficient and frequent transport of goods across the U.S., and increasing urbanization surrounding the Greater Yellowstone Ecosystem (GYE) are the major pathways and vectors for invasive plants into the GYE. The National Park Service and U.S. Forest Service have identified invasive species as significant threats to national parks, forests, and rangelands, and have produced national invasive species strategies that identify monitoring as essential for early detection of new species, as well as status and trends of established species and restoration of native vegetation. Control of invasive exotic plants is also a high priority for the members of the Greater Yellowstone Coordinating Committee's Weed Subcommittee, comprising representatives from federal agencies, state and county governments, and weed management areas within the GYE. The NPS Greater Yellowstone Inventory and Monitoring Network is developing monitoring protocols for Yellowstone and Grand Teton national parks and Bighorn Canyon National Recreational Area that will augment monitoring work already ongoing in the park units. These protocols can be applied to all lands in the GYE, and can expand upon existing coordinated programs of mapping and inventory to improve the capacity to prevent, detect, and control invasive plants.

Introduction

Invasive exotic plants have become an important threat to natural, agricultural, and cultural resources throughout the Greater Yellowstone Ecosystem (GYE). Exotic invasive plants were probably first introduced to the GYE by the early 1800s, well before the establishment of any federal land management units or the homesteading of private lands. Over the last 200 years, introductions of non-native plants have been both accidental and deliberate. Government resource management staff and private landowners have had to contend with these early arrivals, with species that were deliberately introduced during the early years of public and private land management (primarily for food and livestock production and erosion control), and with the ever-increasing numbers of newer species that are being deliberately introduced into the U.S. (primarily for ornamental purposes). Current management policies for public lands have incorporated prevention practices that have greatly lessened both introductions into and dissemination of invasive species throughout land units. Nonetheless, there are still numerous pathways and vectors for exotic species both into the U.S. (by world trade, travel, and immigration) and into the GYE (by increasing land development and human visitors and residents). These include motorized vehicles; bicycles; horse and mule packing; human shoes, clothing, and recreational equipment; aquarium releases; wind and water; and native birds and mammals.

Exotic invasive plants have been shown to threaten native organisms and processes through extinction or local extirpation of native plant and animal species, through competition and alteration of habitats (Walker and Steffen 1997; Wilcove et al. 1998; Parker et al. 1999; Mack et al. 2000; Allendorf and Lundquist 2003), and through hybridization and introgression with native plants (Williamson 1996; Parker et al. 1999). Mechanisms by which invasive exotic plant species can reduce native plant species directly (through competitive exclusion) or indirectly include changes in vegetative structure (e.g., shading of native species) (Walker and Smith 1997), vegetation succession (Walker and Smith 1997), fire cycles (D'Antonio and Vitousek 1992; Brooks et al. 2004), and nutrient cycles (Woods 1997). Animals can be extirpated by the loss of native vegetation

vital for food or shelter (DiTomaso 2000; Shafroth et al. 2005). Invasive exotic plant species also affect native ecosystem properties by (1) modifying physical and chemical conditions, such as insolation, nutrient availability, and salinity; (2) influencing composition of major trophic groups, producers, and herbivores; and (3) altering the frequency or intensity of disturbance regimes, such as fire intensity or frequency, flooding, or pest or pathogen outbreaks (Vitousek 1990).

The fundamental mission of the National Park Service (NPS) is to conserve the "natural objects" and wildlife in park units so as to "leave them unimpaired for future generations" (16 U.S.C. §1). Thus, park management staff have the responsibility to maintain native populations of organisms and native ecosystem functions in perpetuity. One of the primary requirements for successful management of park resources is long-term monitoring of the status and trend of these resources, and to help meet this need the NPS established the national inventory and monitoring program in the 1990s (NPS n/d). The program comprises 32 networks, each of which contains a portion of the 390 park units throughout the U.S. The Greater Yellowstone Inventory and Monitoring Network (GRYN) comprises Yellowstone and Grand Teton national parks and Bighorn Canyon National Recreation Area.

Each network has chosen a set of ecological indicators or "vital signs" to monitor the general ecological condition of natural resources in park units, and invasive plants are a high-priority vital sign for the GRYN. There are currently more than 200 recorded exotic plant species in GRYN park units, and at least 75 of these species are currently known to be or have the potential to be invasive within certain habitat types. Combined with the above-mentioned increasing abundance of pathways, vectors, and new species arrivals, the task of controlling invasives is large and complex. Unfortunately, funds for weed management are inadequate to control all species in all locations. Monitoring procedures developed by the GRYN will help to increase the efficiency and effectiveness of weed control programs and provide needed information for weed management staff.

Development of multi-park invasive plant monitoring protocols

There are four types of invasive plant monitoring for which the GRYN is developing protocols: early detection of new species, status and trend of established populations, effects of invasives on native organisms and ecosystem processes, and restoration of native organisms and ecosystem processes following control of invasives. The goals of the protocols are:

(1) to provide efficient and effective means of locating new populations of invasive plants in backcountry areas of park units;

(2) to inform weed management staff of the status and trends of existing invasive plant populations;

(3) to provide local data on the invasiveness of species to use in prioritization and re-prioritization of weed management activities; and

(4) to provide local data on the effects of invasive species on native organisms and ecosystem processes.

The development of protocols began with the gathering of general information on predicting both invasiveness of exotic species in the GYE and the effects of invasive plants on native ecosystem processes. Then a list of all exotic species known to exist within GRYN park units was compiled, and species were prioritized based on existing park weed management priorities. From this list, a matrix was built containing information on a subset of 85 species. This information covers species biology, phenology, population dynamics, reproduction, habitat affinities, tolerances, known invasiveness, and effects on native vegetation, nutrient cycling, soil properties, hydrology, soil biota, and higher trophic levels. Information was compiled from refereed journal literature, government publications, and species accounts from the Fire Effects Information System (U.S. Forest Service 2006); The Nature Conservancy's Global Invasive Species Initiative (The Nature Conservancy 2006); and reliable Internet sources. When using non-refereed sources, only cited information was used. Anecdotal accounts were disregarded. In addition, existing protocols for monitoring particular species or guilds of species were compiled to provide tested procedures that can be incorporated into the protocols.

The invasive species information matrix will be used to develop specific monitoring objectives for individual species within one or more of the four types of monitoring discussed above. Both the matrix and existing protocols will be used for development of

sampling designs and field measurement methods. Because monitoring funds are quite limited, the least expensive and easiest-to-implement methods will be targeted. They must, however, be informative and relevant to the monitoring objective, and they must provide the precision needed to detect changes in status and long-term trends in populations of invasive plants and the organisms and processes they affect.

The final step in the development of the monitoring protocols is to build a sound, long-term data management and analysis plan and a reporting schedule. Data will be housed in a geospatial database structure that is integrated with other weed management activities within the parks. In addition, integration with other databases maintained by adjacent or overlapping weed management organizations will be facilitated as much as possible.

Application of protocols to the GYE

The GYE comprises both public and private lands, the core of which is Yellowstone and Grand Teton national parks. Surrounding these parks are six national forests; two national wildlife refuges; land parcels managed by eight Bureau of Land Management (BLM) field offices; parcels owned and managed by the states of Idaho, Montana and Wyoming; and privately owned lands. Unlike many other natural resource and human sociological issues in the GYE that are contentious and polarizing, all land managers and many private landowners (especially those who make their living from the land they own) are united in their determination to prevent establishment of new populations and control the spread of and reduce the size of current populations of invasive exotic plants.

Because agency missions and landowner values vary somewhat, the number of species that are regulated by law or are of concern varies. All landowners and managers, however, within a given state and county must follow noxious weed laws, which mandate controlling designated noxious weed species. Additional invasive species are of concern to land managers depending on their missions and goals. The common element among all federal agency missions is to maintain native species, community, and ecosystem functions. Many private landowners in the GYE also have the goal of at least maintaining ecosystem functions on their lands.

Because the ecosystems within the GYE overlap many different agency and landowner boundaries, invasive exotic plant management is already being addressed through coordinated efforts. The Greater Yellowstone Coordinating Committee has a Weed Subcommittee that has been active for 22 years, with more than 100 members from 13 state agencies, 6 federal agencies, 11 counties, and 9 non-governmental organizations. The Weed Subcommittee has developed several weed prevention programs, numerous educational materials, and a consolidated database and map of weed locations for the entire GYE (McClure et al. 2005). In addition to the GYCC Weed Subcommittee, there are 14 cooperative weed management areas that completely cover the GYE geographic area. Weed management areas (WMAs) are created to facilitate cooperation among all land managers and owners to manage common weed problems in a common area. The cooperators in a WMA "jointly prioritize weed management efforts based on species or geographical areas" (BLM et al. 2002).

A necessary component of any weed control program is monitoring of weed populations (NPS 1996; USFS 2004; FICMNEW n/d). Some existing monitoring procedures are carried out by various entities in the GYE. These procedures vary in quantitative rigor, cost and ease of implementation, and integration with other weed management activity databases. The invasive plant monitoring protocols developed by the GRYN can be applied uniformly across the GYE, and will be quantitatively rigorous and integrated with most or all weed management activity databases. The GYCC Weed Subcommittee and the WMAs provide excellent venues for the coordination of monitoring across the GYE. Coordinated monitoring can increase the ability of all regional land managers and landowners to monitor the status and trends of invasive plant populations at an ecosystem level, rather than on the basis of political or geographic areas, and to improve prioritization of management activities.

References

16 U.S.C. §§1–4, National Park Service Organic Act.

Allendorf, F. W., and L. L. Lundquist. 2003. Introduction: population biology, evolution, and control of invasive species. *Conservation Biology* 17(1):24–30.

Brooks, M. L., C. M. D'Antonio, D. M. Richardson, J. B. Grace, J. E. Keeley, J. M. diTomaso, R. J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. *Bioscience* 54(7):677–688.

Bureau of Land Management (BLM), U.S. Forest Service (USFS), and National Park Service (NPS). 2002. Guidelines for coordinated management of noxious weeds: development of weed management

areas. 228 pp. <http://www.weedcenter.org/management/guidelines/tableofcontents.html>.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. *Annual Review of Ecological Systems* 23:63–87.

DiTomaso, J. M. 2000. Invasive weeds in rangelands: species, impacts, and management. *Weed Science* 48 (2):255–265.

Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW). No date. *Pulling together: national strategy for invasive plant management*. <http://www.blm.gov/weeds/PullingTogether/PullingTogether.pdf>.

Mack, R. N., D. Simberloff, W. M. Lonsdale, H. Evans, M. Clout, and F. A. Bazzaz. 2000. Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications* 10(3):689–710.

McClure, C., K. Houston, L. Baker, M. Maj, and S. Dewey. 2005. The Greater Yellowstone Area: weeds without boundaries. Poster displayed at *Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects*. Proceedings of the 8th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, October 17–19, 2005, Mammoth Hot Springs Hotel, Yellowstone National Park, Wyoming.

National Park Service (NPS). No date. *An overview of vital signs monitoring and its central role in natural resource stewardship and performance management*. Ft. Collins, Colo.: National Park Service. 4 pp. <http://science.nature.nps.gov/im/monitor/docs/Vital_Signs_Overview.doc>.

______. 1996. *A strategic plan for managing invasive non-native plants on national park system lands*. Washington, D.C.: National Park Service. <http://www.nature.nps.gov/biology/invasivespecies/strat_pl.htm>.

Parker, I. M., D. Simberloff, W. M. Lonsdale, K. Goodell, M. Wonham, P. M. Kareiva, M. H. Williamson, B. Von Holle, P. B. Moyle, J. E. Byers, and L. Goldwasser. 1999. Impact: toward a framework for understanding the ecological effects of invaders. *Biological Invasions* 1:3–19.

Shafroth, P. B., J. R. Clevery, T. L. Dudley, J. P. Taylor, C. Riper, E. P. Weeks, and J. N. Stuart. 2005. Control of *Tamarix* in the western United States: implications for water salvage, wildlife use and riparian restoration. *Environmental Management* 35(3):231–246.

The Nature Conservancy. 2006. *The global invasive species initiative: invasive plants*. <http://tncweeds.ucdavis.edu/esadocs.html>.

U.S. Forest Service (USFS). 2006. Fire Effects Information System. http://www.fs.fed.us/database/feis/.

______. 2004. *National strategy and implementation plan for invasive species management, USDA Forest Service*. 24 pp. <http://www.fs.fed.us/foresthealth/pubsindex.shtml>.

Vitousek, P. M. 1990. Biological invasions and ecosystem processes: towards an integration of population biology and ecosystem studies. *Oikos* 57:7–13.

Walker, B., and W. Steffen. 1997. An overview of the implications of global change for natural and managed terrestrial ecosystems. *Conservation Ecology* (2). <http://www.ecologyandsociety.org/vol1/iss2/art2/index.html>.

Walker, L. R., and S. D. Smith. 1997. Impacts of invasive plants on community and ecosystem properties. Pages 69–86 *in* J. O. Luken and J. W. Thieret, eds., *Assessment and management of plant invasions*. New York: Springer-Verlag.

Wilcove, D. S., D. Rothstein, J. Dubow, A. Phillips, and E. Losos. 1998. Quantifying threats to imperiled species in the United States. *BioScience* 48(8):607–615.

Williamson, M. 1996. *Biological invasions*. London: Chapman & Hall.

Woods, K. D. 1997. Community response to plant invasion. Pages 56–68 *in* J. O. Luken and J. W. Thieret, eds., *Assessment and management of plant invasions*. New York: Springer-Verlag.

Integrating Landscape-Scale Economic and Ecological Models in the Greater Yellowstone Area: Application to Wolf Recovery

John W. Duffield

Chris J. Neher

David A. Patterson

Department of Mathematical Sciences, University of Montana, Missoula, MT 59812 (john.duffield@mso.umt.edu, 406-243-5569; bioecon@montana.com, 406-721-2265; dapatterson@mso.umt.edu, 406-243-6748)

Abstract

Evaluating land management policies in the Greater Yellowstone Area (GYA) requires recognition that economic and ecological processes are interactive. The focus of this paper is the dynamics of wolves and elk on Yellowstone National Park's northern range. A new paradigm that integrates economic and ecological processes requires at least three elements: (1) ecological models that explain the population levels and distributions of wildlife across the region, (2) an understanding of human motivations and values that attract visitors and residents to the area, and (3) a model that relates visitor and residential expenditures to the regional economy. Wildlife and land management policies over the long term affect the mix of feasible human services related to wildlife, including wildlife viewing, hunting, use of range resources, and livestock depredation. Specific policy decisions that have been significant for the case at hand include expansion of elk winter range north of the park, the decision to reintroduce wolves, and the ongoing transition to state management of wolves. Based on park visitor and hunter surveys spanning a period of 20 years, changes in values related to ungulates and large carnivores are identified. Hunters, park visitors, ranchers, and other users respond to policy changes and redistribute their spending in or out of the region. Impacts of these changing expenditures to the regional economy are measured in a regional input–output model. Empirical findings are presented on the net impacts of wolf reintroduction on the economy of the GYA over the last 10 years.

Introduction

In 1995 and 1996, 31 wolves were reintroduced to the Greater Yellowstone Ecosystem (GYE) and another 35 wolves were released in central Idaho in an attempt to restore the endangered gray wolf to the Rocky Mountains. The restoration of wolves to Yellowstone National Park has become one of the most successful wildlife conservation programs in the history of endangered species conservation. As of 2004, there were approximately 301 wolves in the GYE, and Yellowstone National Park is now considered one of the best places in the world to watch wild wolves. Visibility of the wolves within the park, and public interest in wolves and wolf-based education programs, have far exceeded initial expectations.

During the preparation of the environmental impact statement (EIS) that was completed prior to wolf restoration, more than 170,000 public comments were reviewed to determine the public's key concerns (USFWS 1994). One of the main issues identified during this process was concern about the possible economic effects of wolf restoration. Among the concerns of opponents was the expenditure of public federal funds for the restoration effort, and the potential for negative economic effects on the regional economy. These assumed negative effects included the costs of wolf depredation on livestock; reduced big game populations, resulting in lower economic returns to agencies and businesses that derive revenue from big game hunting; and an expected drop in visitation to Yellowstone and the surrounding ecosystem. Proponents, on the other hand, predicted increased visitation and positive regional net economic impacts caused by the presence of wolves.

Prior to the EIS, a series of studies was conducted on the biological, social, and economic implications of wolf recovery for the Yellowstone area. One of these studies (Duffield 1992) examined the possible economic consequences for the region based on a June 1991 survey of park visitors. This study predicted that the economic impact of wolf

reintroduction on the three-state region (Idaho, Montana, and Wyoming) would be positive; that increased visitation and visitor expenditures would outweigh costs of livestock predation and reduced hunting opportunities. The wolf recovery program is now in its eleventh full year. Yellowstone National Park, in cooperation with state and federal agencies, has implemented a comprehensive research and monitoring program in the GYE to quantify the ecological effects of the restored wolf population. Based on these recent studies, there is now data available to revisit, in part, the earlier analysis, and evaluate the overall economic effects of the initial recovery efforts and the ongoing wolf restoration program.

This paper presents an *ex post* analysis of the impacts of wolf reintroduction on park visitation and spending, livestock depredation, big game populations, and the regional economy.

Data collection

The Yellowstone National Park 2005 Visitor Survey was designed to collect a broad spectrum of information and opinions from park visitors. The survey instrument was divided into four sections, each addressing one general aspect of the visitors' trips or the visitors' attitudes and characteristics. For purposes of the regional economic analysis, information was collected on visitor attitudes toward wolf recovery and wildlife, as well as on expenditures.

The survey was designed as a random sample of the entire population of park visitors. Park visitors in spring, summer, and fall were contacted at park entrance stations. Winter visitors traveling by car were also contacted at the North Entrance station. Oversnow visitors were sampled through guide and outfitter lists. The resulting random sample was weighted appropriately to reflect the actual distribution of park visitation by entrance and season in 2005. A separate sample of visitors was contacted in the Lamar Valley to provide additional data on visitor wildlife viewing. The survey procedure followed a standard Dillman (2000) mail survey methodology using initial contact and repeat follow-ups.

There were 12 survey waves in total over the survey year, which began on December 18, 2004, and ran through December 17, 2005 for the park entrance sample, and included February 10, 2005 through February 9, 2006 for the Lamar Valley sample. Overall, the response rate to the survey was 66.4%. Across waves, this response varied from a low of 57.1% for the midsummer wave 9 to a high of over 75% for both the winter Lamar sample (wave 12) and the spring sample (wave 5). A total of 1,521 responses were obtained from the park entrance population, and 431 in the Lamar.

Trip expenditures

Recreational travel to Yellowstone National Park includes spending by park visitors. A key measure of the significance of a regional resource such as Yellowstone to local area economies is the amount of money visitors from outside the local area spend during their trips. For the sake of measuring local area spending, visitors were asked to list the amount of money they spent on their trips in total, as well as the amount they spent in the states of Montana, Idaho, and Wyoming, and the amount they spent in the local Greater Yellowstone Area (GYA). Table 1 shows reported average trip spending by season and residency for each of the geographic areas. As was expected, local GYA-resident park visitors spent less on their trips to the park than did non-resident visitors. This pattern was consistent across seasons.

Net impacts of wolf recovery on the regional economy

The economic analysis associated with the Yellowstone area wolf reintroduction EIS included an

Table 1. Comparison of visitor spending by season and residency for the 17-county GYA analysis area.

Season/residency	Amount spent in GYA	Amount spent in three-state area	Total trip spending	Sample size
Spring, non-resident	$220.55	$320.24	$673.21	374
Spring, resident	$72.87	$74.99	$105.66	70
Summer, non-resident	$187.85	$349.58	$709.33	369
Summer, resident	$63.67	—	$117.28	22
Fall, non-resident	$279.56	$387.78	$762.19	241
Fall, resident	$112.99	$150.03	$208.94	47

Note: Winter results were only representative of wheeled access, and are not presented.

estimate of how many new recreational visits per year would result from reintroduction of wolves to the park. The 2005 survey included a series of questions designed to allow the percent of current Yellowstone National Park visitation attributable to wolf presence in the park to be estimated (see box).

Table 2 shows (1) the percentage of visitors who responded that one of the reasons for their trip to Yellowstone National Park was the possibility of seeing or hearing wolves, (2) the percentage of visitors who would not have come had it not been for the presence of wolves in Yellowstone, and (3) the calculated percentage of park visitation attributable to wolves. The estimated percentage of Yellowstone visitation attributable to wolves ranged from 1.5% in the spring season to nearly 5% in the fall. Based on the percentage of visitors who only would have come if wolves were present, Table 3 shows the derivation of an estimate of impacts to the three-state region for comparison to the estimate derived by Duffield (1992) prior to reintroduction. In total, it is estimated that visitors coming from outside the three-state region, who are coming specifically to see or hear wolves in the park, spend $35.5 million annually.

Prior to reintroduction, Duffield (1992) estimated, based on park visitor survey responses, that a recovered wolf population in the park would lead to increased visitation from outside the three-state region, resulting in an additional $19.35 million in direct visitor spending within the three states. Between 1991 and 2005, the measure of consumer prices (the CPI-U) has increased 43.4% (from 136.2 to 195.3). Adjusting the 1991 estimate for increases in prices leads to an inflation-adjusted 1991 estimate of $27.74 million per year. This estimate is below the 2005 estimate of $35.5 million, but well within the 95% confidence interval for the estimate of $22.4–$48.6 million. It appears that the 1991 methodology and estimate correspond well to current estimates of wolf impacts on visitor spending.

Visitor survey questions:
Wolf-related visitation

Was the possibility of seeing or hearing wolves one of the reasons for your visiting Yellowstone National Park on this trip?

- ☐ NO
- ☐ YES

IF YES, would you still have chosen to take this trip even if wolves were not present in the Yellowstone National Park?
(please check one)

- ☐ DEFINITELY YES
- ☐ DEFINITELY NO
- ☐ NOT SURE

Estimation of the economic impact of wolf depredation on domestic livestock in the GYA is based on data collected and published by Defenders of Wildlife related to payments from their Wolf Compensation Fund (<www.defenders.org>). Since 1996, annual payments for wolf depredation have averaged about $27,000. In 2004 and 2005, however, payments increased dramatically, averaging $63,818 in those two years. The prediction for livestock predation in the EIS was $1,900–$30,500 in market value of livestock lost per year.

When comparing predicted and observed livestock losses in the GYA due to wolf predation, it should be noted that the EIS estimates were predicated upon a wolf population of 100 wolves,

Table 2. Yellowstone visitor responses on the importance of wolf presence in their decision to visit Yellowstone National Park.

	Spring N=495	Summer N=477	Fall N=322	Winter[1] N=221
Percent responding that "the possibility of seeing or hearing wolves was one of the reasons for visiting Yellowstone NP on this trip."	48.9%	50.04%	55.7%	35.9%
Percent of those above who said they definitely would not have taken trip if wolves were not present in Yellowstone NP	3.1%	7.18%	8.88%	10.2%
Percent of total visitation attributable to the presence of wolves	1.49%	3.59%	4.95%	3.66%

[1] Winter season statistics are from 1998–99 winter Yellowstone National Park survey results asking the same question.

Table 3. Estimated three-state direct expenditure impact associated with wolf presence in Yellowstone National Park.

	Spring	Summer	Fall	Winter [a]
Total recreational visitation to Yellowstone	382,598	1,819,798	547,777	85,478
Percent of visitors from outside the three-state area	70.5%	83.68%	67.59%	82.2%
(A) Recreational visitors from outside the three states	269,770	1,522,807	370,242	70,289
(B) Percent of visitors who would not have visited without the presence of wolves	1.93%	4.78%	3.45%	3.66%
(C) Average spending per visitor within the three states by visitors from outside the area[b]	$361.89	$369.12	$425.50	$510.84
Total estimated annual three-state visitor spending attributable to wolves (A*B*C)	**$1,885,178**	**$26,889,668**	**$5,431,916**	**$1,314,167**
Total estimated annual visitor spending in the three states attributable to wolves				**$35,520,929**
95% confidence interval				**$22,404,274–$48,637,585**

[a] Winter estimates utilize 1999 winter visitor survey estimates (Duffield and Neher 2000).

[b] Average spending was for all visitors from outside the analysis area. Average spending for those who only came for wolves was nearly identical, but due to a much smaller sample size, had a much higher variance.

whereas the actual population in 2004 was 301 wolves. A second point of note is that during the period when wolf numbers were in the general range of that which was predicted for the final wolf population (1997–2000), the value of lost livestock due to wolves ($11,300) fell well within the predicted range. Finally, although depredation losses in the most recent two years (2004–2005) have been twice the upper-end estimate made prior to wolf reintroduction (at $63,818), the wolf population in the area is three times the number upon which the loss projections were based. Therefore, the depredation loss levels per wolf continue to fall within the range projected prior to reintroduction.

With respect to impacts on big game hunting, while a substantial body of recent literature on wolf–prey modeling in the GYE exists, the large majority of this work focuses on the Yellowstone northern range elk herd. Additionally, recent concern over wolf predation of big game has centered on this elk population and associated hunter permits and harvest. While elk populations are at 30-year lows, there have been substantial variations in this population, both prior to and following wolf reintroduction.

The prediction in the 1994 EIS was that reduced hunter harvest of elk, mule deer, and moose in the Greater Yellowstone Recovery Area could result in foregone hunter benefits of $187,000–$465,000 per year. The first estimate is specific to Yellowstone's northern range and associated hunting districts in Montana. It was anticipated that a foregone harvest of up to 9 moose, 122 antlerless mule deer, and 280 elk in adjoining hunting districts in Montana would lead to a loss of 2,300 hunter days annually. The loss specific to elk hunting was estimated to be about $97,000 annually, or about 50% of the total value of foregone hunting opportunities. As in the original, a caveat to these estimates is that they do not account for any substitution behavior by hunters in response to changes in Gardiner (Montana) late hunt opportunities. In other words, it is likely that these are overestimates of hunter losses for any given reduction in permits.

A summary of the hunter harvest data for the Gardiner late hunts is as follows. The long-term average hunter harvest prior to wolf recovery was 1,014 during 1976–1994. For the period after wolf reintroduction, the average hunter harvest was actually higher, at 1,372 for 1995–2004. Hunter success during 1995–2004 (with a mean of 65% and a range of 43–97%) was similar to success during 1976–1994 (mean 64%; range 10–96%). However, Montana Fish, Wildlife and Parks recently has been reducing antlerless permits in the Gardiner late hunt substantially, from 2,882 to 1,400 during 2000–2004, and down to only 100 permits in 2006. However, there have been

no reductions in the northern range for permits, animals harvested, or hunter success for mule deer or moose as a result of wolf restoration (White et al. 2005). The issue is interpreting the role of wolves, climate (a recent extended period of drought), and the unusually high hunter harvest levels in the last decade in explaining changes in elk populations and current hunter harvest opportunities.

In short, the primary question is whether recent declines in elk populations are largely, moderately, or minimally due to corresponding increases in wolf numbers in the area. Estimating the impact of wolf depredation on livestock in the GYA is very straightforward, using published, detailed records of depredation fund payments to ranchers. However, estimating impacts of wolves on big game populations is less clear-cut. There are two generally opposing views regarding the impact of Yellowstone wolves on big game (in this analysis, primarily elk) numbers. The first is that wolf predation is primarily compensatory. That is, wolves primarily take elk that would normally succumb to winterkill, disease, or old age (Vucetich et al. 2005). Under this view, Yellowstone wolves have had little impact on northern Yellowstone elk populations beyond that which would have occurred under wolfless conditions. The second view is that wolf predation of northern Yellowstone elk is largely additive (White and Garrott 2005). That is, wolves have preyed upon elk that by and large would not have succumbed to other causes of mortality, and thus have substantially increased the rate of recent declines in elk populations. A third, middle-ground view is that wolf predation of the Yellowstone northern range elk herd has been partly compensatory and partly additive (Varley and Boyce 2006). Under this view, northern range elk populations have decreased due to wolf predation, but not fully to the extent that would be predicted from the number of elk killed by wolves.

The economic impact projections associated with big game hunting and harvest contained in the 1994 EIS were based on biologists' projections of the impact of wolf predation on big game populations, including a 5–30% reduction in elk population and a 27% reduction in antlerless elk harvest. Three of the species examined in the EIS (deer, moose, and bison) either have seen no reduction in population levels (as was predicted in the EIS) or, in the case of moose, have inadequate data to evaluate current population levels. Impacts in the upper Gallatin drainage are not quantified in this report.

The remaining species, elk (particularly northern herd elk), has provoked substantial concern in recent years as populations have dropped dramatically at the same time as wolf numbers have risen. As described above, a significant amount of research has been done on explaining recent trends in northern range elk populations in the context of wolf reintroduction. While opinions of biologists differ on the impact of wolf predation on elk numbers, several models of elk populations have found wolves either having a minor impact on elk numbers (Vucetich et al. 2005) or having an impact similar to that predicted in the EIS (21% decrease in elk numbers) (Varley and Boyce 2006). From these studies it appears that the original EIS predictions were generally accurate for northern herd elk populations and likely significantly overstated impacts on other GYA big game species (mule deer, bison, and moose).

Conclusions

Overall, it appears that the economic predictions made in the original EIS analysis were relatively accurate. In terms of projections of changes in park visitation, the current estimated percentage increase due to wolf presence has been somewhat lower than predicted (+3.7% estimated v. +4.93% predicted). However, the 1994 predictions were based on a survey of summer visitors to the park, and the current estimate of the percent of summer visitation due to wolf presence is +4.78%, very similar to the EIS predictions. Regarding changes in visitor spending in the local economy due to wolf presence, the current estimate of +35.5 million (confidence interval of $22.4–$48.6 million) is consistent with the 1994 EIS estimate of +27.7 million (2005 dollars). For the issue of wolf depredation of livestock, the EIS estimates were based on assumptions of a recovered wolf population of 100 wolves. Depredation loss levels during the period when wolf numbers were near those predicted were consistently below predicted losses. In 2004 and 2005, when wolves numbered more than 300, losses were twice the high-end estimate of losses predicted in the EIS. One of the most controversial issues currently surrounding wolf recovery in the GYA is that of big game predation and impacts on hunter opportunity and harvest. A review of literature associated with wolf impacts on the northern Yellowstone elk herd shows a divergence of views on the impact wolf predation has had. Two peer-reviewed models of northern herd elk populations, however, have shown the impact of wolves on elk numbers to be either consistent with or below the impact predicted in the EIS.

Acknowledgements

This research was supported by the Yellowstone Park Foundation, the Turner Foundation, and the National Park Service. Glenn Plumb was project director and helped coordinate NPS participation in the project. Many Yellowstone National Park staff contributed to the research, including Doug Smith, Wayne Brewster, John Varley, and Tammy Wert and the entrance station staff. We are especially indebted to Becky Wyman for her work on the Lamar Valley data collection. Our biggest debt is to the approximately 3,000 Yellowstone National Park visitors who responded to our survey.

References

Defenders of Wildlife Compensation Fund data. <http://www.defenders.org>.

Dillman, D. 2000. *Mail and internet surveys: the tailored design method*. New York: John Wiley and Sons.

Duffield, J. 1992. An economic analysis of wolf recovery in Yellowstone: park visitor attitudes and values. Pages 2-31–2-87 *in* J. Varley and W. Brewster, eds., *Wolves for Yellowstone? A report to the United States Congress, volume IV: research and analysis*. National Park Service, Yellowstone National Park. 739 pp.

Duffield, J., and C. Neher. 2000. Winter 1998–1999 visitor survey, Yellowstone National Park, Grand Teton National Park, and the Greater Yellowstone Area. Report for National Park Service, Denver, Colo. 132 pp.

Smith, D. 2005. Yellowstone after wolves: environmental impact statement predictions and ten-year appraisals. *Yellowstone Science* 13(1):7–21.

U.S. Fish and Wildlife Service (USFWS). 1994. *The reintroduction of gray wolves to Yellowstone National Park and central Idaho: final environmental impact statement*. Helena, Mont.: U.S. Fish and Wildlife Service.

Varley, N., and M. Boyce. 2006. Adaptive management for reintroductions: updating a wolf recovery model for Yellowstone National Park. *Ecological Modeling* 193:315–339.

Vucetich, J., D. Smith, and D. Stahler. 2005. Influence of harvest, climate and wolf predation on Yellowstone elk, 1961–2004. *Oikos* 111:259–270.

White, P., and R. Garrott. 2005. Northern Yellowstone elk after wolf restoration. *Wildlife Society Bulletin* 33(3):942–955.

White, P., D. Smith, J. Duffield, M. Jimenez. T. McEneaney, and G. Plumb. 2005. Yellowstone after wolves: environmental impact statement predictions and ten-year appraisals. *Yellowstone Science* 13(1):34–41.

Remote Sensing as a Tool for Observing Rock Glaciers in the Greater Yellowstone Ecosystem

Ian S. Fairweather

HyPerspectives Inc., Bozeman, MT 59718 (406-556-9880, fairweather@hyperspectives.net)

Stacey A. Hager

Yellowstone Ecological Research Center, Bozeman, MT 59718
(406-556-1414, hager@yellowstoneresearch.org)

Abstract

Rock glaciers are found in and adjacent to Yellowstone National Park, primarily in the high elevation regions of the Absaroka and Beartooth mountain ranges. One rock glacier that has been intensely studied is the Galena Creek Rock Glacier, located on the east boundary of the park in the northern Absaroka mountain range. A rock glacier's movement and behavior is characterized by rock and other debris overlying and embedded within the ice mass. These glaciers are found in alpine regions at the foot of rock faces with large supplies of talus and debris. The debris acts as insulation for the ice and prevents solar radiation from ablating the ice surface, allowing rock glaciers to exist at lower elevations and latitudes than regular glaciers. Rock glaciers deform and flow similarly to ice glaciers, but possess some unique characteristics. They are an important mechanism for transporting masses of rock debris in cold, continental, non-glacierized mountain environments. They are also natural storage mechanisms for water, providing watershed runoff in late summer months. Locating and studying these features can be arduous due to their positions at high elevations and rugged terrain. As a result, remote sensing is a superb tool for observing and studying these glaciers. Hyperspectral and multispectral imagery are used to delineate their geographic extent as well as the composition of the debris overlying the ice mass. The distinct spectral signature of ice can be used to extract regions of bare ice at the head of a glacier. Radar images can also be used to reveal rough surface texture and create DEMs for delineating cross-glacier profiles as well as terminal and lateral moraines. Using the geographical extent and height of a glacier (from the topographic profiles), volumes are calculated to deduce water storage. Rock glaciers can also be used as climatic indicators for long-term monitoring.

Glaciers are rivers and sheets of ice that shape the world in which we live. They carve beautiful landscapes and deposit huge boulders and remarkable hills of sediments. Glaciers in all of their forms presently cover approximately 10% of the land on the surface of Earth. This value was once much greater; approximately 30% of the land surface was covered during the last ice age, which ended only 11,000 years ago (Marshak 2001). There are two major types of glaciers, continental and mountain (alpine), and one lesser-known type, the rock glacier.

A glacier is a body of ice formed by the compaction of snow and ice, or an internal recrystallization of water that is thick enough to internally deform and thus flow. The minimum thickness of snow and ice needed for internal deformation is approximately 60 meters. A snowfield that is less than 60 meters thick is considered stagnant, and thus is not a true glacier (Marshak 2001). In the Greater Yellowstone region, many snow and ice bodies are commonly referred to as glaciers, and once were, but today are melting patches of stagnant ice and snow.

In order for a glacier to form and exist, three basic criteria must be met. First, the temperature must be cold enough for winter snow and ice to survive the warm summer months. If the temperatures are too warm, not enough snow will amass to compact into ice and form the glacier. Second, there must be a location where mass can accumulate. Landforms that are too steep (greater than 27°) lose their snow via avalanches; therefore, glaciers usually cannot form on these slopes (Fairweather 2003). Third, there must be addition of mass to the glacier via snowfall, refreezing of water, or avalanching of snow from above. If the glacier fails to receive mass inputs, it deforms to a thickness of less than 60 meters and stops flowing, losing its status as a glacier (Figure 1).

Glaciers move by two main processes: basal slip

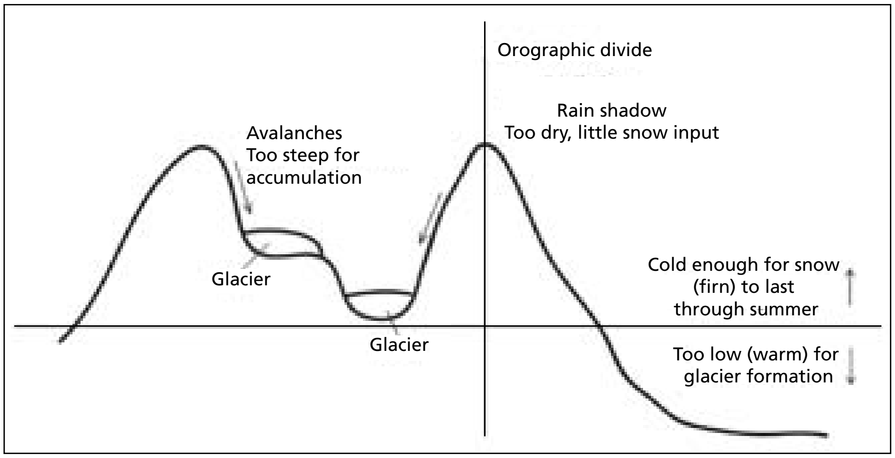


Figure 1. Diagram displaying criteria needed for glacier formation.

and internal deformation. Basal slip movement occurs when the entire glacial mass moves together on a thin layer of water, or a mixture of sediments and water, on the basal (bottom) surface of the glacier. The water, or sediment water mixture, lowers the friction between the glacier and the surface on which it rests (the substrate). Internal deformation occurs when the internal structure of the glacier slowly deforms without breaking apart or completely melting. This internal deformation can be visualized as crystals slowly deforming and sliding by one another. The crystals change their shape, and old crystals are destroyed while new ones are created (Tarbuck and Lutgens 1996). A glacier is technically called a visco-plastic, not a solid, for this reason (Patterson 1996). Glaciers typically move at velocities of between 30 and 100 meters per year, although some surging glaciers have been clocked at velocities of up to 54 meters per day (Kamb et al. 1985).

Continental glaciers are the vast ice sheets that presently cover the surface of Antarctica and Greenland. They covered most of northern Europe and North America during the ice ages. Mountain glaciers are much smaller than these ice sheets. They presently exist in all major mountain ranges at a variety of latitudes around the world. They are even found on the equator in the high Andes Mountains of South America. These glaciers are also responsible for creating dramatic landscapes in our own backyard. The Beartooth, Absaroka, Wind River, and Teton mountain ranges have all been sculpted by these powerful rivers of ice, and all of these ranges presently contain remnant glaciers from the past ice age.

Rock glaciers are less commonly known than ice glaciers. They are very similar to ice glaciers in that they are composed of thick, internally deforming ice, but rock glaciers have a layer of rock debris or talus measuring one meter or more on the surface of the ice (Figure 2). The debris layer acts as an insulator for the ice and reflects incoming solar radiation, allowing rock glaciers to exist at elevations and latitudes lower than those at which ice would typically survive if it were not insulated. We find many of these features in and around the Greater Yellowstone region. Many people have probably hiked on a rock glacier without even realizing that they were walking on a moving and deforming body of ice.

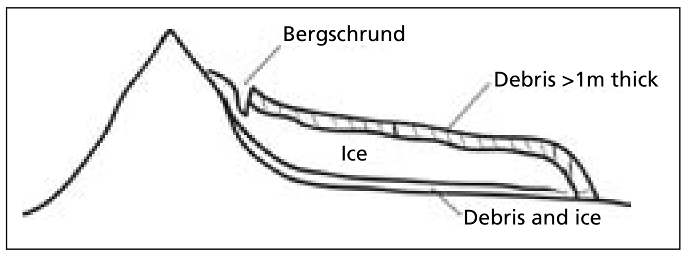


Figure 2. Cross-section view of a rock glacier.

Rock glaciers are presently formed in glacierized mountain ranges with extremely high erosion rates. The large amount of eroding debris covers the ice surface, and some rock debris becomes incorporated into the upper layers of the ice mass by the refreezing of melt water. Rock glaciers are also formed in regions with ordinary erosion rates. In this case, a slowly receding glacier is inundated with rock debris and becomes covered. Eventually, enough material accumulates on the surface and becomes incorporated into the ice for geomorphologists to label it a rock glacier (Marshak 2001). This second type of rock glacier is the kind we presently find in Greater Yellowstone.

Debris-covered glaciers have not been studied as extensively as ice glaciers in the scientific community, but limited research has been performed. The majority of this research has been conducted in the field, on the surface of rock glaciers. Geographers have mapped the geographic extents of these

features with Global Positioning Systems (GPS) and by map and compass. Geologists have conducted seismic profiles to calculate the thickness of ice and debris and drilled holes through them to view their internal structure. Hydrologists have poured dye into rock glaciers to discover their internal drainage patterns and studied their seasonal drainage patterns. The difficulty of this research is that most rock glaciers are in remote, rugged, wilderness areas. As a result, only a handful of rock glaciers have been extensively studied, including the Galena Creek rock glacier in the Absaroka mountain range, seven kilometers east of Yellowstone National Park. This rock glacier has been heavily researched because there is a road leading to it, and switchbacks cross the glacier itself numerous times (Konrad and Humphrey 2000; Konrad et al. 1999; Potter 1972).

Remote sensing is a tool commonly used to study ice glaciers in many different regions around the world, utilizing many platforms and techniques (Bishop et al. 2003; Duncan et al. 1998; Fairweather 2003; Østrem 1975). Rock glaciers rarely have been studied with these methods for reasons unknown to this author. There are several benefits and also difficulties to studying rock glaciers with remote-sensing techniques.

Remote sensing is the study and observation of the surface of Earth using reflected or emitted electromagnetic energy, captured remotely via satellite or an airborne platform. There are two major types of remote sensing: active and passive. Passive remote sensing uses electromagnetic radiation produced by the sun as the energy source for the imagery. The main types of passive remote sensing are optical imagery and hyper/multispectral imagery. In optical remote sensing, photographs of Earth's surface are taken from aircraft flying at various altitudes using the visible or the near-infrared parts of the electromagnetic spectrum. The spatial extent of rock glaciers can be delineated from the photographs, but this is the limit of information that can be extracted from optical imagery. Figure 3 is an aerial photograph of the Galena Creek rock glacier.

COURTESY S. K. KONRAD

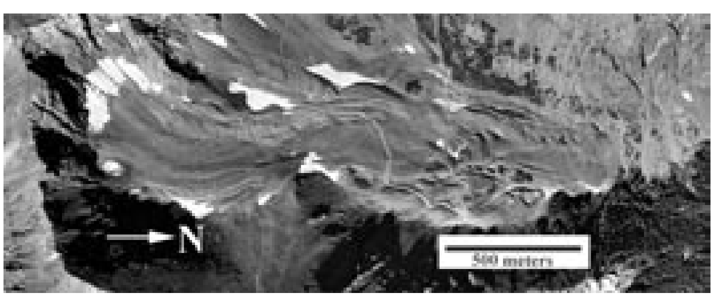


Figure 3. Aerial photograph of Galena Creek rock glacier, Absaroka Mountains, Wyoming.

Multispectral and hyperspectral remote sensing images are captured by sensors that detect visible light as well as UV and infrared sections of the electromagnetic spectrum. Multispectral imagery typically consists of 3–10 wide bands (0.6 to –0.02 um in width), including the three in the visible spectrum. This type of sensor can be mounted on an aircraft, but is typically mounted on a satellite platform. Landsat, SPOT, and ASTER are some examples of multispectral satellite platforms. The benefits of this type of imagery are that image acquisition is relatively cheap compared to other remote sensing images, capture is not weather-dependent (although cloud cover can obscure an image), the spatial extent is very large (Landsat image is 31,450 km^2, and ASTER image is 3,600 km^2) and the return time is generally around 10–20 days. These benefits can also be drawbacks to multispectral imagery. Because the satellites are in a programmed orbit, capturing images at specific times (for sun angle) and dates can be difficult if not impossible. Another limit to this imagery is the spatial resolution of the images. Space-borne platforms typically have coarse spatial resolution: 30 m for a Landsat image and 15 m for a SPOT or ASTER image. This coarse spatial resolution can make distinguishing rock glaciers very difficult. This type of imagery would be useful for geologists who already know the location of their region of interest, or are working at locations that support spatially large rock glaciers such as Alaska, the Himalayas, and the Karakoram. This type of imagery is not very useful for the researcher studying rock glaciers in the Greater Yellowstone region.

Hyperspectral imagery can consist of hundreds of very narrow bands (.01 um separating bands) that provide spectral information valuable to researchers. Not only can the spatial extents of rock glaciers be discriminated, but data that are invisible to the naked eye also can be extracted from the captured wavelengths. For example, bare ice can be discriminated due to its unique spectral signature. Freshly broken rock debris covering a rock glacier will also have a different spectral signature than in-place, weathered bedrock surrounding the glacier. These unique spectral differences may increase the ease of detection and characterization of these features.

Active remote sensing platforms broadcast

directed patterns of electromagnetic radiation to illuminate Earth's surface, then receive the portion scattered back to the instrument to capture an image (Campbell 2002). RADAR (RAdio Detection And Ranging) and LiDAR (Light Detection And Ranging) are the forms of active remote sensing commonly used today. RADAR sends pulses of microwaves and radio waves to the ground surface. The velocity of these waves is known, so the distance to an object or surface can be calculated by measuring the time it takes for a pulse of energy to be sent, hit an object, and return to the sensor. LiDAR is similar, but it sends a laser pulse to measure the distance to the ground surface. Because this form of remote sensing uses its own energy and is not dependent upon variations in solar radiation, it can be used in less-than-optimal weather and daylight conditions.

LiDAR data can be used to create high resolution DEMs (digital elevation models) of Earth's surface. These DEMs can be used to discriminate rock glaciers due to their surface characteristics. In a mountainous area such as the Greater Yellowstone region, a valley that does not contain a glacier or a rock glacier will have a U-shaped profile. If a rock glacier exists in this valley there will be a bump, or an irregularity to the U-shape. With RADAR or LiDAR, a rock glacier that is difficult to detect visually or spectrally can be detected by viewing the topographic profile of a valley. This technique can also be used to estimate the volume of a rock glacier. The spatial extent of a rock glacier can be determined from optical imagery, and the thickness can be inferred from the cross-valley profiles. Using these inputs, a rough estimate of ice volume and thus water storage can be calculated.

Rock glaciers are fascinating features present in mountainous regions. These features erode mountains and move sediment. They are also an important water storage mechanism in some environments. Remote sensing is a tool commonly used to study geologic features and detect changes on the surface of Earth. Scientists have not used this technology in the past to study rock glaciers, but it is a new and promising method for studying these features in the Greater Yellowstone region and in mountainous regions around the world.

References

Bishop, M. P., J. S. Kargel, H. H. Kieffer, D. J. MacKinnon, B. H. Raup, and J. F. Shroder, Jr. 2000. Remote-sensing science and technology for studying glacier processes in High Asia. *Annals of Glaciology* (31):164–170.

Campbell, J. B. 2002. *Introduction to remote sensing.* Third edition. New York: The Guilford Press.

Duncan, C. C., A. J. Klein, J. G. Masek, and B. L. Isacks. 1998. Comparison of Late Pleistocene and Modern glacier extents in Central Nepal based on digital elevation data and satellite imagery. *Quaternary Research* (49):241–254.

Fairweather, I. S. 2003. *A remote sensing and GIS method to determine accumulation area ratios (AARS) for Himalayan glaciers*. M.S. thesis, University of Wyoming, Laramie, Wyo.

Kamb, B., C. F. Raymond, W. D. Harrison, H. Engelhardt, K. A. Echelmeyer, N. Humphrey, M. M. Brugman, and T. Pfeffer. 1985. Glacier surge mechanism: 1982–1983 surge of variegated glacier, Alaska. *Science* 227:469–479.

Konrad, S. K., and N. F. Humphrey. 2000. Steady-state flow model of debris-covered glaciers (rock glaciers), *in* M. Nakawo, C. F. Raymond, and A. Fountain, eds., *Debris-covered glaciers*. Proceedings of a workshop held at Seattle, Washington, USA. IAHS Publication no. 264., Wallingford, U.K.

Konrad, S. K., N. F. Humphrey, E. J. Steig, D. H. Clark, N. Potter, Jr., and W. T. Pfeffer. 1999. Rock glacier dynamics and paleoclimatic implications. *Geology* 27(12):1131–1134.

Marshak, S. 2001. *Earth: a portrait of a planet*. New York: W. W. Norton & Company.

Østrem, G. 1975. ERTS Data in glaciology: an effort to monitor glacier mass balance from satellite imagery. *Journal of Glaciology* 15.

Patterson, W. S. B. 1994. *The physics of glaciers*. Tarrytown, New York: Elsevier.

Potter, N., Jr. 1972. Ice-cored rock glacier, Galena Creek, northern Absaroka Mountains, Wyoming. *Geological Society of America Bulletin* 83:3025–3057.

Sabins, F. F. 1996. *Remote sensing principles and interpretation*. New York: W. H. Freeman and Company.

Tarbuck, E. J., and F. K. Lutgens. 1996. *Earth*. Upper Saddle River, NJ: Prentice Hall.

Yellowstone: A Model for Ecosystem Research

K. Michael Foos

Indiana University East, 2325 Chester Blvd., Richmond, IN 47374 (765-973-8303, foos@indiana.edu)

Abstract

Studies on the various aspects of an ecosystem rely heavily on prior research. Because research has been part of the mission of Yellowstone National Park for many years, there is myriad information upon which scientists can rely. For example, a study of the northern elk herd 30 years prior to my own work on a fungal association permitted me to address a problem that would not have been imagined otherwise. In addition, studies of ecosystems often focus on natural environmental conditions, and it is becoming increasingly difficult to locate areas that are not greatly impacted by outside influences. Within the Yellowstone ecosystem, it is possible for scientists to have relatively free access to large geographic areas containing several different ecosystems that are mostly untouched by human interference. It is important that the research function of Yellowstone be recognized as a powerful influence that can make a great difference in the direction of ecosystem research now and in the future. As more and more areas are subdivided to provide for sprawling human communities, large areas of unaltered land with uncultivated plants and free-roaming animals are becoming increasingly limited. In the future, Yellowstone will play an even more critical role in the study and description of North American ecosystems.

I have been doing research on the distribution of fungi in the Yellowstone ecosystem for many years (Foos 1989; Foos and Royer 1989; Foos 1993; Foos 2001). These fungi have been reported in different geographic locations around the world; found growing in several different climates; and associated with a number of different hosts. In this study I wanted to determine whether the various climates, ecosystems, and hosts affected the growth of the fungus—that is, whether different strains or species of the organism could be found in different ecosystems, or whether it was merely happenstance when different strains of organisms were found in different geographic areas.

As I began to develop this project, I tried to determine where to conduct the study. The criteria I used were the following: (1) I sought an area that consisted of several hundred square miles, with many different communities within the greater ecosystem. (2) The environment had to be relatively natural, that is, it should be an unaltered environment with as few signs of human intervention as possible. (3) It needed to have a range of climatic conditions. Particularly, the annual rainfall should vary from one location to another to ensure variation in the vegetation within the study area and that temperature variations would be sufficient to mimic the range of conditions within wide areas of the temperate zone. (4) Because the fungus of interest is associated with animal hosts—specifically herbivores, and I restricted this study to ungulates—I sought an area that was an open system with free-ranging, native ungulates. At the same time, I wanted to exclude domesticated animals. (Domesticated animals might receive feed supplements from other areas, which would, in part, negate any attempt to correlate native vegetation with the distribution of the fungus.) (5) To be confident that the above conditions were met, I needed to identify an area that had been studied over time where records of climate, vegetation, and grazing patterns were well-documented and readily available. (6) Further, it would be necessary to find an area in which oversight would ensure the possibility of long-term research without appreciable changes to the ecosystem. There are not many areas that meet these criteria.

So I chose Yellowstone as the area in which to do my ecosystem study. Not because it was a national park. Not to help park managers make better decisions from the data I might provide. I chose this area because I needed to learn about the distribution of a fungus, and this place was unique in its ability to meet my needs. So while much of the research conducted in the national parks focuses on management issues, my project was intended to improve understanding of the relationships of organisms. However, I would like to emphasize that studies begun as pure research often provide information that can be applied to decisionmaking processes. Studies of several organisms here in Yellowstone National Park, particularly of the habitats of "charismatic megafauna," have driven a number of management decisions; however, I suspect that research on fungal distribution will

not have much of an impact on park policies.

The reason for relating these details of my own work is to lay a foundation for making some remarks about ecosystem studies and the needs that scientists engaged in ecosystem research have when selecting study areas. Often among these needs are large areas of land with unrestricted access. If you were to imagine the needs of an individual engaged in migration studies, studies of plant succession, or studies of animal territoriality, it is easy to see why large areas might be required. Further, these areas must be open systems; they can not be fenced or developed as urban areas with high-density human populations. Just the vastness of Yellowstone alone invites ecosystem studies. Studies of bears and fish provide well-known examples of research that requires open systems and long-term commitments (Craighead et al. 1995; Varley and Schullery 1996). Currently there is much discussion of the reintroduction of wolves to this same ecosystem. We might ask, "Why was Yellowstone selected as an area to reintroduce wolves?" There are a number of national forests and national wildernesses that might have been suitable. The answer to this question includes the criteria I listed earlier. Yellowstone provides a large, open-system natural area, with a complex ecosystem and an abundance of long-term research studies (Smith et al. 2003). Further, it is an area under strict supervision, managed by individuals with a mandate to preserve the area in its natural state for generations to come.

When Yellowstone was created on March 1, 1872, "for the benefit and enjoyment of the people", it was necessary to engage research to determine what was here. The Hayden expedition of the summer of 1872 (supported by a government grant of $75,000) was established to complete a thorough exploration of the Yellowstone region. In addition to being charged with mapping the area, this was a scientific research expedition that included geologists, mineralogists, botanists, and photographers (Haines 1977). These were individuals who could describe many of the abiotic as well as the biotic factors found within the area. Their early characterizations of the area have acted as foundations upon which later research has been based, and they are benchmarks against which later descriptions can be compared. So in many respects, this expedition laid the foundation for ecosystem study in this region. Other studies were begun shortly after the creation of the park. For example, a major fish population study was completed in the late 1880s (Jordan 1891), less than two decades after the park's founding.

Over the years, organisms residing in the area have been studied extensively. These records have been kept and are available to the public, so today's scientists have years of data from prior studies to use as foundations for current studies. This is one of the characteristics of the Yellowstone ecosystem that makes it a model for ecosystem study. Background study is necessary to studies of interactions of organisms in communities or ecosystems, and in Yellowstone, geological, climatic, and biological records are available to provide the necessary background upon which to engage in further research. For example, while pursuing a fungal distribution study, I came across information about an endemic disease in Yellowstone's northern elk herd (Worley and Barrett 1964). Lungworm disease had been studied extensively in this elk herd more than 20 years before I began my study of fungi. Upon learning of the elk lungworm studies, I redirected my study to the northern elk herd and demonstrated that the conditions were right for the fungus I was studying to function as a vector for spreading the etiological agent of this disease within the northern elk herd (Foos 1997). The earlier research had provided information to suggest that another study would be appropriate. It is often the case that earlier studies suggest additional research. One of the very important things that makes Yellowstone a model ecosystem is that there have been so many earlier studies that the background is here as a foundation upon which new research can be set.

Much research in national parks, and indeed, in Yellowstone National Park, is instituted by park administrators to help in making decisions about park management. Christie Hendrix (pers. comm.) reports that of approximately 240 researchers who have permits to engage in research in Yellowstone right now, 104 of the studies could be applied to making management decisions within the park. The other 136 studies are not designed to provide information for management applications. Clearly, research is important to help develop park policy. At the same time, I want to suggest that the Greater Yellowstone Ecosystem is an area in which ecosystem research can and should thrive regardless of the area's status as a national park. I'd like to stress the importance of pure research relative to applied research. While the distinctions are sometimes difficult to make, it is clear that some research can be directed toward current decisionmaking situations and other research is designed to help us understand the world around us. Pure research may not have any direct

bearing on park management; on the other hand, it might. Further, if it does not have a bearing on park management now, it may in the future. A couple of years ago, Kathy Sheehan and others were engaged in ecosystem research studying the microorganisms that live in acidic thermal streams within Yellowstone to see if they contained pathogenic amoebae (Sheehan et al. 2003a). During this study, they found a microbe that sometimes causes meningitis in a hot spring where tourists often swim. The results of this study—designed to determine the composition of microbial communities in the hot springs—have been used to make management decisions. This project that began as pure research to help describe the world around us led to an investigation of an aspect of the original work that has had a direct bearing on the management of the park (Sheehan et al. 2003b). The results of this study led park managers to place signs near thermal swimming areas to warn swimmers of the risk.

Individuals who conduct research in Yellowstone National Park must have a research permit. The use of research permits is a valuable part of research oversight in Yellowstone, and the process by which permits are awarded influences the role of research in the park. Recently, Alice Wondrak Biel (2004) published a detailed historical account of the practice of issuing research permits and the ways in which this practice has changed over the years. Presently, requests for permits to do scientific research in Yellowstone call for a peer review and provide conditions under which research materials may be collected and maintained. There is also a requirement to submit an annual report of research progress. These requirements do several things that make Yellowstone a model area for ecosystem research. First, an assessment of the proposal and the peer review process help ensure the quality of the research. This, in turn, increases the likelihood that the results of the research, upon which others may base their future research, will be valid. The requirement for an annual report encourages those engaged in the research to complete and document their work. It lets others know what research is being done and makes the scientific community aware of the research environment. The initiation of a study on one aspect of an ecosystem might suggest additional studies to others in the same area.

Research builds upon prior research in virtually all areas of science. However, this seems particularly true of ecosystems research, where the many varied organisms in a community interact with each other in one way or another. An example of research encouraging research can be seen in the work initiated by Thomas Brock when he first systematically studied microorganisms in Yellowstone's hot springs (Brock 1995). Prior to the 1960s, there was little awareness of the various forms of life in the park's thermal springs. After Brock's initial work on the organisms found in hot springs, however, a whole new generation of scientists began research on the microbes in the communities found in these features. (Of course, it probably helped that a protein from one of the bacteria that Brock found provided a key enzyme that is required for entire areas of molecular biology.) Now, dozens of scientists study the microbes of Yellowstone's hot springs, and the information about these communities and the various aspects of their ecosystems is being generated very rapidly (Brock 1998; Ward 1998). Much of this research can be generalized to make assumptions about hot springs worldwide. Also, much of the research—while initially ecosystem work—has provided techniques and information that can be used in molecular techniques and lead to new discoveries about a wide range of organisms everywhere.

We often read reports that emphasize the particular importance of protecting ecosystems of the Amazon and other rainforests because they might contain undiscovered organisms that could provide new medicines, or may in some other way affect quality of life. The same can be said about the Yellowstone ecosystem. But just as the ecosystem must be protected, research in the ecosystem must be encouraged. Just because *Taq* polymerase, isolated from *Thermus aquaticus* found in Mushroom Spring, revolutionized molecular biology and introduced the possibility of DNA sequencing and the multitude of practical applications resulting from that discovery, it does not mean that Yellowstone's gifts to the world have all been given. There will be other discoveries as research continues in the Yellowstone ecosystem. Some will be remarkable and others will be of little note, but we cannot know which aspects of ecosystem research will be most important before the research is initiated. I can't image that Dr. Brock was thinking about revitalizing the entire area of molecular biology when he was collecting bacteria from Yellowstone hot springs nearly 40 years ago.

The vital role of the national parks as sites for ecosystem research has been supported by many individuals for years. In the 1990s, there were many calls for research not only in Yellowstone, but as a mission for all the national parks (Parsons 1989;

National Research Council 1992; Risser and Lubchenco 1992; Zube 1996; Sellars 1997). It seems that scientists were not the only ones who thought that research in national parks would be valuable. In 1998, Congress mandated research as a component of the missions of national parks (Harmon 1999). Yellowstone has been at the forefront of providing support and encouragement to research in the park. Perhaps it has to do with the mission or policies of the park, or perhaps it has to do with the people. Yellowstone has been very lucky to have had a cadre of visionary individuals who have overseen research in the park and supported the many scientists who have engaged in research here.

I have always received a warm welcome and a helpful exchange of ideas while in Yellowstone doing research. In addition, over the years, the systematic review of applications for permits and process of submission of annual reports has become easier to maneuver. There is a history of science here, with all of the documentation that one may want, now housed in a magnificent new facility in Gardiner, Montana. There are people who are interested and willing to help. And there are a multitude of research questions to be answered in Yellowstone. Nowhere else is there an open ecosystem so vast and so varied that provides an opportunity for long-term ecosystem research.

Ecosystem research can and should thrive here in the Greater Yellowstone Ecosystem. It is an open, natural area with a wide range of climatic conditions in which native plants and animals live and grow relatively unhampered by the environmental changes that have occurred in other parts of the world over the past decades. It is the kind of place that can provide insight into the environment as it was in the past far better than almost anywhere else. It is important that ecosystem research be nurtured in Yellowstone. Much research may not be useful to help make park management decisions. However, even if the research does not provide information that is useful to park management, it is essential that the mission and policies of Yellowstone encourage ecosystem research now and into the future to help describe the natural world as it is and, in some cases, as it was.

References

Brock, T. D. 1995. The road to Yellowstone—and beyond. *Annual Review of Microbiology* 49:1–28.

______. 1998. Early days in Yellowstone microbiology. *ASM News* 64:137–140.

Craighead, J. J., J. S. Sumner, and J. A. Mitchell. 1995. *The grizzly bears of Yellowstone: their ecology in the Yellowstone ecosystem, 1959–1992*. Washington, D.C.: Island Press.

Foos, K. M. 1989. Isolation of *Pilobolus spp.* from the northern elk herd in Yellowstone National Park. *Journal of Wildlife Disease* 25:302–304.

______. 1993. *Pilobolus* ecology. *Yellowstone Science* 1(3):2–5.

______. 1997. *Pilobolus* and lungworm disease affecting elk in Yellowstone National Park. *Mycological Research* 101:1535–1536.

______. 2001. *Pilobolus*: a fungus that grows in Yellowstone. *Yellowstone Science* 9(1):17–20.

Foos, K. M., and J. A. Royer. 1989. A survey of *Pilobolus* from Yellowstone National Park. *Mycotaxon* 34:395–397.

Haines, A. L. 1977. *The Yellowstone Story, vol. 1*. Boulder, Colo.: Colorado Associated University Press and Yellowstone Library and Museum Association.

Harmon, D. 1999. The new research mandate for America's national park system: where it came from and what it could mean. *The George Wright Forum* 16(1):8–23.

Jordan, D. S. 1891. A reconnaissance of streams and lakes in Yellowstone National Park, Wyoming, in the interest of the U.S. Fish Commission. *Bulletin of the United States Fish Commission* 9:41–63.

National Research Council. 1992. *Science and the national parks*. Washington, D.C.: National Academy Press.

Parsons, D. J., ed. 1989. *Evaluating national parks as sites for long-term studies*. New York: Springer-Verlag.

Risser, P. G., and J. Lubchenco. 1992. *Report of a workshop for a national park service ecological research program*. Washington, D.C.: National Park Service.

Sellars, R. W. 1997. *Preserving nature in the national parks: a history*. New Haven, Conn.: Yale University Press.

Sheehan, K., M. J. Ferris, and J. M. Henson. 2003a. Detection of *Naegleria* sp. in a thermal stream in Yellowstone National Park. *Journal of Eukaryotic Microbiology* 50:263–265.

Sheehan, K., J. A. Fagg, M. J. Ferris, and J. M. Henson. 2003b. PCR detection and analysis of the free-living amoeba *Naegleria* in hot springs in Yellowstone and Grand Teton National Parks. *Applied and Environmental Microbiology* 69:5914–5918.

Smith, D. W., R. O. Peterson, and D. B. Houston. 2003. Yellowstone after wolves. *BioScience* 53:330–340.

Varley, J. D., and P. Schullery. 1996. Yellowstone Lake and its cutthroat trout. Pages 49–73 *in* William L. Halvorson and Gary E. David, eds., *Science and ecosystem management in the national parks*. Tucson, Ariz.: The University of Arizona Press.

Ward, D. M. 1998. Microbiology in Yellowstone National Park. *ASM News* 64:141–146.

Wondrak Biel, A. 2004. The bearer has permission: a brief history of research permitting in Yellowstone National Park. *Yellowstone Science* 12(3):5–20.

Worley, D. E., and R. E. Barrett. 1964. *Studies on the parasites of the northern Yellowstone elk herd*. Washington, D.C.: National Park Service.

Zube, E. H. 1996. Management in national parks: from scenery to science. Pages 11–22 *in* William L. Halvorson and Gary E. Davis, eds., *Science and ecosystem management in the national parks*. Tucson, Ariz.: The University of Arizona Press.

Greater Yellowstone Wildlife in Science and Myth: We are from Mars; They are from Earth

Mary Ann Franke

125 Spotted Fawn Court, Sedona, AZ 86351 (928-284-2774, maryannfranke@aol.com)

Abstract

The diverse wildlife management policies witnessed in Greater Yellowstone over the years reflect changes in both the scientific knowledge and the myths that affect how we relate to wild animals. During his 1903 visit, big game hunter Theodore Roosevelt found Yellowstone's "semi-domesticated" grizzly bears "delightful" and "quite harmless" if "reasonable precaution" was taken. The myth of the harmless Yellowstone bear was eventually overtaken by the belief that wildlife management should be based on ecological concepts rather than entertainment value, but advances in scientific knowledge did not mean that we abandoned myths altogether. On the contrary, the pursuit of scientific rationales for wildlife policies continued to feed existing myths and give rise to new ones, including the mythic ideal that values wildlife for its wildness. But not everyone agrees, whether the animals in question are bears, bison, wolves, or cutthroat trout. Is there anything inherently more "natural" about wildlife that is unaffected by humans, one of Earth's keystone species? In traditional views still held by many American Indians, the relationship between humans and other species is one of interdependence. All interest groups in a wildlife controversy are apt to claim that science is on their side, but what really fuels the debates are the myths that we want to believe about animals in Greater Yellowstone.

Introduction

Although myths are often thought of as traditional stories that came into being to explain some natural phenomenon, to call something a myth in modern parlance has become a way of dismissing it as a fallacy unsupported by scientific or historical fact. According to one dictionary definition, the term "myth" may refer to a "recurring theme that appeals to the consciousness of a people by embodying its cultural ideals or by giving expression to commonly felt emotions" (Woolf 1980). In that sense, a myth is not inherently false; what makes something a myth is its cultural resonance or emotional appeal. My use of the term "myth" therefore refers not just to specific stories, like how the pronghorn got its stripes; it's also a way of looking at different assumptions that affect how we live with wild animals in Greater Yellowstone.

John Gray, who wrote *Men Are From Mars, Women Are From Venus,* didn't literally believe that men are from Mars, but by framing the issue that way, he appealed to an emotion commonly felt by women (Gray 1992). For much of Euro-American history in the New World, we've treated wildlife as if we believed that we are from Mars—as if we were a species from another planet that extracts what it wants and can eventually close the door on Earth and leave the mess behind. As Aldo Leopold said, "we abuse land because we regard it as a commodity belonging to us" rather than "a community to which we belong" (Leopold 1949).

The pristine myth

Sometimes one generation's science is dismissed by the next generation as myth, but the gradually evolving story we tell about the past incorporates changing myths as well as new empirical evidence. A striking example of this is the myth that North America was "virgin" land until Europeans arrived to live here. Until relatively recently, it was widely assumed that the continent's aboriginal inhabitants were too few in number and too primitive in their civilization to have had any significant impact on their environment. For centuries this assumption has helped support myths that encouraged Euro-Americans to view themselves as a superior race, as discoverers with a manifest destiny. It also allowed Euro-Americans to view American Indians either as inconsequential heathens or as noble savages who lived in harmony with nature and left no mark upon the land. John Craighead (1991) has written that "pre-Columbian Yellowstone was indeed a pristine wilderness. . . . and native Americans were an important member of the biota," a view that seems to regard pre-Columbian American Indians as a species of wildlife.

But now the increasingly popular view is that

the North American population in 1491 was far larger and more technologically advanced than previously thought, and that European diseases swept through the Americas so much in advance of Europeans themselves that what the settlers discovered was a post-apocalyptic landscape in which American Indians were no longer present in sufficient numbers to engineer the landscape through hunting, fires, and agriculture as they had in the past. While this view can be supported by certain archeological and anthropological evidence, it also appeals to certain contemporary myths about the superiority of American Indian culture and the need for human manipulation of wilderness areas. Instead of trying to preserve some mythical Eden in such places, this reasoning goes, we should emulate traditional American Indian practices to make our environment a more accommodating home (Mann 2005).

The myth of species extirpation as a distinctively Euro-American transgression has also been overturned by scientific research. According to the overkill theory, human predation was at least partly responsible for the extinction of the largest mammals that were present about 15,000 years ago, including mammoths, mastodons, and cheetahs (Martin and Klein 1984). After learning at a tribal consultation how obsidian points are dated, Elaine Quiver, an Oglala Sioux elder, advised National Park Service archeologists to look for "a big sliver of obsidian" that was used, she said, to "take care of the dinosaur"; then, we could figure out "when the dinosaur disappeared" (Quiver 2003). The overkill concept has also been extended to Greater Yellowstone by those who cite evidence that hunting by American Indians kept pre-Columbian ungulate populations low (Kay 1994).

Historians like William Cronon have called the idea that humans can leave nature untouched by their passage "the myth of wilderness." Cronon claimed that the removal of American Indians to create an "uninhabited wilderness . . . reminds us just how invented, just how constructed, the American wilderness really is." Charles Kay has also referred to wilderness without human influence as a "myth," and believes that it was "created, in part, to justify the appropriation of aboriginal lands and the genocide that befell native peoples." In noting that the National Park Service has referred to Yellowstone as "America's Serengeti," Kay wrote, "It's true. They're both unnatural systems. The Serengeti is a romantic, European, racist view of what an ecosystem should look like. What's more unnatural than an ecosystem without human predators?" (Hanscom 1997).

In "Greater Yellowstone's Native Ungulates: Myths and Realities," Joel Berger regarded comparisons of Greater Yellowstone to the Serengeti as a myth because the Serengeti has 31 native ungulate species, whereas Greater Yellowstone has been "impoverished in terms of its ungulate fauna" since the Miocene epoch, having only seven ungulate species, five of which migrate to lower elevation areas beyond park boundaries where "enormous ecological changes have occurred." Berger pointed out that the conservation of Greater Yellowstone will be influenced more significantly by what occurs in areas outside its two parks than by what occurs within them (Berger 1991). Humans will continue to alter the ecosystem by interfering with wildlife in various ways. It's a question of which interferences are socially acceptable at a given point in time because they are compatible with the dominant myths.

Dancing flies and gentle bears

In the nineteenth century, images like those of the Grand Canyon of the Yellowstone created by Thomas Moran and William Henry Jackson helped shape the myth of the Yellowstone area as a primeval wilderness on which neither American Indians nor wildlife had left visible footprints. These paintings and photographs, from which wildlife were usually absent, do not qualify as scientific evidence that wildlife was rare when Yellowstone was established in 1872, but the way artists chose to represent the area does suggest that wild animals were not regarded as the iconic part of the landscape that they are now. Big game animals were still commonplace in much of the country as a source of food, fur, and hides, and carnivores were still commonly regarded as a source of trouble.

The first vision of Yellowstone as a wildlife refuge came primarily from hunters who wanted protection for game species in the park so that the animals would multiply and leave its boundaries. This desire led to certain myths about "good" and "bad" animals, but species have been switched back and forth between these categories as opinions have changed over time. When Secretary of the Interior Henry M. Teller prohibited the killing of certain animals in Yellowstone in 1883, bears and other predators were not included (*Forest and Stream* 1883). But as tourism increased, the emphasis shifted from protecting the animals most popular among hunters to those popular with park visitors. Even the wildlife species that were considered "good" were valued for

reasons that weren't entirely the same as those of today. Whatever John Muir's virtues as a naturalist and proponent of wilderness preservation, his anthropomorphic descriptions of nature may strike modern readers as a Disneyland-style Fantasia. "Gladly we see the flies dancing in the sunbeams," he said of Yellowstone in 1898, "while the whole wilderness is enlivened with happy animals." He described Yellowstone's bears as "gentle now, finding they are no longer likely to be shot," and claimed that "no town park you have been accustomed to saunter in is so free from danger as the Yellowstone" (Muir 1898).

The bears became "good" when they became habituated to the proximity of humans. Decades later, Yellowstone National Park naturalist Merrill Beal thought that one reason why the U.S. Army began enforcing the hunting ban in Yellowstone was that "lonely" soldiers "in remote stations had formed enjoyable companionships with wilderness creatures," and "were delighted by the universally charming wild life trait of responding with confidence and alacrity to friendly human advances." When park managers realized that "Yellowstone birds and mammals would quickly recognize overtures of friendship and protection," they thought that "nearly every species in the Park might become as tame as range cattle if given an opportunity to move safely within rifle shot for several years" (Beal 1946).

Wild animals as livestock

In early concepts of wildlife preservation, an animal's "wildness" was often regarded as an undesirable trait, an excusable reason for an animal's demise, and something to be overcome if possible. In 1902, when Secretary of the Interior Ethan Allen Hitchcock requested funding from Congress "for the purchase of buffalo and the corralling of them in Yellowstone Park," he pointed out that by keeping them "under government supervision, it is believed that a herd of pure-blooded American bison may be domesticated" (Hitchcock 1902). Yellowstone's acting superintendent Major John Pitcher thought that the small herd of wild bison remaining in Pelican Valley "may possibly die out completely," but he expected that the 17 bison obtained from ranchers could "become very tame" if kept fenced in Lamar Valley. It was his intention "to feed and handle the new herd of buffalo in the same manner that domestic cattle are handled in this country, and . . . to brand them U.S. in such a way that they can always be identified as United States property" (Pitcher 1904).

Even Theodore Roosevelt, who took pride in his adventures as a big game hunter, regarded the habituation of Yellowstone wildlife as synonymous with tameness and something to be encouraged. After his 1903 visit to the park, he wrote, "To any lover of nature it could not help being a delightful thing to see the wild and timid creatures of the wilderness rendered so tame. . . . At times the antelope actually cross the Park line to Gardiner . . . and feed unmolested in the very streets of the town; a fact which shows how very far advanced the citizens of Gardiner are in right feeling on this subject." He described bears "boldly hanging around crowded hotels for the sake of what they can pick up," and considered them "quite harmless so long as any reasonable precaution is exercised" (Roosevelt 1905).

Twenty years later, Yellowstone National Park naturalist Milton Skinner described the grizzly bear "as a peaceful, self-respecting animal," and claimed that "there is no danger of the Yellowstone bears attacking or hurting people," although he admitted that "we often have some very exciting encounters with them when they are after our food" (Skinner 1925). Horace Albright, who was Yellowstone's superintendent in the 1920s before becoming director of the National Park Service, also regarded the value of wildlife as being directly proportional to the delight the animals could provide park visitors. But for Albright, this meant disputing the notion that the bison in Lamar Valley were "tame," which sounded rather dull. He had the park rangers stage roundups, which he described as "about the last opportunities to see . . . the fearful and impressive buffalo stampedes." In this way, Albright used a large bison herd that was accustomed to being corralled to portray the myth that these were wild animals. The real herd of wild bison in Yellowstone wouldn't have been so cooperative. As Albright saw it, the Lamar bison herd was "not tame at all except that it was provided with hay in winter and was kept under control by the gamekeeper" (Albright and Taylor 1928).

Elsewhere in Wyoming, the only reason to feed and tolerate large herds of wild ungulates was so that the animals could be hunted. "The time has finally come, and I can see whereby it is necessary to handle our game herds the same as a stock man handles his stock," said Wyoming Fish and Game Commissioner Bruce Nowlin in 1927. "The stock man knows just the number of stock he must sell each year in order to make provision for the number he can care for during the winter months." Nowlin's successor, Robert Hocker, expressed the same view four years later: "Game management is identical with livestock man-

agement," Hocker said. "The number of animals you have winter range for, and . . . the number you can afford to feed, determines the numbers at which you wish to hold your herd" (Blair 1987).

By the 1930s, the growing opinion that wildlife management should be based on ecological concepts rather than public recreation was starting to affect some wildlife policies in Greater Yellowstone. But instead of lessening the hold of myths, the trend toward scientific rationales for wildlife policies continued to feed existing myths and give rise to new ones. Science has often been used to put old wine into new bottles—to help support archaic myths such as those about creationism, racial superiority, and the balance of nature.

Like the concept of intelligent design, the balance of nature idea is so appealing that it has continued to affect how people explain natural phenomena despite considerable evidence to the contrary. Under this model, design flaws or imbalances in the natural environment are often attributed to what humans have done or failed to do. In 1946, Yellowstone manager Rudolph Grimm stated, "It is our responsibility to maintain in a natural condition the range plant cover as well as the wildlife population of this range. In order to attain such a state, we must bring about and maintain an equitable balance between the amount of range forage produced and the number of animals using this range" (Grimm 1946). The expectation that "natural condition" and "equitable balance" could be achieved through the right human manipulations was evident as the National Park Service culled thousands of elk in Yellowstone until the late 1960s.

The 1963 Leopold Report (i.e., "Wildlife Management in the National Parks") agreed that the National Park Service should "manage the habitat to achieve or stabilize it at a desired stage," and that "population control becomes essential" when "animal populations get out of balance with their habitat and threaten the continued existence of a desired environment" (Leopold et al. 1963). However, the report recommended that the park service obscure in every possible way any "observable artificiality," because the goal was to create "the mood of wild America" and "a reasonable illusion of primitive America." That meant sustaining certain myths about what primitive America was like.

Natural regulation as a myth

The myth that Euro-Americans discovered a pristine wilderness in the New World may have expired, but the story of Greater Yellowstone told by most ecologists, historians, and American Indians continues to be one in which the Indians did not have a long-term effect on wildlife as we know it until they acquired horses. The favored story changed in the 1960s, however, after the only apparent effect of reducing the elk herds was to increase public resistance to the practice. Some biologists began to question whether elk could destroy their habitat through overpopulation, proposing that forage limitations and starvation in winter would keep the herd below the range's ecological carrying capacity, a process referred to as "natural regulation." According to this view, Yellowstone had only marginal habitat for aspen and willow, browsing by a large elk herd was to be expected, and any changes in Yellowstone flora and fauna that occurred in the twentieth century were primarily the result of climate variability and fire suppression (Yellowstone National Park 1997).

Ecological and historical evidence can be mustered to support this belief, but it also attracted those who, especially prior to the reintroduction of wolves, liked to think Yellowstone was "natural" just the way it was, as a wildlife sanctuary with large, unmolested ungulate herds. As one National Park Service naturalist explained, "the removal of the wolf probably didn't have much effect on the elk or deer, because in Yellowstone wolves seem never to have served the function of controlling populations" (Schullery 1984). The doubling in size of the northern elk herd after culling ended cast more doubt on the idea that the range was overgrazed, but the unexpectedly large fluctuations quashed the idea that natural regulation would lead to some kind of sustained balance. Wildlife managers began to realize that balance was a largely subjective matter; people were apt to consider a species out of balance if it caused property damage, if a favored species declined, or if some animals died because they could not survive the winter. But some critics of National Park Service policies continued to dismiss natural regulation as a myth—"nothing more than a policy of waiting for bad weather" (Chase 1986).

The concept of natural regulation as it's been used in Greater Yellowstone is also regarded as a myth by some American Indians. A Salish from the Flathead Reservation has said, "Although the park claims it is managing for natural regulation, it is not natural to shoot buffalo in the winter. It is necessary to harvest animals when they are in good condition" (Ravndal 1997). Winter is "the time the animals should be at rest," Haman Wise of the Eastern

Shoshone agreed. “The buffalo should have a rest period someplace to revise their spirituality” (Wise 2000). Historically, the Indians did sometimes hunt buffalo in the winter when they were hungry, or because they preferred fresh meat to dried pemmican, or because that’s when the buffalo were wearing their warmest robes (Isenberg 2000). What matters about these Indians’ beliefs is not their historical accuracy, but that they appeal to emotions commonly felt by Indians.

Some people believe that humans have altered Greater Yellowstone too much for park managers to realistically consider leaving nature to itself, and that without interventions to compensate for human disturbances, something “unnatural” or otherwise unacceptable happens to ungulate populations and their habitat. By the early 1990s, an increasing number of people believed that what Yellowstone really needed was human intervention in the form of wolf reintroduction.

The new wolf

The wolves of Greater Yellowstone have, at least in much of the mainstream press, undergone a complete image makeover since they were eradicated from the area in the 1930s. Once the embodiment of all that was bad about untamed wilderness, now they are widely regarded as the savior of the little wilderness that remains. In his 1978 book, *Of Wolves and Men,* Barry Lopez wrote, “biologists have given us a new wolf, one separated from folklore. But they have not found the whole truth. For example, wolves do not kill just the old, the weak, and the injured. They also kill animals in the prime of health. And they don’t always kill just what they need; they sometimes kill in excess. And wolves kill each other. The reasons for these acts are not clear. No one—not biologists, not Eskimos, not backwoods hunters, not naturalist writers—knows why wolves do what they do” (Lopez 1978).

Although nearly 30 years have passed since Lopez wrote that, biologists still haven’t found the whole truth, and some people believe that biologists are still trying to perpetuate old myths, like the one that regards the wolf as an endangered species, or that wolves never attack humans. Most wildlife managers have done their best to separate the wolf from its folklore, but because we still can’t always explain why wolves do what they do, and because we don’t always like the results, the folklore persists. The myths of wolf restoration in Greater Yellowstone in 1995 as either a great conservation triumph or a colossal blunder are still very much with us.

Although Rick Bass disdained Yellowstone as “prey-infested” in his 1992 book, *The Ninemile Wolves*, he opposed the release of wolves in the park. He believed it was as phony as the park’s buffalo purchase of 1902—something done for the sake of tourism rather than for ecological integrity. In 1997, those willing to donate $5,000 to the cause could “become a full partner in Yellowstone National Park’s historic wolf recovery program in a special and personal way.” In an advertisement in *Wolf Tracker*, the Yellowstone Wolf Foundation offered to “inscribe your name—or the name of a loved one—onto a new radio-telemetry collar just before it is placed on a wild Yellowstone wolf.” When the collar was “retrieved” in three years, it would be “shipped to you for your family’s permanent safe-keeping and education.” In *The New Wolves*, Bass compared the transport of wolves from Canada to a shopping trip undertaken “to fill in the emotional blanks of a fractured landscape” (Bass 1998), and he would probably feel the same way about spending $5,000 to get your name inscribed in a radio collar. Bass is loyal to the cause of wolves, which he regards as offering the best chance of erasing the boundary lines that fragment the West, but he wanted them to be allowed to return to Yellowstone on their own, without the intrusion of radio collars and intensive monitoring.

Rather than support John Muir’s myth that national park boundaries provide a safety net for wild animals, wilderness advocates like Bass see the boundaries as strangling wildlife. Yet Bass has joined those who believe in the nearly miraculous transformation of Greater Yellowstone as a result of wolf reintroduction. As Bass saw it in 2005, the wolves “have reshaped huge sections of an awkwardly leaning ecosystem;” now “there is color in the land again” (Bass 2005). Those who thought there was color in the land before wolves returned must have been looking at it through rose-tinted glasses, and that would include the National Park Service staff who co-authored a 1986 book that stated, “it remains open to question whether the ecosystem ‘needs’ wolves in some absolute sense” (Despain et al. 1986). Less than two decades later, a park service biologist was claiming that “wolves are to Yellowstone what water is to the Everglades” (Thompson 2003).

Diligently protected species

The labeling of good and bad animals changes over time, and a species may continue to be favored in one part of Greater Yellowstone after it has be-

come a pariah in another. After 1994, when the National Park Service began spending millions of dollars to save the native Yellowstone cutthroat trout by removing non-native lake trout from Yellowstone Lake, the state of Wyoming continued to put thousands more lake trout into Jackson Lake every year. And when the Wyoming Game and Fish Department announced plans last year to phase out this stocking program, their primary stated reason was the apparently deleterious effect of the program on the lake trout, not on the native cutthroat (Wyoming Game and Fish Department 2004).

Although both elk and bison are native species, elk continue to be treated more like "good animals" throughout Greater Yellowstone. The recent *Draft Bison and Elk Management Plan for the National Elk Refuge and Grand Teton National Park* included a section that explained "The Role of Elk" in the Jackson area. Elk were described as "diligently protected," "important to residents and interest groups," "important to backcountry users as well as to people that never leave the road," and "at the mercy of sometimes severe winters" (U.S. Department of the Interior 2005). The document made no mention of elk's depredation of ranchers' haystacks, the cost of the feedgrounds and vaccination using biobullets, or the role elk presumably had in transmitting brucellosis to Wyoming livestock in recent years.

The next section of the plan, "The Role of Bison," described the problems caused by the Jackson bison herd, which has been at the mercy of more critical thinking than the elk. "All of the adults were destroyed" in 1963 because of brucellosis. Not only do these animals currently pose a "risk of disease transmission to elk and livestock," but they also "disrupt feeding operations" for the elk, "displace and injure elk," "eat supplemental feed provided for elk," cause "damage to habitats," "damage to private property," "conflicts with landowners," and pose a "risk to human safety."

American Indians have challenged the myth of bison as the bad guys at consultation meetings the National Park Service began holding in 1996 because of the tribes' objections to how bison were being treated at the Yellowstone boundary. Haman Wise from the Wind River Reservation has felt obliged to repeatedly explain what he calls "the part nobody understands." "You really don't know why the buffalo leaves, do you?" he says to park staff. "The buffalos leave the park because they have to eat that certain medicine plant. That takes care of all the ailments in their body. . . . That's why you don't see very much aborting in buffalo" (Wise 2000).

The park service believes it knows better, but "scientific" explanations for why bison leave the park can get as bogged down as a snowshoe in spring slush. According to one authoritative analysis, bison leave the park because of "population dynamics . . . influenced by density-independent winter stress conditions . . . social behaviors, . . . learned behaviors, . . . [and] a combined winter severity index including a weighted measure of snow (40%), temperature (40%), and rain (20%). . . . [O]ther variables seem to be dampened or compensatory with natural mortality. . . ." (Cheville et al. 1998). Another report concluded that "Bison move beyond park boundaries in winter in response to forage limitation caused by interactions between population density, variable forage production (driven by spring/early summer precipitation), snow conditions, and herbage removal primarily by bison and elk" (Gates et al. 2005).

As for abortions in Yellowstone bison, the scientific consensus is that they are infrequent because the abortion rate drops in any ungulate herd that has become chronically infected with brucellosis (Cheville et al. 1998). Yet until the 1990s, the National Park Service's defense of its bison management policy routinely suggested that abortions were infrequent because the bacteria may have co-evolved with bison in North America (Yellowstone National Park 1972). The park service's critics couldn't prove that *Brucella abortus* was an exotic species brought by European livestock, unless you believed American Indian reports that brucellosis and undulant fever were previously unknown on this continent. But the idea that the bacteria were native to Greater Yellowstone was appealing to people who didn't like the idea that Yellowstone bison were susceptible to some lowly livestock disease and who opposed taking drastic measures against the bison. As National Park Service Director William Mott explained in 1987, the agency's responsibility to future generations "extends to disease organisms such as those causing brucellosis . . . when they are a natural component of the park ecosystems we are mandated to protect" (Mott 1987).

Beyond scientific measurement

Some American Indians believe they have a special responsibility to a certain animal because its spirit appeared to them in a dream or during a vision quest and granted them a special power. An Indian visited by the pronghorn spirit, for example, might receive the power to call pronghorn and keep

them spiritually captive until they could be killed. But this partnership with animals comes with a set of obligations, including rituals to be performed. In Shoshone traditions, a slain pronghorn was placed with its head to the east and addressed with respect. The hunters would offer the animal's eyes and skull to the spirit world by suspending them from trees (Dramer 1997). In ceremonies to honor their guardian spirits, the Assiniboine bear dreamers may paint black circles around their eyes and mouths, wear necklaces made of bear claws, and tie their hair into two clumps to resemble bears' ears. In battle, these bear dreamers confronted the enemy holding knives made from a bear's jaw bone, and they imitated the sound of a bear, believing the power of the bear would protect them (Rockwell 1991).

When we hear stories that express the connection between people and wildlife in terms of sacred rituals, we may feel some condescension toward beliefs so lacking in any scientific basis, or we may envy the apparent intimacy of the relationship. But our view of wild animals continues to be colored by myths, even if we're unaware of them, and by taking the long view of human history in Greater Yellowstone, we can see that myths have served a purpose by enabling people to explain what cannot be satisfactorily understood or justified based on scientific evidence alone.

For example, consider the killing of bison by licensed hunters in Montana for the first time in 15 years that is scheduled to commence in less than a month [November 2005]. In its environmental assessment, Montana Fish, Wildlife and Parks described its proposed hunt as both a means of removing "persistent problem animals" and a "fair chase." Although the definition of fair chase lies largely with the hunter, it's generally understood to mean that the balance of power is such that the hunted animal has some chance of eluding the hunter. It's difficult to imagine that a system could be fair or at least logical in which long-range plans call for the bison to stand still and take their medicine when approached by a wildlife biologist shooting biobullets at them, but to run away and behave like wild animals when approached by a hunter. However, the idea of a fair chase bison hunt in Montana may be considered mythical not because it could never happen, but because the concept of fair chase has become "a recurring theme that appeals to the consciousness of a people by embodying its cultural ideals." Many people in Western culture, few of whom are hunters, have come to assume that when a game animal is shot on public land in circumstances that do not qualify as fair chase or self-defense, the killing is somehow unethical. As stipulated in the bill passed by the 2003 Montana Legislature, any hunting season for bison was to be "conducted under ethical hunting conditions, i.e., fair chase" (Montana Fish, Wildlife and Parks 2004).

The concept of a fair chase has some ecological basis, because the behavior of a prey species that knows it is prey and defends itself accordingly resembles the natural selection process in which the species has evolved. But from an ethical standpoint, the use of fair chase as the defining characteristic is quite arbitrary. Although opponents of hunting bison that have learned no fear of humans tend to claim the activity is "as sporting as shooting a parked truck" (McMillion 2005), for some American Indians it is sport hunting that is inherently unethical or even sacrilegious. From this perspective, what makes killing a wild animal ethical is not the difficulty of the pursuit, but the respect and relationship of mutual obligation that you share with the animal. According to many traditional Indian beliefs, an animal that is approached in the right spirit will give itself willingly to the hunter.

The flip side of the myth that we are separate from the rest of nature is the idea that we are just a species like any other or, as Aldo Leopold put it, that "men are only fellow-voyagers with other creatures in the odyssey of evolution" (Leopold 1949). J. Baird Callicott has suggested that if the "works of man" are "entirely natural and the products of evolutionary phenomena," then they may be "symbiotically integrated with other contemporaneous evolutionary phenomena; they may in principle be beneficial to the biotic communities" we inhabit (Callicott 1991). Seeing ourselves as part of the continuum of nature can give us a sense of kinship with other animals, but it can also offer a rationale for all our predatory behavior. Other animal species must adapt to their environment to meet their biological needs, whereas humans can far more rapidly and extensively alter their environment to meet both their needs and desires. Humans are also, as far as we know, the only species that can create myths about other animals rather than simply learn facts about them. As the philosopher Holmes Rolston III has pointed out, if we did not interfere with and rearrange nature, we would have no human culture (Rolston 1994). Instead of regarding ourselves as fellow voyagers with other creatures, or as their masters or stewards, Henry Beston suggested that we need "perhaps a

more mystical concept" of animals:

> We patronize them for their incompleteness, for their tragic fate for having taken form so far below ourselves. And therein do we err. For the animal shall not be measured by man. In a world older and more complete than ours, they move finished and complete, gifted with the extension of the senses we have lost or never attained, living by voices we shall never hear. They are not brethren, they are not underlings: they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendour and travail of the earth (Beston 1928).

References

Albright, H. M., and F. J. Taylor. 1928. *"Oh, Ranger!" A book about the national parks*. Stanford, Calif.: Stanford University Press.

Bass, R. 1992. *The Ninemile wolves*. Livingston, Mont.: Clark City Press.

______. 1998. *The new wolves*. New York: Lyons Press.

______. 2005. Wolves return to Yellowstone. *Orion* (August). <http://www.oriononline.org/pages/om/05-4om/Bass.html>.

Beal, M. D. 1949. *The story of man in Yellowstone*. Caldwell, Idaho: Caxton Printers.

Berger, J. 1991. Greater Yellowstone's native ungulates: myths and realities. *Conservation Biology* 5(3):353–363.

Beston, H. 1928. *The outermost house: a year of life on the great beach of Cape Cod*. New York: Doubleday.

Blair, N. L. 1987. *The history of wildlife management in Wyoming*. Casper, Wyo.: Wyoming Game and Fish Department.

Callicott, J. B. 1991. The wilderness idea revisited: the sustainable development alternative. Pages 237–266 *in* J. B. Callicott and M. P. Nelson, eds., *The great new wilderness debate*. Athens, Ga.: University of Georgia Press.

Chase, A. 1986. *Playing God in Yellowstone: the destruction of our first national park*. New York: Atlantic Monthly Press.

Cheville, N. F., D. R. McCullough, L. R. Paulson, N. Grossblatt, K. Iverson, and S. Parker. 1998. *Brucellosis in the Greater Yellowstone Area*. Washington D.C.: National Academy Press.

Craighead, J. J. 1991. Yellowstone in transition. Pages 27–38 *in* R. B. Keiter and M. S. Boyce, eds., *The Greater Yellowstone Ecosystem: redefining America's wilderness heritage*. New Haven: Yale University Press.

Despain, D., D. Houston, M. Meagher, and P. Schullery. 1986. *Wildlife in transition: man and nature on Yellowstone's northern range*. Boulder, Colo.: Roberts Rinehart.

Dramer, K. 1997. *The Shoshone*. Philadelphia: Chelsea House Publishers.

Forest and Stream. 1883. An important Park order, Jan. 18, 1883. 19(25): 481.

Gates, C. C., B. Stelfox, T. Muhly, T. Chowns, and R. J. Hudson. 2005. *The ecology of bison movements and distribution in and beyond Yellowstone National Park: a critical review with implications for winter use and transboundary population management, April 2005*. Calgary, Alberta: Faculty of Environmental Design, University of Calgary.

Gray, J. 1992. *Men are from Mars, women are from Venus: a practical guide for improving communication and getting what you want in your relationships*. New York: HarperCollins.

Grimm, R. 1946. Quoted in minutes of Absaroka Wildlife Conservation Committee meeting, September 21–22, Yellowstone National Park Archives.

Hanscom, G. 1997. Politics tangles with science. *High Country News* 29(17):3.

Hitchcock, E. A. 1902. Letter from the Secretary of the Interior, transmitting to the Senate facts in relation to the preservation of the American bison in the United States and Canada, July 1, *in* U.S. Senate, American bison in the U.S. and Canada, 57th Congress, 1st session, S. 445. Washington, D.C.: Government Printing Office.

Isenberg, A. C. 2000. *The destruction of the bison: an environmental history, 1750–1920*. Boston: Cambridge University Press.

Kay, C. 1994. Aboriginal overkill, the role of Native Americans in structuring western ecosystems. *Human Nature* 5(4):359–398.

Leopold, A. S., S. A. Cain, C. M. Cottam, I. M. Gabrielson, and T. L. Kimball. 1963. *Wildlife management in the national parks*. Washington, D.C.: Advisory Board on Wildlife Management.

Leopold, A. 1949. *A Sand County almanac*. New York: Oxford University Press.

Lopez, B. H. 1978. *Of wolves and men*. New York: Scribner.

Mann, C. C. 2005. *1491: new revelations of the Americas before Columbus*. New York: Knopf.

Martin, P. S. and R. G. Klein, eds. 1984. *Quaternary extinctions: a prehistoric revolution*. Tucson: University of Arizona Press.

McMillion, S. 2005. Bison hunt gets go-ahead. *Bozeman Chronicle* (September 9). <http://www.bozemandailychronicle.com/articles/2005/09/09/news/01bisonhunt.txt>.

Montana Fish, Wildlife and Parks. 2004. *Draft bison hunting environmental assessment*. Helena, Mont.: Montana Fish, Wildlife and Parks.

Mott, W. P. 1987. Letter to U.S. Senator Steven Symms. May 29. Yellowstone National Park Archives.

Muir, J. 1898. The Yellowstone Park. *Atlantic Monthly* 81:15–28.

Pitcher, J. 1904. Annual report of the acting superintendent of the Yellowstone National Park to the Secretary of the Interior, 1903. Washington, D.C.: U.S. Government Printing Office.

Quiver, E. 2003. Statement made during Yellowstone National Park tribal consultation meeting, Mammoth Hot Springs, Wyo., June 5.

Ravndal, V. 1997. A general description of the social and cultural environment surrounding the bison/brucellosis issue in the greater Yellowstone ecosystem. Vertical files, Yellowstone National Park Library.

Rockwell, D. 1991. *Giving voice to bear: North American Indian rituals, myths, and images of the bear*. Niwot, Colo.: Roberts Rinehart Publishers.

Rolston, H., III. 1994. *Conserving natural value*. New York: Columbia University Press.

Roosevelt, T. 1905. *Outdoor pastimes of an American hunter*. New York: Arno.

Schullery, P. 1984. *Mountain time*. Schocken, New York: Nick Lyons Books.

Skinner, M. 1925. *Bears in the Yellowstone*. Chicago: A. C. McClurg & Company.

Thompson, N. 2003. Wolves bring a surprising ecological recovery to Yellowstone. *Boston Globe* (September 30).

U.S. Department of the Interior. 2005. *Draft bison and elk management plan and environmental impact statement for the National Elk Refuge, Grand Teton National Park, and John D. Rockefeller, Jr., Memorial Parkway*. Lakewood, Colo.: U.S. Fish and Wildlife Service.

Wise, Haman. 2000. Statement made during Yellowstone National Park tribal consultation meeting, Mammoth Hot Springs, Wyo. April 26. Haman Wise and other American Indians made similar statements about bison use of medicinal plants at other consultation meetings, including those on October 11, 2000, April 24, 2001, and October 15, 2002.

Woolf, H. B., ed. 1980. *Webster's new collegiate dictionary*. Springfield, Mass.: G. & C. Merriam Company.

Wyoming Game and Fish Department 2004. *Angler Newsletter* (Jackson Region) 1 (May):1.

Yellowstone National Park. 1972. Brucellosis and the Yellowstone bison. Information Paper No. 17, April 5. Yellowstone National Park Archives.

Yellowstone National Park. 1997. *Yellowstone's northern range: complexity and change in a wildland ecosystem*. Mammoth Hot Springs, Wyo.: National Park Service.

Integrating Natural Resource Monitoring Across State and Federal Agencies

Cathie Jean

AJM Johnson Hall, P.O. Box 173492, Montana State University, Bozeman, MT 59717
(406-994-7530, cathie_jean@nps.gov)

Abstract

Opportunities exist for state and federal agencies in Greater Yellowstone to work together on monitoring natural resources where the populations of interest or monitoring objectives cross agency and state boundaries. In fact, the National Parks Omnibus Management Act of 1988 instructs the National Park Service to develop ". . . monitoring programs in cooperation with other Federal monitoring and information collections efforts to ensure a cost-effective approach." From a conceptual standpoint, coordinating monitoring programs with neighboring state and federal agencies is an essential step toward a more integrated approach. However, in reality, different budget cycles, planning schedules, and data management requirements can handicap the best of intentions. I will evaluate contemporary case studies in which ecological, spatial, temporal and/or programmatic integration of natural resource monitoring is working despite the differences in agency requirements.

Introduction

One of the more difficult aspects of designing a comprehensive monitoring program is integrating monitoring projects so that the interpretation of a whole monitoring program yields information more useful than that of individual parts (NRC 1995). The Greater Yellowstone Inventory and Monitoring Network has a unique opportunity to at least consider monitoring objectives that enhance our ability to interpret the condition and trend of natural resources across the Greater Yellowstone Ecosystem (GYE). It is an opportunity that warrants investigation into methods that integrate natural resource monitoring across state and federal agency boundaries.

There are many reasons to strive for better integration. First, integration can result in a more comprehensive monitoring portfolio, which in turn enhances our ability to interpret the condition and trend of natural resources and gives us the potential to yield information more useful than that of individual parts. Another important reason for better integration is the 1998 National Parks Omnibus Management Act (16 U.S.C. §5934 (2000)). This act instructed the secretary of the interior to undertake a program of inventory and monitoring of National Park System resources to establish baseline information and provide data on long-term trends in the condition of the National Park System. It also instructed the National Park Service (NPS) to develop monitoring programs in cooperation with other federal monitoring and information collection efforts to ensure a cost-effective approach.

What is meant by integration?

Integration is the act of bringing together disparate parts into a united, harmonious, or interrelated whole. As it applies to natural resources monitoring in the GYE, there are a number of ways for integration to happen. An obvious way is to interface and pool data across agency boundaries such that it is possible to interpret ecosystem health across a broad landscape.

Data collected in the NPS today need to meet national-level quality standards and need to be accessible for use in wise and defensible decisionmaking at all levels (Miller 2001). Land managers need to be able to share and aggregate their data with data from other adjacent agency lands to support landscape-level and national planning and policy formation. A primary basis of the NPS's Natural Resource Challenge (NPS 1999) initiative is the provision of scientifically credible information for informed decisionmaking.

However, pooling data into a common database does not in itself allow for meaningful interpretation. So what more should we consider when trying to integrate across boundaries?

Key factors to successful integration

Data management is a primary factor to consider when designing an integrated monitoring program. Steps can be taken to ensure that data collected by different agencies is comparable and that databases interface across agencies. There are also other important factors involving the ecological, spatial,

temporal, and programmatic aspects of a monitoring project. The NPS Inventory and Monitoring (I&M) Program (NPS 2005) has described the following forms of integration:

Ecological integration involves considering the ecological linkages among system drivers and the components, structures, and functions of ecosystems when selecting vital signs (a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources). An effective ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem. One approach for effective ecological integration is to select vital signs at various hierarchical levels of ecological organization (e.g., landscape, community, population, genetics; see Noss 1990).

Spatial integration involves establishing linkages of measurements made at different spatial scales within a national park or network of parks, or between individual park programs and broader regional programs (i.e., NPS or other national and regional programs). It requires understanding of scalar ecological processes, the co-location of measurements of comparably scaled monitoring indicators, and the design of statistical sampling frameworks that permit the extrapolation and interpolation of scalar data.

Temporal integration involves establishing linkages between measurements made at various temporal scales. It is necessary to determine meaningful timelines for sampling different indicators while considering characteristics of temporal variation in these indicators. For example, sampling changes in the structure of a forest overstory (e.g., size-class distribution) may require much less frequent sampling than that required to detect changes in the composition or density of herbaceous groundcover. Temporal integration requires nesting the more frequent and, often, more intensive sampling within the context of less frequent sampling.

Programmatic integration involves the coordination and communication of monitoring activities within and among parks, among divisions of the NPS Natural Resource Program Center, and among the NPS and other agencies, to promote broad participation in monitoring and use of the resulting data. Finally, there is a need for the NPS to coordinate monitoring, planning, design, and implementation with other agencies to promote data sharing among neighboring land management agencies, while also providing context for interpreting the data (NPS 2005).

Bridging state and federal agencies

Integration should be considered early in a monitoring program to ensure full consideration of the ecological, spatial, and temporal aspects of a monitoring design. However, even when considered early, there are cases and situations in which integration is not reasonable due to differing agency objectives and funding cycles. Agencies must recognize their common objectives and reconcile their differences—not only in regard to ongoing monitoring programs but also during the planning phases of new monitoring. In either case, the NPS I&M program has endorsed the development of well-written monitoring objectives as a prerequisite to monitoring design. Olsen et al. (1999 *in* Jean et al. 2005) noted that "Most of the thought that goes into a monitoring program should occur at this preliminary planning stage. The objectives guide, if not completely determine, the scope of inference of the study and the data collected, both of which are crucial for attaining the stated objectives." Once monitoring objectives are defined, the feasibility of integration with other parks and with adjacent lands to support landscape-level monitoring can be evaluated. In the NPS I&M program, monitoring objectives are written into monitoring protocols (Oakley et al. 2003) that are shared with neighboring agencies.

Monitoring protocols are detailed study plans that explain how data are to be collected, managed, analyzed, and reported (Oakley et al. 2003). They are an important requirement that enhances the NPS's ability to integrate data across state and federal agencies. Oakley et al. (2003) articulated four important reasons for taking the extra effort to complete a monitoring protocol:

> Monitoring protocols are 1) a key component of quality assurance for monitoring programs to ensure that data meet defined standards of quality with a known level of confidence, 2) necessary for the program to be credible so that data stand up to external review, 3) necessary to detect changes over time and with changes in personnel, and 4) necessary to allow comparisons of data among places and agencies.

Overcoming pitfalls and obstacles

A number of authors have described pitfalls and obstacles to sharing data and offered recommendations for overcoming these problems (NRC 1995). Starting with the presumption that "data worth collecting are worth saving," the National Resource

Council (NRC; NRC 1995) suggested setting aside 10% of a project's total cost for data management. This cost estimate should include adequate funds for preparing thorough metadata that service the needs of all potential users. The NRC recommended that efforts to establish data standards focus on a key subset of common parameters whose standardization will best facilitate data interfacing. Additionally, the data requirements, data characteristics and quality, and scales of measurement and sampling should be well defined at the outset. The NRC's investigations led it to identify 10 keys to successful data interfacing:

1. Be practical;
2. Use appropriate information technology;
3. Start at the right scale;
4. Proceed incrementally;
5. Plan for and build on success;
6. Use a collaborative approach;
7. Account for human behavior and motivation;
8. Consider needs of participants as well as users;
9. Create common needs for data; and
10. Build participation by demonstrating the value of data interfacing.

In another example, Steve Hale (1999) presented a tongue-in-cheek case for "managing data badly" in which he offered database managers 10 techniques to guarantee that no one would ever use their data. For example, "to avoid bias, metadata (information about data) should be written by people not familiar with the scientific discipline." In a follow-up commentary, Hale (2000) outlined similar techniques specific to scientists responsible for managing data, including a tip on avoiding tedious work by not verifying the accuracy of the data and skipping metadata altogether. Hale concluded (in earnest) with three basic things that managers could do better. These were to (1) place good quality data sets where they can be obtained, (2) make entries in data dictionaries so data sets can be found, and (3) write metadata files so data sets can be understood.

In all likelihood, the need for integration across state and federal agencies will grow as scientists and managers demand landscape and regional status and trend monitoring. Well-defined monitoring objectives and good data management will allow for integration and serve both today's and future land managers.

For more information on National Park Service monitoring guidelines, visit the I&M website at <http://science.nature.nps.gov/im/monitor/index.cfm>.

References

Hale, S. S. 1999. How to manage data badly (Part 1). *Bulletin of the Ecological Society of America* (October):265–268.

Hale, S. S. 2000. How to manage data badly (Part 2). *Bulletin of the Ecological Society of America* (January):101–103.

Jean, C., A. M. Schrag, R. E. Bennetts, R. Daley, E. A. Crowe, and S. O'Ney. 2005. *Vital signs monitoring plan for the Greater Yellowstone Network*. Bozeman, Mont.: National Park Service, Greater Yellowstone Network.

Miller, A. B. 2001. Managing data to bridge boundaries. Pages 316–320 *in* D. Harmon, ed., *Crossing boundaries in park management*. Proceedings of the 11th Conference on Research and Resource Management in Parks and on Public Lands. The George Wright Society Biennial Conference, Denver, Colorado, April 16–20, 2001. Hancock, Mich.: The George Wright Society.

National Park Service (NPS). 1999. *Natural Resource Challenge: the National Park Service's action plan for preserving natural resources*. Washington, D.C.: National Park Service.

National Park Service (NPS). 2005. Guidelines for monitoring natural resources in our national parks. <http://science.nature.nps.gov/im/monitor/index>.

National Research Council (NRC). 1995. *Finding the forest in the trees: the challenge of combining diverse environmental data*. Washington, D.C.: National Academy Press.

Noss, R. F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4:355–364.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. *Wildlife Society Bulletin* 31:1000–1002.

Olsen, A. R., J. Sedransk, D. Edwards, C. A. Gotway, W. Liggett, S. Rathbun, K. H. Reckhow, and L. J. Wong. 1999. Statistical issues for monitoring ecological and natural resources in the United States. *Environmental Monitoring and Assessment* 54:1–45.

Progressivism Comes to Yellowstone: Theodore Roosevelt and Professional Land Management Agencies in the Yellowstone Ecosystem

Jeremy Johnston

Northwest College, 231 West 6th St., Powell, WY 82435
(307-754-6008, jeremy.johnston@northwestcollege.edu)

Abstract

This paper will examine Theodore Roosevelt's involvement in the creation of professional governing agencies to manage the Yellowstone ecosystem in the spirit of progressivism. Throughout the Progressive Era, many professional governing agencies were created to regulate the basic economic and social needs of the American nation. This movement was evident during the administration of Theodore Roosevelt and would have a lasting impact on the Yellowstone ecosystem. In 1905, Theodore Roosevelt and Gifford Pinchot created the U.S. Forest Service (USFS). The following year, Roosevelt appointed retired army general S. B. M. Young, the park's first civilian superintendent since the U.S. Cavalry assumed the management of Yellowstone. Roosevelt instructed Young to work on plans to create a civilian park guard; however, Roosevelt later rejected this idea, and with Pinchot's support, planned to place Yellowstone National Park under USFS control. This idea was unsuccessful, however, and Yellowstone remained under military supervision until the creation of the National Park Service in 1916 (an agency that Roosevelt fully supported). The attempt to organize land management agencies for Yellowstone reflects the efforts of Progressives to create professional agencies to handle governmental issues such as the management of federal lands. By examining the origins of the USFS and the National Park Service in relation to the Progressive Era and the Roosevelt Administration, we can understand the commonality of these two differing agencies that share the task of managing the Yellowstone ecosystem.

Introduction

Throughout the Progressive Era, many professional governing agencies were created to regulate the basic economic, social, and political needs of the American nation. This movement toward professional federal government agencies was evident during the administration of Theodore Roosevelt (1901–1909), and left a lasting impact on the Yellowstone ecosystem. In 1905, Roosevelt placed the nation's forest reserves under the direct supervision of Gifford Pinchot and created the modern U.S. Forest Service (USFS). In the following year, Roosevelt appointed retired army general Samuel Baldwin Marks Young to be the first civilian superintendent of Yellowstone National Park to serve in that position since the U.S. Cavalry had assumed the management of Yellowstone in 1886. Roosevelt instructed Young to work on plans for a civilian park guard that would manage the park; however, Roosevelt later rejected this idea and, with Pinchot's support, planned to place Yellowstone under forest service control. This idea was unsuccessful, however, and the park remained under military supervision after Roosevelt's term of office ended. Roosevelt's hand-picked successor, William H. Taft, continued to support the creation of a civilian park guard, but the park remained under military control until the creation of the National Park Service in 1916, under the administration of Roosevelt's political opponent, Woodrow Wilson. Roosevelt fully supported the creation of a civilian park guard, even if it was achieved during Wilson's term of office.

Roosevelt's efforts to create a civilian park guard, and his later support of the National Park Service (NPS), reveal a side of the president that is rarely revealed in the history of the environmental movement. Many historians and environmental writers have classified Roosevelt as a conservation-minded environmentalist who argued for scientific use of the land—not as a preservation-minded environmentalist who favored protection of the aesthetic landscape. Roosevelt's involvement in the creation of the NPS and USFS, however, clearly indicated that he supported not only the conservation movement as advocated by Gifford Pinchot, but also the preservation movement as advocated by John Muir. Theodore Roosevelt can not be characterized as a sole supporter of any side of the early environmental movement in the Progressive Era.

Urbanization and its impact on the West

The forces that would transform the administration of Yellowstone National Park did not emerge in the canyons of the Yellowstone River, but within the canyons of the tenements, factories, and mansions lining the streets of the nation's rapidly expanding eastern cities. In the aftermath of the Civil War, America's economy shifted away from rural agriculture and toward the industry concentrated in the nation's urban centers. Having profited from the production of munitions and other materials during the Civil War, small factories grew into major international corporations, trusts, and monopolies that dominated the American economy. The tentacles of these massive corporations, in the form of railroad tracks, reached deep into the American West to devour its vast natural resources (Cashman 1984; Painter 1987; Summers 1997; Trachtenberg 1982; Wiebe 1967).

Eventually, only small pools of America's wilderness remained, one of which was the Yellowstone ecosystem. Congress offered some protection to this area in 1872, by setting aside Yellowstone National Park as a "pleasuring ground for the benefit and enjoyment of the people." Congress took another major step toward saving the natural resources of the West with the passage of the Forest Reserve Act of 1891, which granted presidential authority to establish national forest reserves. That year, President Benjamin Harrison used this newly acquired power to set aside the Yellowstone Park Timberland Reserve, expanding federal protection of the Yellowstone ecosystem to the south and east of Yellowstone National Park.

Unfortunately, the new political status of these lands did not mean they were spared from demands on the resources within them. Timber disappeared in fires started by careless tourists and at the hands of timber thieves. Wildlife numbers declined from market hunting. Geysers and hot springs fell prey to visitors who collected natural specimens for souvenirs, soaped the geothermal features for entertainment, and slaughtered countless numbers of wildlife and fish for their meals. Developers claimed large tracts of land and constructed various grades of concessions to profit from the increasing numbers of visitors to the region. Due to the lack of a professional land management agency or police force, visitors, market hunters, and developers continued their despoliation of the lands for personal gain at great expense to the natural features of the region (Bartlett 1985; Haines 1977 v1; Schullery 2004).

Theodore Roosevelt fully understood the transformation brought on by the shift from agronomy to industry, as well as its impact on the demand for natural resources, writing:

> The growth of this nation by leaps and bounds . . . has been due to the rapid development, and alas . . . to the rapid destruction of our natural resources. Nature has supplied to us in the United States . . . more kinds of resources in a more lavish degree than has ever been the case at any other time or with any other people. Our position in the world has been attained by the extent and thoroughness of the control we have achieved over nature; but we are more, and not less, dependent upon what she furnishes than at any previous time of history since the days of primitive man (Roosevelt 1927 v16, 121–122).

Another emergent force from the eastern cities that would impact the management of the Yellowstone ecosystem was the political corruption and ineptitude arising from machine politics, known as the "spoils system." Before the age of civil service, government representatives did not hire or appoint employees on the basis of their skills, education, or previous employment; rather, it was a job candidate's political connections that were important. A lack of secret ballots clearly identified supporters and non-supporters, allowing the bosses to reward voter support with patronage positions. The spoils system also had a hold on the federal government—especially the executive offices (under presidential authority) that managed the newly created federal public land reserves—which helped ensure that the management of federal lands in the Yellowstone ecosystem would not be very effective. Presidents and their cabinet members rewarded their political supporters with patronage positions while non-supporters—even individuals within their own political parties—were fired regardless of their management skills, knowledge of the areas they were charged with protecting, or previous service.

Leaders of industry quickly realized how to use this system to their advantage, promoting their own economic goals via machine politics and increasing their monopolistic hold on the nation. For instance, Crédit Mobilier, a "dummy" construction company associated with the Union Pacific Railroad, was used to bilk millions of dollars out of the federal government coffers under the Pacific Railway Act. It became the center of public attention when a key stockholder, Congressman Oakes Ames, used Crédit Mobilier stock to influence the passage of

favorable legislation. The Crédit Mobilier scandal clearly reflected the power and control that large corporations wielded over both the legislative and executive branches of the federal government, and railroads used this influence to expand their hold on the West. This was never more evident than in the Northern Pacific Railroad's attempts to direct the creation and future of Yellowstone National Park and the surrounding region (Runte 1990).

Many of Yellowstone's early civilian superintendents, appointed by the secretary of the interior under the spoils system, came from territorial offices that were ripe with incompetent or corrupt appointees. Often, these appointees also had strong political and economic ties to the railroad corporations. Yellowstone's first superintendent, Nathaniel P. Langford, who enjoyed strong Republican connections and was a former territorial officer from Montana, clearly served the Northern Pacific Railroad's interest more than the public's interest. In fact, after the construction of the Northern Pacific stalled due to the collapse of Jay Cooke's finances (precipitating the Panic of 1873), Langford essentially abandoned his position as park superintendent. During his tenure, Langford visited Yellowstone only one time (Bartlett 1985; Haines 1977 v1; Langford 1972; Schullery 2004).

Patrick H. Conger, Yellowstone's third superintendent, reflected the ineptitude fostered by the spoils system. Early park historian Hiram Chittenden noted, "Of this Superintendent, it need only be said that his administration was throughout characterized by a weakness and inefficiency which brought the Park to the lowest ebb of its fortunes, and drew forth the severe condemnation of visitors and public officials alike" (Chittenden 1964, 112). Conger and the assistant secretary of the interior allowed the Northern Pacific (which finally completed its tracks in the early 1880s), operating under the guise of the Yellowstone Park Improvement Company, to claim thousands of acres in government leases and establish monopolistic control over the main attractions of the park. This company also began logging operations and slaughtered wildlife to feed its workers.

In 1884, Robert E. Carpenter replaced Conger as superintendent of Yellowstone through the political connections of his brother, who was the governor of Iowa. According to Chittenden, the new superintendent viewed Yellowstone National Park as "an instrument of profit to those who were shrewd enough to grasp the opportunity. Its protection and improvement were matters of secondary consideration" (Chittenden 1964, 116). Carpenter attempted to further the hold of the Northern Pacific Railroad on the park by lobbying for some of the lands within its boundaries to be opened for private occupancy by the railroad.

The forest reserves also suffered under the spoils system. In 1880, the Division of Forestry, led by Franklin Hough, was created under the Department of Agriculture with the purpose of making recommendations regarding the administration of the national forest reserves, which at that time were under the domain of the Department of the Interior (Steen 1991). Three years later, the capable Hough was replaced by Dr. N. H. Egleston, whom famed forester Gifford Pinchot described as "one of those failures in life whom the spoils system is constantly catapulting into responsible positions" (Pinchot 1947, 135).

Pinchot also noted many problems within the Department of the Interior, one in particular: "Since jobs on the Forest Reserves were for distribution to politicians, Commissioner Binger Hermann of the General Land Office was careful to get his while the getting was good. The average appointee was plenty bad enough, but Binger's personal appointments were horrible," he wrote (Pinchot 1947, 162). Pinchot went on to describe numerous instances of incompetent employees hired under the spoils system. Many forest supervisors, hired due to nepotism and patronage, were too old, frail, corrupt, and ignorant of forestry to perform the basic tasks required of their positions. "An elderly man," wrote Pinchot, "who had been cashier in a bank, was a close friend of the Commissioner. He frankly admitted he had no knowledge of forest conditions and didn't know one tree from another. But Binger made him Forest Inspector, the most important and responsible post of all" (Pinchot 1947, 163–164).

Influential congressmen also forced their appointees onto forest reserves. "Uncle" Joe Cannon, Speaker of the House, appointed several men whom Pinchot deemed ineffective; he described one individual as "a one-lunger with one leg" (Pinchot 1947, 164). Some appointees collected paychecks from the Department of the Interior without setting foot onto the forest reserves. Pinchot summed up the effect of these supervisors and rangers:

> Take it by and large, the Interior Department's field force on the Forest Reserves was enough to make angels weep. Naturally it aroused strong opposition to the whole Reserve System. However lightly the Western men

> of those days may have held the land laws, they had high standards of personal courage and hardiness, and they were not lazy. Such men could have nothing but contempt for a service manned by the human rubbish which the Interior Department had cheerfully accepted out of Eastern and Western political scrap heaps and dumped into the Forest Reserves (Pinchot 1947, 167).

Surprisingly, some effective individuals were appointed to Yellowstone National Park and the Yellowstone Timberland Reserve. Famed artist and rancher A. A. Anderson, placed in charge of the Yellowstone Timberland Reserve, was one such supervisor. Anderson limited grazing on the forest lands, worked to enlarge the boundaries of the reserve, and established an efficient administrative organization to manage the vast lands under his control. Anderson later recalled,

> Gifford Pinchot, after accompanying me on a tour of inspection, reported to the President that the Yellowstone Reserve was one of the best organized, patrolled and managed forest reserves in the country. It was indeed gratifying to receive a letter from President Roosevelt saying in part: 'Mr. Anderson, I believe you have the right ideas in forestry matters. Go ahead and carry them out, knowing you have the Department of the Interior and the President solidly behind you' (Anderson 1927, 385).

Likewise, Philetus W. Norris served as an effective superintendent of Yellowstone. Norris explored and mapped new areas in the park, studied the park's geological and archeological resources, wrote the park's first detailed set of rules and regulations, and attempted to establish a functional administrative organization to manage the park. Norris's administration made significant strides in protecting Yellowstone; unfortunately, Norris soon ran afoul of the Northern Pacific Railroad's interests in the park, and of local residents who were angered by Norris's involvement in changing a mail route. Norris's political enemies moved quickly to replace him with Patrick Conger, who quickly demonstrated his intentions to promote the railroad's interests in Yellowstone.

It should be noted that both Anderson and Norris were unusual public servants for their time, being wealthy men who did not need a government salary in order to survive. Both were well-connected politically, although a political struggle cost Norris his job. Their most unusual characteristic, however, was that they both had a strong personal desire to protect the lands under their direct supervision. This was especially true of Anderson, whose ranch bordered the forest reserve—a fact that may have increased his motivation (Anderson 1933; Haines 1977; Schullery 2004).

Congress provided some legislative protection to the Yellowstone ecosystem under the spoils system, but it tended only to respond to blatant problems, rather than providing preventive measures to avoid future problems. This process was slow and relied on active individuals and organizations, such as the Boone and Crockett Club, to identify the problems and lobby for legislative action (Haines 1977 v1; Reiger 1975). For instance, when the Yellowstone Park Improvement Company moved to establish a monopoly over Yellowstone during Patrick Conger's administration, General Phil Sheridan generated enough publicity that Congress made provisions under the Sundry Civil Appropriations Bill of 1883 to limit the size of leases. More importantly, the bill contained a provision wherein the U.S. military could assume the management of Yellowstone upon the request of the secretary of the interior. When Congress subsequently failed to appropriate any funds for the management of Yellowstone in 1886, the U.S. Cavalry was sent to the park. When a writer from *Forest and Stream,* the literary voice of the Boone and Crockett Club, reported on a blatant case of poaching in Yellowstone, Congress responded with passage of the Lacey Act. The Lacey Act established fines and penalties to punish poachers in Yellowstone, as well as a court system to prosecute accused poachers and other criminals. In 1894, Congress created further provisions restricting leases and their operations within Yellowstone National Park with the passage of the Hayes Act (Chittenden 1964; Haines 1977 v1).

Machine politics impacted federal management of the Yellowstone ecosystem through the end of the nineteenth century. Fortunately, the U.S. Cavalry protected the park from most of its immediate threats. The Yellowstone Timberland Reserve, however, endured mismanagement under the spoils system until Theodore Roosevelt became president and expanded Pinchot's authority over the forest reserves.

The Progressives and the creation of professional government agencies

While the spoils system negatively impacted the Yellowstone ecosystem, another force from the cities brought positive change to the region:

Progressivism. The Progressive Movement emerged as a combination of a number of reform movements that were active in the 1870s and 1880s. These groups included urban reformers, women's suffragists, members of the Populist Party, and prohibitionists. Beginning in the 1890s, middle-class America fought to save American capitalism from the unregulated industrialists, the corrupt spoilsmen, and the radical labor union leaders who threatened social revolution. The Progressives adopted many reforms from earlier political movements—especially the Populist Movement—as their own and pushed them onto the national scene as a collective political movement (Cashman 1984; Chambers 1992; Cooper 1990; Diner 1998; Gould 2001; Hofstadter 1955; Link and McCormick 1983; McGerr 2003; Painter 1987; Summers 1997; Sullivan 1996; Trachtenberg 1982; Wiebe 1967).

Progressive reforms included the end of the spoils system and the tight control held by political bosses, through increased and uninhibited political participation of the electorate. Democratic reforms such as initiatives and referendums allowed more direct participation in the creation of legislation. The electorate was expanded through women's suffrage, and the use of the secret ballot prevented party bosses from knowing who voted for which party and which candidates. Progressives also hoped to replace the inept political officeholders appointed under the spoils system by creating both a merit system guided by a civil service process and strong executive federal powers that bypassed the kinds of legislative political squabbles that were responsible for slowing administrative responses to social problems. Progressives strongly advocated the creation of more professional government bureaucracies staffed with professionals appointed on the basis of their educational background and work skills instead of their political connections. Progressives hoped that these professional government employees would successfully manage much-needed social and economic reforms as well as the conservation of public lands.

Progressives successfully implemented many of these reforms at various local levels of government. After a major hurricane destroyed the city of Galveston, Texas, in 1900, killing at least 6,000 people, its citizens created a commission of professional city administrators to assume the duties and responsibilities of an elected mayor. The movement to create more professional governing agencies also took hold at the state level and became popularly known as the "Wisconsin Idea." The "Wisconsin Idea" was the brainchild of Wisconsin governor Robert "Battling Bob" LaFollette, who recruited a "brain trust" from the University of Wisconsin to help his administration address the new demands placed on the state by the rise of urbanization and industrialism.

At the same time when local and state governments desired to increase professional standards, many occupational fields increased their level of professionalism through licensing and self-regulation administered by professional associations. Doctors, for instance, began to rely more and more on the American Medical Association for licensing standards and guidelines. Lawyers, engineers, and other professionals also developed closer working relationships with their respective associations. By virtue of their licensing processes, those associations also assumed more authority within government. One association that greatly benefited from the closer relationship of government and professional agencies was the American Forestry Association (AFA), founded in 1875. The AFA enjoyed political influence throughout the Progressive Era by working with the forest reserves and later, the USFS (Diner 1998).

Theodore Roosevelt praised the Progressives and their efforts to alleviate America's political, social, and economic problems, likening them to America's pioneers. In a 1910 article for *The Outlook*, he expressed his hope that the spirit of Progressivism could also address resource conservation:

> The same qualities that have enabled Americans to conquer the wilderness, and to attempt tasks like the building of the Panama Canal and the sending of the battle fleet around the world, need to be applied now to our future problems; and these qualities, which include the power of self-government, together with the power of joining with others for mutual help, and, what is especially important, the feeling of comradeship, need to be applied in particular to that foremost of national problems, the problem of the preservation of our natural resources.
>
> The question has two sides. In the first place, the actual destruction, or . . . at any rate the needless waste, of the natural resources must be stopped. In the second place . . . these resources must be kept for the use of the whole people, and not handed over for exploitation to single individuals or groups of individuals (Roosevelt 1927 v16, 23–24).

Indeed, the conservation movement benefited

greatly from the end of the spoils system and the creation of professional land management agencies, brought about because many Progressives feared that continued waste and mismanagement of America's natural resources would spell an end to the United States. George Perkins Marsh's 1864 book, *Man and Nature,* strongly influenced this sense of doom, painting a gloomy picture for the future of the U.S. if its natural resources continued to disappear. The goal of Marsh's book was "to indicate the character and, approximately, the extent of the changes produced by human action in the physical conditions of the globe we inhabit; to point out the dangers of imprudence and the necessity of caution in all operations which, on a large scale, interfere with the spontaneous arrangements of the organic or the inorganic world." Marsh hoped his book would "suggest the possibility and the importance of the restoration of disturbed harmonies and the material improvement of waste and exhausted regions; and, incidentally, to illustrate the doctrine, that man is, in both kind and degree, a power of higher order than any of the other forms of animated life, which, like him, are nourished at the table of bounteous nature" (Marsh 2003). To demonstrate his points, Marsh examined the decline of ancient civilizations in connection with environmental destruction. He also compared these ancient civilizations to events that were occurring in modern nations across the globe.

Theodore Roosevelt: conservationist and preservationist

An assassin's bullet brought Progressivism to the federal arena. On September 6, 1901, President William McKinley, a conservative Republican with strong ties to the industrial giants of his age, was shot and fatally wounded by Leon Czolgosz at the Pan-American Exposition in Buffalo, New York. After lingering for a few days, McKinley passed away and Theodore Roosevelt became the next president of the United States. Roosevelt received the news of McKinley's declining condition during a hunting trip in the Adirondack Mountains—a portentous setting, given that his administration would do more to save the wilderness areas of North America than any presidency before or since. Unfortunately, Roosevelt's conservation record is often boiled down to numbers, and not enough historians have gone beyond those numbers to examine his other contributions to the movement. The numbers, however, are indeed impressive. During Roosevelt's term of office, 150 forest reserves, 51 federal bird preservations, 18 national monuments, 5 national parks, and 4 national game preserves were established—a total of more than 230 million acres. This amounted to 84,000 acres set aside per day of Roosevelt's administration (Gable 1984).

Roosevelt later reflected on the reasons why he supported conservation during his administration. His remarks reflected concerns similar to those of Marsh:

> I have always been fond of history and of science, and what has occurred to Spain, to Palestine, to China, and to North Africa from the destruction of natural resources is familiar to me. I have always been deeply impressed with [Justus von] Liebig's statement that it was the decrease of soil fertility, and not either peace or war, which was fundamental in bringing about the decadence of nations. While unquestionably nations have been destroyed by other causes, I have become convinced that it was the destruction of the soil itself which was perhaps the most fatal of all causes. But when, at the beginning of my term of service as President, under the influence of Mr. Pinchot and Mr. [Frederick H.] Newell, I took up the cause of conservation, I was already fairly well awake to the need of social and industrial justice; and from the outset we had in view, not only the preservation of natural resources, but the prevention of monopoly in natural resources, so that they should inhere in the people as a whole (Roosevelt 1927 v17, 317).

Roosevelt's conservation record has sometimes been unjustly characterized as demonstrating an attempt to instill conservation policies at the expense of preservation policies. The growing split between the two sides became evident during Roosevelt's administration, but was more reflective of the attitudes and beliefs of Gifford Pinchot and John Muir than those of Roosevelt, himself. These two men and their ideas came to the public forefront during a clash over the future of a reclamation project located within the boundaries of Yosemite National Park. As the city of San Francisco expanded, developers searched for ways to improve the water supply into the city. The major fire resulting from the San Francisco earthquake of 1906 greatly intensified the clamor to bring an effective water system to the city, even if it came at the expense of damming Yosemite's scenic Hetch Hetchy Valley. Roosevelt deeply believed in preserving the national parks, but also could not turn his back on San Francisco's water problem. He asked the city to search for another dam site, but when

none was found, Roosevelt hesitatingly indicated his support for the dam to be constructed in Yosemite. He later told Robert Underwood Johnson, editor of *Century Magazine* and a strong opponent of the dam, that the decision to support Hetch Hetchy was one that he extremely doubted. Still, the damage was done, and the conservation movement split into two opposing factions, the conservationists under Pinchot and the preservationists under Muir. The issue of Hetch Hetchy was finally settled when President Woodrow Wilson signed the bill authorizing the construction of the dam within Yosemite (Huth 1990; Nash 1967).

Theodore Roosevelt's involvement in the Hetch Hetchy controversy has clouded many interpretations of his conservation and preservation work. Often overlooked, for example, is that his administration brought progressive reform to the Yellowstone ecosystem by creating the professional land management agencies that continue to administer our public lands today. Roosevelt took considerable personal interest in the Yellowstone region, which helped motivate his desire to properly protect both the lands within the Yellowstone Timberland Reserve and Yellowstone National Park through professionalization of their management. He became acquainted with the problems impacting the region through his connections with famed naturalist writer George Bird Grinnell. Together, the two men formed the Boone and Crockett Club and dedicated its membership to the protection of the Yellowstone National Park. They campaigned to end poaching in the park and fought attempts by the railroads to build inside its boundaries.

Roosevelt visited the region on two separate trips in 1890 and 1891. The first trip was a sightseeing expedition with his wife and sister, both of whom he entertained by pretending to be a bear late at night. The second trip was an elk hunting expedition near the Two Ocean Pass area, south of Yellowstone National Park. Through his visits to Yellowstone and his work with the Boone and Crockett Club, Roosevelt came to see Yellowstone as a wilderness preserve and wildlife refuge (Benson 2003; Collins 1989; Cutright 1985; Cutright 1956; Johnston 2004a; Johnston 2004b; Johnston 1993; Parsons 1993; Reiger 1972; Reiger 1975; Schullery 1978; Ward 1993; Ward and McCabe 1988).

Roosevelt and the creation of professional land management agencies

To preserve the Yellowstone ecosystem and to protect and properly manage its natural resources, Roosevelt needed to create a professional government agency. Roosevelt realized that the military was not the appropriate organization for the task, and that the spoils system had led to ineffective land management. His background made him well suited to create an agency to remedy the situation. In the 1880s, President Harrison had appointed Roosevelt to the Civil Service Commission. Democratic president Grover Cleveland had kept Roosevelt, a Republican, working on the commission during his administration. This experience allowed Roosevelt a close view of the inefficiency of the spoils system and the benefits of a merit system accomplished by civil service reform.

After his stint on the Civil Service Commission, Roosevelt had served as New York City Police Commissioner. As commissioner, Roosevelt continued to advocate governmental reform and worked tirelessly to create a more professional standard of law enforcement for the New York Police Department. He advocated testing police candidates, pushed for the creation of an academy to promote specialized training in law enforcement, supported new technological advances in law enforcement, and recommended physical and pistol training for policemen. Roosevelt's efforts represented the beginnings of modern professional law enforcement.

Later, as governor of New York, Roosevelt pushed for the modernization of the New York Fisheries, Forest, and Game Commission. Working with Gifford Pinchot and Frederick H. Newell, future director of the Bureau of Reclamation, Roosevelt worked to preserve forests, game, and fish within New York State. He urged the recruitment of professional foresters and game wardens to achieve this goal (Roosevelt 1913, 323–325). In his 1900 annual address, Governor Roosevelt praised the commission for its achievements and urged the New York Assembly to continue its support, echoing the words of the Yellowstone National Park Organic Act: "The subject of forest preservation is of the utmost importance to the State. The Adirondacks and Catskills should be great parks kept in perpetuity for the benefit and enjoyment of the people" (Roosevelt 1927 v15, 54).

Roosevelt also recognized the connections between a strong "national character" and scientific conservation of water, game, and timber. A forest, for instance, was a

> . . . great sponge which absorbs and distils the rain-water; and when it is destroyed the

> result is apt to be an alternation of flood and drought. Forest-fires ultimately make the land a desert. . . . Every effort should be made to minimize their destructive influence. We need to have our system of forestry gradually developed and conducted along scientific principles. When this has been done it will be possible to allow marketable lumber to be cut everywhere without damage to the forests. . . .

Forests also offered valuable habitat for a variety of game, as well as opportunities for recreational activity:

> A live deer in the woods will attract to the neighborhood ten times the money that could be obtained for the deer's dead carcass. . . . Hardy outdoor sports, like hunting, are in themselves of no small value to the national character, and should be encouraged in every way. Men who go into the wilderness, [or] . . . who take part in any field-sports with horse or rifle, receive a benefit which can hardly be given by even the most vigorous athletic games (Roosevelt 1927 v15, 54).

To accomplish these goals, Roosevelt recommended that greater numbers of professional game wardens be trained and hired, and that "none save fit men must be appointed and their retention in office must depend purely upon the zeal, ability, and efficiency with which they perform their duties" (Roosevelt 1927 v15, 53–54).

Upon assuming the presidency, Roosevelt quickly began working on the creation of a professional land management agency for the conservation and preservation of the national forest reserves and their vast natural resources. He recommended the transfer of the forest reserves to the Department of Agriculture and requested that certain areas of forest reserves be set aside as game preserves. Roosevelt also recommended the promotion of public recreation within the forests and parks by establishing free campgrounds "for the ever-increasing numbers of men and women who have learned to find rest, health, and recreation in the splendid forests and flower-clad meadows of our mountains. The forest reserves should be set apart forever for the use and benefit of our people as a whole and not sacrificed to the short-sighted greed of a few," he wrote (Roosevelt 1927 v15, 102–104). In his second annual message, delivered on December 2, 1902, Roosevelt again recommended legislation for the protection of big game on forest reserves—especially for elk, which were being slaughtered for their antlers (Roosevelt 1927 v15, 161).

In 1903, Roosevelt visited Yellowstone National Park as part of a larger western tour. The few days he spent in the park offered Roosevelt the opportunity to examine its management under the U.S. Army. Famed naturalist writer John Burroughs, who accompanied Roosevelt on this visit, noted, "Near the falls of the Yellowstone, as at other places we had visited, a squad of soldiers had their winter quarters. The President called on them, as he had called upon the others, looked over the books they had to read, examined their housekeeping arrangements, and conversed freely with them" (Burroughs 1907, 72–73).

This may have been when Roosevelt became concerned regarding the future management of Yellowstone and began formulating ideas for replacing the military police force with a professional civilian agency. Perhaps Roosevelt noted in his visits the conditions that S. B. M. Young would note later, in 1907:

> [In Yellowstone,] regimental and squadron organizations are not only disturbed, but the troop organization is largely demoralized by subdividing the men into small parties far separated for indefinite periods of time without the personal supervision of an officer. . . . The enlisted men . . . are not selected with special reference to the duties to be performed in police patrolling, guarding, and maintaining the natural curiosities and interesting 'formations' from injury by the curious, the thoughtless, and the careless people who compose a large percentage of the annual visitors in the park, and in protecting against the killing or frightening of the game and against forest fires (Young 1907, 25).

In the national forests, Roosevelt recommended more professionalism from the rangers appointed to watch over them. In a letter to a former Rough Rider and newly appointed forest ranger, Roosevelt outlined the qualities he desired in such men: "You have been appointed a Forest Ranger," wrote Roosevelt.

> Now, I want . . . very seriously to impress upon you that you have got to do your duty well, not for your own sake, but for the sake of the honor of the [Rough Rider] regiment. I recommended you because under me you showed yourself gallant, efficient and obedient. You must continue to show these qualities in the government service exactly as you did [in] the regiment. You must let no

> consideration of any kind interfere with the performance of your duty. You are to protect the government's property and the forests and to uphold the interests of the department in every way. Now, remember that I expect you to show yourself an official of far above the average type; and you are to stand or fall strictly on your merits (Roosevelt 1951 v3, 130).

In Roosevelt's fourth annual message, December 6, 1904, the president praised the Department of Agriculture for its development into an educational institution with 2,000 specialists advocating forestry practices for the forest reserves, and stressed that the reserves, themselves, needed to be moved to Department of Agriculture, where the knowledge and skills were located. "I have repeatedly called attention to the confusion which exists in government forest matters because the work is scattered among three independent organizations. The United States is the only one of the great nations in which the forest work of the government is not concentrated under one department, in consonance with the plainest dictates of good administration and common sense," said Roosevelt (Roosevelt 1927 v15, 237). Roosevelt noted that the results of the transfer would be better forest work; forests would be handled by men in the field, and forests would become self-supporting. He also emphasized the need to maintain public lands as game refuges, recommended that continued support be given to preserving Yellowstone wildlife, and urged that the park's boundaries be expanded southward and that additional parks be added to the system to provide more protected habitat to wildlife.

As Roosevelt began his second term in office, he continued arguing for the professional management of federal lands. In his fifth annual message, December 5, 1905, Roosevelt commended the new U.S. Forest Service and noted that through this agency, the usefulness of the forest reserves greatly expanded. Roosevelt also suggested the transfer of the national parks to the new forest service, so the parks could benefit from the protection of the new agency (Roosevelt 1927 v15, 315). Roosevelt continued pushing for new national parks, arguing that Yosemite should be accepted from the state of California and the Grand Canyon should be set aside as a national park, and again argued that parks were necessary wildlife refuges. He proposed bringing back buffalo, through parks or refuges, for economic interests, and again called for the expansion of Yellowstone National Park's boundaries to the south and to the east for the protection of winter ranges for elk (Roosevelt 1927 v15, 326–327).

Congress finally responded to Roosevelt's wishes regarding the forest reserves by passing legislation that provided for the transfer of 63 million acres of forest land from the Department of the Interior to the Bureau of Forestry under Gifford Pinchot in the Department of Agriculture. The lands were officially transferred on February 1, 1905. Later that same year, the Bureau of Forestry changed its official title to the United States Forest Service, and Pinchot began expanding an agency staffed with professional foresters and rangers to carry out the responsibilities of managing the forest reserves:

> Supervisors and Rangers are appointed only after civil-service examinations. They must be residents of the State or Territory in which the National Forest is situated and between the ages of 21 and 40. . . . The life a man has led, what is his actual training and experience in rough outdoor work in the West, counts for more than anything else. Lumbermen, stockmen, cowboys, miners, and the like are the kind wanted. Forest Guards are appointed from those who have passed the ranger examination (Pinchot 1907).

Throughout the remainder of his term, Roosevelt continued calling for the increased protection of the forest reserves and national parks. In his sixth annual message, December 3, 1906, Roosevelt noted the progress being made to benefit the West with irrigation and forest preservation through his conservation programs, and called for the further expansion of forest reserves (Roosevelt 1927 v15, 376). In 1907, Congress responded negatively, with legislation preventing the president from setting aside any further forest reserves, now called national forests, in six western states. Roosevelt signed the legislation only after he set aside a great number of new reserves, many of which further protected the Yellowstone ecosystem.

In 1907, Major John Pitcher, who was Roosevelt's friend and Yellowstone's acting superintendent, retired from military service, thus creating an opening for the position of park superintendent. Roosevelt viewed Pitcher's retirement as an opportunity to create a professional agency, similar to the USFS, to manage Yellowstone National Park. To achieve this goal, Roosevelt appointed the first civilian superintendent of Yellowstone to serve since the military had begun to manage the park in 1886. Roosevelt's replacement was his old friend and fel-

low officer from the Spanish–American War, Samuel Baldwin Marks Young. In the Civil War, Young rose from the status of private in the Pennsylvania Infantry to general in the Pennsylvania Calvary. After the war, he was reassigned to military campaigns against American Indians in the West. Young was appointed acting superintendent of Yellowstone Park in 1897, but served in that position for only a few months (Haines 1977 v2). In 1904, Young retired from the military after a successful career. Because Young had previous experience with the position of superintendent, Roosevelt wanted him back in the park.

With Young's acceptance ("I am always ready to be of service to you and your administration," he told Roosevelt, "and the proper maintenance and protection of the Yellowstone park and wildlife is of much interest to me"), the position of park superintendent reverted back to civilian control (Roosevelt Papers, 3/28/1907). Choosing a former military man with previous experience in the position was wise on the part of Roosevelt, as it smoothed the transition from military enforcement to civilian control. Young was also a good friend of Roosevelt's, which made it possible for Roosevelt to influence park policy.

Young's main task as superintendent was to oversee the transfer of power from military to civilian control. In a letter to William Loeb, the president's secretary, Young presented his "scheme for the organization of a . . . 'National Park Guard'" (Roosevelt Papers, 9/7/1907). His proposal called for a chief inspector, four assistants under the inspector, and 20 full-time men, with an additional seasonal crew of 15 men in the summers. In addition, Young wanted to hire a clerk, a buffalo keeper and assistant, a blacksmith, and a driver. Young estimated the annual cost of the new civilian force to be $50,000. That figure excluded his salary as superintendent, which he agreed to waive, and Young called it a bargain: "the cost of maintaining the troops here far exceeds the amount estimated as the cost of maintaining a park guard," he wrote (Roosevelt Papers, 9/7/1907).

In December 1907, Roosevelt wrote to Young supporting his idea of an independent park guard, which Roosevelt wanted to be administered by the U.S. Forest Service (Roosevelt Papers, 12/11/1907). The president expressed regret that he could not make anything happen before the end of the year; he wanted to wait until he could find a congressman willing to sponsor the move—possibly Senator Thomas H. Carter from Montana (Roosevelt Papers, 12/11/1907).

During the following summer, an event transpired that caused Roosevelt and Young to press even harder for a civilian park force. On August 24, 1908, 17 stagecoaches were held up, and the passengers robbed. The perpetrator had waited until the cavalry patrol, traveling in front of a line of 25 stages, had passed, then proceeded to hold up stage after stage. The passengers, angered over their losses, met at the Lake Hotel to voice their concerns over the inability of the military to keep gun-toting bandits out of the park. They also expressed anger at the soldiers' inability to catch the criminal responsible for the act. In concluding the meeting, the victims drew up a petition demanding that the government reimburse them for losses of more than $2,100. They also criticized the army's effectiveness at policing the park; thus, the military came under close public scrutiny (Haynes 1959, 15–20). When Young informed the president of the situation, Roosevelt responded, "I am sorry to say that it simply strengthens the impression that I had already gained. I fear that the only solution is to take the army out of the Park and have rangers of the [James] McBride [a civilian park scout] type do all the work" (Roosevelt Papers, 9/12/1908). In a following letter, Roosevelt re-emphasized his desire to establish a national park guard under Young's command (Roosevelt Papers, 9/15/08).

In the end, Roosevelt's and Young's plan to create a civilian park guard did not succeed, and in 1908, Young left Yellowstone—not, as some historians have concluded, because of the stagecoach robbery, but rather to become governor of the U.S. Soldiers Home in Washington, D.C. Roosevelt, who accepted Young's resignation reluctantly, informed Young that he intended to replace all of the park's current army staff with new soldiers to ease public criticism and appoint Major Lloyd Benson to the superintendent position. With Benson's acceptance, the park was again placed under the control of an acting military superintendent (Roosevelt Papers, 10/16/1908).

Roosevelt did not give up his hopes for a civilian park guard easily. In his last annual message to Congress, he advocated placing all national parks adjacent to national forests under the exclusive control of the U.S. Forest Service, rather than maintain them under the current, disjointed management scheme:

> I urge that all our national parks adjacent to national forests be placed completely under the control of the forest service of the Agricultural Department, instead of leaving them as they now are, under the Interior Department and policed by the army. The Congress should provide for

> superintendents with adequate corps of first-class civilian scouts, or rangers, and, further, place the road construction under the superintendent instead of leaving it with the War Department. Such a change in park management would result in economy and avoid the difficulties of administration which now arise from having the responsibility of care and protection divided between different departments. The need for this course is peculiarly great in the Yellowstone Park (Roosevelt 1927 v15, 525–526).

With Roosevelt's request to place some of the national parks under the control of his friend Pinchot, preservationists feared they would lose out to the conservationists yet again. Although this plan would have accomplished Roosevelt's goal of placing Yellowstone National Park under the control of a professional land management agency to protect its resources, it would have greatly exacerbated the stress between advocates of differing management policies for national parks and national forests. Preservationists feared that national parks would come to be managed as national forests and, as such, preservation-based management of federal lands would be replaced by conservation-based economic development, which very well could destroy the sanctity of national parks as scenic playgrounds. Was that what Roosevelt wanted?

Roosevelt himself said no, clearly stating his desires to keep national parks in a natural condition: "[Yellowstone], like the Yosemite, is a great wonderland, and should be kept as a national playground. In both, all wild things should be protected and the scenery kept wholly unmarred" (Roosevelt 1927 v15, 525–526). In addition, with the parks controlled by Pinchot, Roosevelt was likely to retain his influence to direct park policies. However, Congress did not act on his request, and the national parks remained under the army's supervision until 1916, when the National Park Service was finally created.

Taft and Wilson under Roosevelt's shadow

As Roosevelt left the office of the presidency, he handpicked his successor, William H. Taft. Taft quickly alienated the former president by firing his star conservationist, Gifford Pinchot, in the aftermath of a historically notorious spat between Pinchot and Interior Secretary Richard Ballinger. Progressives concluded that Taft was returning control of the country to the conservative Republicans whom Roosevelt had kept at bay. In the area of preservation, however, Taft's administration continued to work to achieve Roosevelt's original goal of establishing a civilian park guard to oversee the national parks. In his annual message to Congress in December 1910, Taft explained his reasoning: "Our national parks have become so extensive and involve so much detail of action in their control that it seems to me there ought to be legislation creating a bureau for their care and control." He also reiterated Roosevelt's earlier call for the Grand Canyon to be given national park status (Taft 1910).

Based on the recommendation of J. Horace McFarland, president of the American Civic Association, Interior Secretary Ballinger called together a number of park supporters to meet in Yellowstone in 1911 to discuss the future of the national parks. On the basis of their report, Taft again requested Congress to create a civilian agency, or National Park Service, to oversee the parks. Roosevelt proffered a written treatise in support of the idea:

> There are in the United States thirteen National parks. . . . At present, as the Secretary of the Interior has pointed out . . . each of these parks is a separate and distinct unit for administrative purposes. Special appropriations are made for each park, and the employment of a common supervising and directing force is impossible. . . . A bill is before Congress for the creation of a Bureau of National Parks, the head of which shall have the supervision, management, and control of all the National parks and National monuments in the country, and shall have the duty of developing these areas so that they shall be the most efficient agencies possible for promoting public recreation and public health through their use and enjoyment by the people. . . . The new bureau should be called the National Park Service. . . . The establishment of the National Park Service is justified by considerations of good administration, of the value of natural beauty as a National asset, and the effectiveness of outdoor life and recreation in the production of good citizenship (Schullery 1986, 141–142).

Despite the support of Roosevelt and Taft, who had become political enemies due to an emerging split between progressive and conservative Republicans, Congress did not pass a bill creating a National Park Service. The new bureau would have to wait for a few more years. In the meantime, the presidential election of 1912 proved to be one of the most interesting elections ever held in the United States. The Democratic Party nominated the progressive Wood-

row Wilson, while Roosevelt and Taft campaigned against each other under the banners of the Republican Party and the newly formed Progressive Party (also known as the Bull Moose Party), as well as against their other rivals, Wilson and Socialist Party candidate Eugene V. Debs.

With the campaign focused primarily on economic reform, Roosevelt and Taft split the Republican vote, and Woodrow Wilson won the presidency. Wilson, who did not have much of a conservation record going into his presidency, did not contribute much to the conservation/preservation movement until he signed the National Park Service bill in 1916. It is worth noting that the agency's creation appears as little more than a footnote in many histories of the time; Wilson's biographers have tended to focus more on Wilson's economic reform and his international struggles, largely ignoring the creation of the National Park Service. Park service framer Horace Albright confirmed that Wilson himself did not consider conservation to be of primary import during his presidency:

> . . . President Woodrow Wilson was totally uninterested in conservation, national parks, or anything that pertained to the great outdoors. Whatever fine things occurred during his administration, like the creation of the National Park Service, came through [Interior] Secretary Franklin Lane. Neither of them should be counted as conservationists, but Lane let us [Albright and NPS Director Stephen T. Mather] have free rein for the most part and in general didn't care to interfere with our judgments. Wilson just wasn't a conservationist in any sense of the word (Albright and Schenk 1999, 301).

In fact, Albright actually claimed to have "snuck" the park service bill through for Wilson's signature by placing it in the same folder with an army appropriations bill, hoping Wilson would sign both:

> [At] . . . the Capitol . . . the enrolling clerk . . . said they hadn't had any call for th[e NPS] legislation and the President signed bills only on certain days. As we were talking, the phone rang. I gathered from the conservation . . . that it was the White House . . . and that they wanted some bill sent over to be signed. When the . . . clerk hung up, I asked politely if that was the White House, and the clerk said yes, adding they wanted the army appropriations bill sent over. I said, "Be a good fellow and stick the Parks Act in the same envelope." He did, and I hopped a street car and got to . . . [legislative clerk Maurice] Latta's office before the bill arrived. . . . Latta said he would see if he could get it to the President some time during the evening . . . so I gave him the phone number where I could be reached. About 9:00 P.M. the phone rang and it was Latta, who told me: "the President signed the bill." I went right down town to the postal telegraph office and sent Mather a night letter . . . : 'PARK SERVICE BILL SIGNED NINE O'CLOCK LAST NIGHT. HAVE PEN USED BY PRESIDENT IN SIGNING FOR YOU' (Albright and Cahn 1985, 42–43).

Despite Albright's account, it is hard to believe that Wilson would have signed any piece of legislation without knowing its details and implications—especially one that created a new bureaucratic agency. Given his scant interest in conservation affairs generally, one could surmise that Wilson signed the bill for political reasons. According to Wilson biographer Arthur S. Link, Wilson signed much of his progressive legislation in 1916 to win Progressives over to the Democratic Party (Link 1954). The timing was appropriate, for by that time Roosevelt had requested that Progressive Party members return to the Republican Party to defeat Wilson and the Democrats. Clearly the bill was supported by many Progressive conservationist and preservationists; first NPS director Stephen T. Mather, for instance, was a former Progressive Party member who supported Wilson after the signing of the bill. Signing the bill also gave Wilson a measure of accomplishment in the conservation arena. He may have seen it as a way to counter the environmental legacy of Roosevelt and the Republicans, thus reducing the possibility for criticism of his conservation record in the upcoming presidential election debates.

However, as in the 1912 election, conservation was not a major campaign issue in 1916. The Democrats re-nominated Wilson; Roosevelt agreed to campaign for Republican Party nominee Charles Evans Hughes. Both candidates focused more on international issues regarding the expanding war in Europe, with domestic policies remaining in the background and conservation receiving only brief mention. The Republican Party platform simply stated: "We believe in a careful husbandry of all the natural resources of the nation—a husbandry which means development without waste; use without abuse" (Republican Party platform 1916). The 1916 Democratic Party platform on conservation was almost as brief:

> For the safeguarding and quickening of the life of our own people, we favor the

> conservation and development of the natural resources of the country through a policy which shall be positive rather than negative, a policy which shall not withhold such resources from development but which, while permitting and encouraging their use, shall prevent both waste and monopoly in their exploitation, and we earnestly favor the passage of acts which will accomplish these objects, reaffirming the declaration of the platform of 1912 on this subject (Democratic Party platform 1916).

The nation re-elected President Wilson, perhaps in part because, according to Link, Wilson had adopted most of Roosevelt's Progressive platform and instituted its policies during his administration before the 1916 election in order to win over more votes from alienated progressives (Link 1954). Journalist William Allen White noted: "Naturally [the Progressives] turned to Wilson. He, at least, had Progressive achievement; not what they had hoped for, but something upon which to build. So the Progressives, looking at his liberal record, gave the election to Mr. Wilson" (White 1929, 316–317).

The Progressive Movement came to an end in the aftermath of World War I. By 1920, most Americans were willing to follow Warren G. Harding's "return to normalcy." Progressive reform remained idle until the Great Depression brought about the ascension of another Roosevelt, as well as progressive reforms under the New Deal. Yet the reforms enacted during the Progressive Era continue to impact the United States today. This is no more evident than in the Yellowstone ecosystem. The U.S. Forest Service and National Park Service, professional land management agencies conceived by Roosevelt, continue to monitor and protect this vast wilderness area. Although the evolution of both agencies would lead to the practice of different forms of land management, both remain a lasting monument to Theodore Roosevelt's conservation leadership and the Progressive Era.

References

Albright, H. M., and R. Cahn. 1985. *The birth of the National Park Service*. Salt Lake City: Howe Brothers.

Albright, H. M., and M. Albright Schenck. 1999. *Creating the National Park Service: the missing years*. Norman: University of Oklahoma Press.

Anderson, A. A. 1927. The Yellowstone forest reserve. *Annals of Wyoming* 4(4) (April).

______. 1933. *Experiences and impressions: the autobiography of Colonel A. A. Anderson*. New York: The Macmillan Company.

Bartlett, R. A. 1985. *Yellowstone: a wilderness besieged*. Tucson: University of Arizona Press.

Benson, T. W. 2003. *President Theodore Roosevelt's conservation legacy*. Haverford, Pa.: Infinity Publishing.

Burroughs, J. 1907. *Camping and tramping with Roosevelt*. Boston: Houghton Mifflin.

Cashman, S. D. 1984. *America in the Gilded Age: from the death of Lincoln to the rise of Theodore Roosevelt*. Third edition. New York: New York University Press.

Chambers, J. W. 1992. *The tyranny of change: America in the Progressive Era, 1890–1920*. Second edition. New York: St. Martin's Press.

Chittenden, H. M. 1964. *The Yellowstone National Park*. Norman: University of Oklahoma Press.

Collins, M. L. 1989. *That damned cowboy: Theodore Roosevelt and the American West*. New York: Peter Lang Publishing, Inc.

Cooper, J. M. 1990. *Pivotal decades: the United States, 1900–1920*. New York: W. W. Norton & Company.

Cutright, P. R. 1956. *Theodore Roosevelt the naturalist*. New York: Harper & Brothers.

______. 1985. *Theodore Roosevelt: the making of a conservationist*. Urbana: University of Illinois Press.

Democratic Party platform. 1916. <http://www.presidency.ucsb.edu/platforms.php>.

Diner, S. J. 1998. *A very different age: Americans of the Progressive Era*. New York: Hill and Wang.

Gable, J. 1984. President Theodore Roosevelt's record on conservation. *Theodore Roosevelt Association Journal* 10(3) (Fall).

Gould, L. L. 2001. *America in the Progressive Era, 1890–1914*. Harlow, U.K.: Pearson Education Limited.

Haines, A. L. 1977. *The Yellowstone story*. Two volumes. Niwot, Colo.: Colorado Associated University Press.

Haynes, J. E. 1959. *Yellowstone stage holdups*. Bozeman, Mont.: Haynes Studio Inc.

Hofstadter, R. 1955. The Age of Reform. New York: Vintage Books.

Huth, H. 1990. *Nature and the American*. New edition. Lincoln: University of Nebraska Press.

Johnston, J. 1993. Presidential preservation: Theodore Roosevelt and Yellowstone wildlife, *in* P. Roberts, ed., *Readings in Wyoming history*. Laramie, Wyo.: Skyline West Press/Wyoming Almanac.

______. 2004a. Preserving the beasts of waste and desolation: Theodore Roosevelt and predator control in Yellowstone, *in* P. Schullery and S. Stevenson, eds., *People and place: the human experience in Greater Yellowstone*. Proceedings of the 4th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, October 12–15, 1997, Mammoth Hot Springs Hotel, Yellowstone National Park, Wyoming. Yellowstone National Park, Wyo.: Yellowstone Center

for Resources.

______. 2004b. Theodore Roosevelt's quest for wilderness: a comparison of Roosevelt's visits to Yellowstone and Africa, *in* A. Wondrak Biel, ed., *Beyond the arch: community and conservation in Greater Yellowstone and East Africa*. Proceedings of the 7th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, October 6–8, 2003, Mammoth Hot Springs Hotel, Yellowstone National Park, Wyoming. Yellowstone National Park, Wyo.: Yellowstone Center for Resources.

Langford, N. P. 1972. *The discovery of Yellowstone Park*. Lincoln: University of Nebraska Press.

Link, A. S. 1954. *Woodrow Wilson and the Progressive Era*. New York: Harper & Brothers.

Link, A. S., and R. L. McCormick. 1983. *Progressivism*. Arlington Heights, Ill.: Harlan Davidson, Inc.

Marsh, G. P. 2003. *Man and Nature*. Reprint. Seattle: University of Washington Press.

McGerr, M. 2003. *A fierce discontent: the rise and fall of the Progressive Movement in America, 1870–1920*. New York: Free Press.

Nash, R. 1967. *Wilderness and the American mind*. Third edition. New Haven: Yale University Press.

Painter, N. I. 1987. *Standing at Armageddon: the United States, 1877–1919*. New York: W. W. Norton & Company.

Parsons, C. 1993. *George Bird Grinnell: a biographical sketch*. Millbrook, N.Y.: Grinnell and Lawton Publishing.

Pinchot, G. 1907. *The use of the national forests*. Washington, D.C.: U.S. Department of Agriculture.

______. 1947. *Breaking new ground*. Reprint. Washington, D.C.: Island Press.

Reiger, J. F., ed. 1972. *The passing of the Great West: selected papers of George Bird Grinnell*. Norman: University of Oklahoma Press.

______. 1975. American sportsmen and the origins of conservation. Revised edition. Norman: University of Oklahoma Press.

Republican Party platform. 1916. <http://www.presidency.ucsb.edu/platforms.php>.

Roosevelt, T. 1913. *Theodore Roosevelt: an autobiography*. New York: Charles Scribner's Sons.

______. 1927. *The works of Theodore Roosevelt*. Twenty volumes. H. Hagedorn, ed. New York: Charles Scribner's Sons.

______. 1951. *The letters of Theodore Roosevelt*. Eight Volumes. E. E. Morison, ed. Cambridge: Harvard University Press.

______. 1969. Theodore Roosevelt papers. Microfilm. Washington, D.C.: Library of Congress Manuscript Division. Cited as Roosevelt Papers.

Runte, A. 1990. *Trains of discovery*. Revised edition. Niwot, Colo.: Roberts Rinehart, Inc.

Schullery, P. 1978. A partnership in conservation: Roosevelt and Yellowstone. *Montana the Magazine of Western History* (Summer):2–15.

______, ed. 1986. *Wilderness writings*. Salt Lake City: Gibbs M. Smith, Inc.

______. 2004. *Searching for Yellowstone: ecology and wonder in the last wilderness*. Helena: Montana Historical Society Press.

Steen, H. K. 1991. *The U.S. Forest Service: a history*. Reprint. Seattle: University of Washington Press.

Sullivan, M. 1996. *Our times: America at the birth of the 20th century*. Edited with new material by Dan Rather. New York: Scribner.

Summers, M. W. 1997. *The Gilded Age, or the hazard of new functions*. Upper Saddle River, N.J.: Prentice Hall.

Taft, W. H. 1910. Second annual message to Congress. <http://www.theamericanpresidency.us/1910.htm>.

Trachtenberg, A. 1982. *The incorporation of America: culture and society in the Gilded Age*. New York: Hill and Wang.

Ward, G. B. 1993. *Boone and Crockett national collection of heads and horns*. Second edition revised. Cody, Wyo.: Buffalo Bill Historical Center.

Ward, G. B., and R. E. McCabe. 1988. Trailblazers in Conservation, *in* W. H Nesbitt and J. Reneau, eds., *Records of North American big game*. Ninth edition. Dumfries, Va.: The Boone and Crockett Club.

White, W. A. 1929. *Woodrow Wilson*. New York: Houghton Mifflin.

Wiebe, R. H. 1967. *The search for order, 1877–1920*. New York: Hill and Wang.

Young, S. B. M. 1907. Annual report of the superintendent of the Yellowstone National Park. Washington, D.C.: Government Printing Office.

Conservation That Works: Yellowstone and the Future of Hope

Richard L. Knight

Professor of Wildlife Conservation, Colorado State University

Closing Keynote, October 19, 2005

Richard L. Knight is interested in the ecological effects associated with the conversion of the Old West to a New West. A professor of wildlife conservation at Colorado State University, he earned his graduate degrees from the University of Washington and the University of Wisconsin. While at Wisconsin, he was an Aldo Leopold Fellow and conducted his research at Aldo Leopold's farm, living in "The Shack." Before becoming an academic, he worked for the Washington Department of Game, developing the non-game wildlife program. Presently, he sits on a number of boards, including the Colorado Cattlemen's Agricultural Land Trust and the Quivira Coalition. He is also on the board of directors for the journals *Conservation Biology* and *Ecological Applications.* He was selected by the Ecological Society of America for the first cohort of Aldo Leopold Leadership Fellows, which focus on leadership in the scientific community, communicating with the media, and interacting with the business and corporate sectors. His books include *A New Century for Natural Resources Management* (1995, Island Press), *Stewardship Across Boundaries* (1998, Island Press), *Ranching West of the 100th Meridian* (2002, Island Press), *Aldo Leopold and the Ecological Conscience* (2002, Oxford Univ. Press), and *Ecosystem Management: An Adaptive, Community-Based Approach* (2002, Island Press). With his wife, Heather, he works with his neighbors in Livermore Valley, Colorado, on stewardship and community-based activities.

> "All Americans, but especially Westerners whose backyard is at stake, need to ask themselves whose bureaus these should be. Half of the West is in their hands. Do they exist to provide bargain-basement grass to favored stockmen whose grazing privileges have become assumed, and bought and sold along with the title to the home spread? Are they hired exterminators of wildlife? Is it their function to negotiate coal leases with energy companies, and to sell timber below cost to Louisiana Pacific? Or should they be serving the much larger public whose outdoor recreations of backpacking, camping, fishing, hunting, river running, mountain climbing, and, God help us, dirt biking are incompatible with clear-cut forests, overgrazed, poison-baited, and strip-mined grasslands? Or is there a still higher duty—to maintain the health and beauty of the lands they manage, protecting from everybody—the watershed and spawning streams, forests and grasslands, geological and scenic splendors, historical and archaeological remains, air and water and serene space, that once led me, in a reckless moment, to call the Western public lands part of the geography of hope?"
>
> —Wallace Stegner, 1987, *The American West As Living Space*

Wallace Stegner appreciated that half of the geography of the American West is the birthright of all Americans. He also realized that these lands are under constant pressure for many uses, ranging from mining non-renewable resources to the sustainable uses of other services that wildlands provide. The challenge, Stegner realized, was to put land health above land use. Only then could humans truly have a long-term relationship with the land that sustains us. History has told the story over and over that when humans place land use, such as logging, grazing, mining, and outdoor recreation, ahead of land health, the result is something we don't like: a degraded environment. When land health, on the other hand, is given primacy, then land uses can be allowed, but only to the degree that that they don't affect the land principle. Healthy lands allow sustainable human uses; degraded lands give back less and less over time.

This challenge lies at the heart of sustainable human–land relationships in the Greater Yellowstone Area (GYA), a region that is both public and private, and that contains the richest portion of our natural heritage still found in the conterminous United States. The stewards of this region convened a meeting at Mammoth Hot Springs during October 17–19, 2005, to examine the "hard lessons and bright prospects" gleaned from a "century of discovery." I

was asked to summarize the contents of the presentations. I will begin by emphasizing the key points of the six keystone speakers: Harvey Locke, Jack Ward Thomas, Sarah E. Boehme, Dale N. Bosworth, Monica G. Turner, and Karen Wade. Enjoyably, these distinguished individuals from the realms of science, conservation, and art history all exemplified a message that offers hope for Yellowstone's future: conservation that works is conservation that works for both natural and human communities. Actions that benefit one at the expense of the other are not conservation.

Following this, I will discuss briefly two themes that emerged from the other presenters: (1) the importance of private lands in the GYA, and (2) that federal agencies will have to work differently to work better.

Keynote speakers

I have tried to capture the kernel of the speakers' comments. My most heartfelt apologies to them where I have gone astray. In acknowledging the inspiration I derived from listening to the speakers, I would be remiss not to praise as well the perceptive audience that fleshed out the speakers' intentions with wonderfully insightful questions.

Harvey Locke (Superintendent's International Lecture) described the ongoing efforts to ensure that wildlife will always have the opportunity to move freely through the vast region from the Yukon to the Yellowstone. It is a story of on-the-ground conservation, involving scores of human communities and spanning countless administrative boundaries, including the international border of the U.S. and Canada. Near the end of his presentation, Mr. Locke posed the question of whether Yellowstone-to-Yukon was possible. He answered his own question by reminding us that every generation has a dream. The dream of nineteenth-century America was Manifest Destiny—the conquering of land and nature in settling our western frontier and building a transcontinental nation. Why not, he asked, dream in the twenty-first century for [at least] a minimal amount of land left wild for animals and people to wander across? In so doing, we would ensure a movement corridor that keeps the northern Rocky Mountains more connected than fractured. A minimal amount of respect for minorities would surely cause us to agree, wouldn't it?

To the delight of everyone, Dr. Jack Ward Thomas (A. Starker Leopold Lecture) devoted his remarks to recapping 100 years of conservation history. Beginning with unregulated exploitation, which led to the Progressive Era of Theodore Roosevelt and the blossoming of the conservation movement guided by Gifford Pinchot, Dr. Thomas then traced the rise of John Muir and the preservation movement. Conservation—the wise use of natural resources—stood in opposition to unregulated exploitation and in contrast to preservation. Conservation and preservation parted ways over building the Hetch Hetchy Dam in Yosemite National Park. This was followed by the crisis of the Progressive Faith, which resulted in the environmental movement, crowning its emergence with Rachel Carson's *Silent Spring* in 1962 and Earth Day in 1970. Today, according to Dr. Thomas, we are witnessing the rebirth of conservation under the contemporary natural resource management paradigm christened Ecosystem Management. Dr. Thomas seemed to echo Wallace Stegner's admonition that ". . . the worst thing that can happen to a piece of land, short of coming into the hands of an unscrupulous developer, is to be left open to the unmanaged public." What we are seeing today is the abandonment of our management responsibilities to public lands. Shrinking the federal workforce has created a crisis for the one-third of America that comprises the federal domain. Is this what happens when, in the words of a popular conservative ideologue, "we shrink government to the size of a bathtub"? What America needs today are elected officials who, in the words of Theodore Roosevelt, believe, "I am the steward of the public good."

Dr. Sarah E. Boehme (Aubrey L. Haines Lecture) surveyed the work of artists Thomas Moran and Albert Bierstadt, as well as photographer William Henry Jackson in developing America's perception of its first national park. Art not only spurred the protection of this grand area but also promoted its economic development. Whereas a superficial examination of the role of art in the American psyche may limit its perceived importance, the Yellowstone idea clearly discounts this perception. Art, as much as science and economics, shapes how Americans and citizens of the world view the GYA and Yellowstone National Park. By understanding the relevance of art today in the American West, one is left with a three-dimensional appreciation that Yellowstone is a reflection not only of how we view ourselves but also of how art shapes our perceptions. To appreciate the grandeur of Yellowstone requires one to exercise not only the left side of his/her brain, but the right as well.

Due to a power failure, U.S. Forest Service Chief

Dale N. Bosworth gave his remarks by candlelight, without aid of notes or PowerPoint. As evidence of his eloquence, he was honored with a standing ovation! The chief discussed what have come to be called the "Chief's Four Threats" to our national forests: [poor] forest health, unmanaged outdoor recreation, invasive species, and the loss of open space on private lands adjacent to national forests. After reviewing these points, he stressed the importance of getting the issues right when designing conservation efforts to address these threats. For example, logging is not the issue we should focus on; the issue is forest health and whether we are logging on an ecologically sustainable basis (Knight et al. 2000). Motorized recreation is not the issue, it's unmanaged recreation (Knight and Gutzwiller 1995). Similarly, the issue we focus on should not be endangered species, it should, instead, be invasive species, the number-one threat to federally listed threatened and endangered species on all lands (Czech et al. 2000). And, lastly, it's not grazing on public lands that is the issue, it's the loss of private ranchlands to exurban developments that rim national forests that will make managing public lands ever more difficult in the years to come (Knight and Landres 1998; Czech et al. 2000; Knight et al. 2002). Chief Bosworth concluded by predicting that the twenty-first century will be the century of restoring lands that have been degraded through non-sustainable uses over the past two centuries. Stewardship, he believed, will be at the heart of conservation that works in the decades to come.

When Dr. Monica G. Turner took the podium, the audience was treated to what has, regretfully, become an exception: an academic who can clearly explain the relevance of her research. The salient point of Dr. Turner's prodigious research in the Greater Yellowstone Ecosystem was this: "When you've seen one ecosystem, you've seen one ecosystem." Likewise, using results that she and her colleagues have acquired over two decades of research, she illustrated the importance of conducting science at the appropriate spatial and temporal scales. Dr. Turner must be the delight of the media, as she is able to explain complexity in a way that our diverse publics can understand. Understanding how ecosystems work is, of course, not simple, but the media insists on telling the story in a simple way. Bending to this need, but not sacrificing the real-world difficulty of ecosystem complexity, Dr. Turner unraveled mysteries of fire, forests, and climate change with clarity and insights. Not only does her approach benefit the public, it also allows natural resource managers to use the "authority of the resource" to explain why management actions are necessary. When resource practitioners can justify their prescriptions with good science, the public is much more willing to agree and comply with limitations placed on their use of natural resources.

An old sage once commented that there are two kinds of people, "takers" and "caretakers." Ms. Karen Wade clearly belongs to the latter. An administrator, organizer, conservationist, land manager, and activist, Ms. Wade embodies all that is right with individuals who are more concerned with their responsibilities to land and people than their rights. She told a series of stories that served to illustrate all that is good about people who feel obligations to healthy human and natural communities. Importantly, she also disagreed with an earlier speaker who had said that "adventurism is not rewarded by bureaucracies." Ms. Wade went on record in opposition to this truism, and offered one of her own: "well-behaved managers seldom make history." In so doing, she mirrored the thoughts of Aldo Leopold (1947), who urged us to not be afraid ". . . to throw your weight around on matters of right and wrong in land-use." Leopold went on to say, "Cease being intimidated by the argument that a right action is impossible because it does not yield maximum profits, or that a wrong action is to be condoned because it pays. That philosophy is dead in human relations, and its funeral in land-relations is overdue." I suspect that Ms. Wade would agree.

Private lands in the Greater Yellowstone Area

The Yellowstone region comprises 36 million acres, of which 32% is privately owned. Importantly, this private land occurs at the lower elevations, is the best watered, and has the deepest soils (Hansen et al. 2002). A prominent participant at the conference commented that, "The private lands in the GYA are the biggest threat to the GYA." What he meant by this, of course, is that the region is experiencing unprecedented population growth, and private lands are disappearing as working ranches and reappearing as ranchettes that cover hillsides faster than Herefords can exit. When public land neighbors are measured by acre instead of by thousands of acres, how can managers manage public lands?

Critically, the acreage lost to housing developments is occurring at a more rapid rate than the population growth. For example, population growth in rural residential development from 1970 to 2000

in the Yellowstone area increased by 58%. The acres of rural residential development during this 30-year time period, however, increased 350% (Sonoran Institute 2005).

One of the speakers at the conference asked the question, "Are public lands adequate to keep wolves and grizzlies alive in the GYA?" He had the courage to answer his own question: no. Another speaker also spoke truth with courage when he said, "Social expectations are that we can build our homes anywhere and agencies will protect us from fire." These comments get to the heart of the role of private lands in the GYA. The natural heritage of the GYA cannot be saved without consciously protecting it; business as usual will bring ruin to the very attributes that presently make it one of our Earth's natural treasures.

Speakers and audience participants interacted well in regard to what can be done about this threat that is gobbling up the private land in the GYA. Four suggestions emerged. First, insist on smart growth. Without growth management and coordination between cities and counties in the GYA, local policies will simply shift unplanned growth from one area to the next. Thanks to the Sonoran Institute (2005), the region now knows that with smart growth procedures there will be only a 1% loss of agricultural lands and a 3% loss of natural areas in the next 15 years, whereas growth as usual will result in a 15% loss of agricultural lands and an 8% loss of natural areas.

Second, economic incentives need to be developed to ensure that private lands stay in open space and out of residential and commercial development. Sales taxes, tax credits, and other innovative methods can be used to place conservation easements on ranch and farm lands, or to purchase private lands for open space when they appear on the market.

Third, smart growth and the protection of open space is smart business and good for the bottom line. The GYA is more of an amenity-based economy today than a natural resource-extraction economy. People are not coming to the region to ranch, log, or mine; they are coming to "ranch the view." Elected officials need to be aware that by despoiling the beauty and natural heritage of the area, they are hastening the day when amenity refugees decide to take their money and go somewhere else (Power and Barrett 2001).

And fourth, keeping land in agriculture is fiscally prudent. Property taxes from ranchette developments do not even approximate the costs of county services and school districts. For example, in the state of Wyoming, for every dollar of property taxes that comes from ranchettes, the costs of county services and school districts are $2.40 (University of Wyoming 2000). Conversely, county services and school districts only cost $0.69 for every dollar of property taxes that comes from farm and ranch lands. Cows don't go to school, and sheep don't drive!

The final piece of wisdom came from a speaker who said, "We can take action now to reduce unplanned growth in the long run. Rather than be victims of change, we can plan for it, shape it, and emerge as a region known for its vibrant communities, prosperous economies, and open spaces. With effective planning, this can be our legacy for the GYA."

Federal agencies: working differently to work better

A surprising message that emerged from the conference was the realization that the days when agencies could make decisions in isolation are rapidly disappearing. Whether it is federal agency collaborating with federal agency or, increasingly, seeking to work with a non-governmental organization, state agency, American Indian tribe, or private landowner, federal agencies today are increasingly sharing their authority rather than being the sole disperser of it. The sentiment at the conference was that whether this approach was popular or not, it was inevitable. Due to the downsizing of the federal government, the increasing volume of unfunded federal legislation and resulting paperwork, and the changing sentiments of the American public, collaboration is the watchword of conservation that works today.

Historically, the Yellowstone conferences were largely about scientists talking to scientists. The 2005 meeting marked a turning point in which scientists found themselves talking with citizens, managers, non-governmental organizations, conservationists, and environmentalists. Perhaps this occurred because scientists are beginning to realize that science doesn't make policy but, when done well, it can help inform policy. This change in approach may have also occurred due to the increasing realization that whereas administrative boundaries are often straight lines, ecosystems are not. This truth is emphasized by the fact that issues affecting the GYA are as much social as they are natural. To work effectively across these boundaries requires a new way of doing conservation and acknowledging the inevitable: that our fates and the fates of our land are entwined and

indivisible (Knight and Landres 1998). So whereas many of the speakers admitted that the agencies are no longer in charge, they did agree that agencies can serve as critical levers in the transition of a society that takes its environment seriously.

Acknowledgments

Special thanks to Charles Preston and Virginia Warner for making my stay in the Yellowstone area such an enjoyable visit.

References

Czech, B., P. R. Krausman, and P. K. Devers. 2000. Economic associations among causes of species endangerment in the United States. *BioScience* 50:593–601.

Hansen, A. J., R. Rasker, B. Maxwell, J. J. Rotella, J. D. Johnson, A. Wright Parmenter, U. Langner, W. B. Cohen, R. L. Lawrence, and M. R. V. Kraska. 2002. Ecological causes and consequences of demographic change in the New West. *BioScience* 52:151–162.

Knight, R. L., and K. J. Gutzwiller, eds. 1995. *Wildlife and recreationists: coexistence through management and research*. Washington, D.C.: Island Press.

Knight, R. L., and P. B. Landres, eds. 1998. *Stewardship across boundaries*. Washington, D.C.: Island Press.

Knight, R. L., F. W. Smith, S. W. Buskirk, W. H. Romme, and W. L. Baker, eds. 2000. *Forest fragmentation in the southern Rocky Mountains*. Niwot, Colo.: University Press of Colorado.

Knight, R. L., W. C. Gilgert, and E. Marston, eds. 2002. *Ranching west of the 100th meridian*. Washington, D.C.: Island Press.

Leopold, A. 1947. The ecological conscience. Pages 338–346 *in* S. L. Flader and J. B. Callicott, eds., *The river of the Mother of God and other essays by Aldo Leopold*. Madison: University of Wisconsin Press.

Power, T. M., and R. N. Barrett. 2002. *Post-cowboy economics*. Washington, D.C.: Island Press.

Sonoran Institute. 2005. *Yellowstone 2020: creating our legacy*. Bozeman, Mont.: Sonoran Institute.

Stegner, W. 1987. *The American West as living space*. Ann Arbor: University of Michigan Press.

University of Wyoming. 2000. *Wyoming property taxes and costs of county services and schools*. Laramie, Wyo.: Department of Agricultural and Applied Economics, University of Wyoming.

The Need and Opportunity for Landscape-Scale Conservation in the Yellowstone-to-Yukon Region: A Vision for the Twenty-First Century

Harvey Locke

Canadian Parks and Wilderness Society

Superintendent's International Lecture, October 18, 2005

Harvey Locke grew up in southern Alberta. His family has been in the Bow Valley for seven generations; they were among the area's earliest European settlers. He first visited Yellowstone in 1979, and knew intuitively there was a connection between it and the Canadian Rockies. This interest grew into helping create the Yellowstone-to-Yukon Conservation Initiative, for which he now serves as strategic advisor. He is also a program advisor to Tides Canada Foundation, based in Toronto, where he oversees the Sage Climate Project and conducts a philanthropic consulting practice. He serves as senior advisor for conservation to the Canadian Parks and Wilderness Society, an advisor to the Canadian Boreal Initiative, a director emeritus of The Wildlands Project, a member of the World Commission on Protected Areas, a member of the executive committee of the Eighth World Wilderness Congress, and a trustee of the Eleanor Luxton Historical Foundation. He has also served as senior program officer for the environment at the Henry P. Kendall Foundation in Boston, and as president of the Alberta Liberal Party. In 1999, *Time Canada* magazine named him one of Canada's leaders for the twenty-first century.

Note: The text that follows is an edited transcription of Mr. Locke's remarks at the conference.

I want to say thank you so much, Superintendent Lewis, for having me here, and to the program committee for thinking of inviting me to give this talk. I have an interesting life and I get to do a lot of cool things, but for reasons that are personal to me, there is no greater honor that I could ever be given than to be asked to give the Superintendent's International Lecture at Yellowstone National Park. There really is nothing that I could ask for more.

That feeling has to do with a bit of who I am in life. My family is from Banff National Park. My parents both grew up there; my Mum still lives there. I first visited Yellowstone on my way home from college in 1979. I was going to my seasonal job in Banff National Park via here, and I came over into the Grand Teton country and came up through the park and I was, like everyone else, touched by the magic of this place. I was living then with my aunt, Mary Alice Stewart, who was the first director of the archives of the Canadian Rockies and is the person who got me interested in national parks as an idea, as opposed to as a place where we just went all the time. When I got to her place, Aunt Mary said simply, "Yellowstone is the greatest national park," and she was right. Everyone in the world knows that she was right.

But what I'd like to say to you today is that though Yellowstone is the navel of the conservation universe, and all things in conservation radiate from it, no park is an island unto itself. No ecosystem is an island unto itself, and that applies equally to Yellowstone. For Yellowstone is part of something much bigger than even the Greater Yellowstone Ecosystem. Indeed, it is attached to the landscape that we call the Canadian Rockies and something you call "something north of the northern Rockies."

I want to talk to you about people, wild animals, and the power of a vision. To start, I will take you on a little trip to the rest of the Rocky Mountain range to which Yellowstone is attached. In the summer of 1993, I photographed a grizzly bear track and a wolf track side by side on a trail deep into a 16-day walk across the Willmore Wilderness Park in Alberta. At the time, this experience was not possible in Yellowstone. There were no wolves here then. However, for years, people here had a vision of getting them back. They pursued it, and within three years of my hike, wolves from near Hinton, Alberta (near Willmore), and from near Fort St. John, British Columbia, were reintroduced. And now, in 2005, I come to the Lamar Valley in Yellowstone because it is the best place to see wolves that come from my home province. That is the power of a vision.

But visions also operate at much bigger scales. The scale that really matters is what's going on in people's heads every day. The painting, *American Progress,* in the Autry Museum collection,

NPS

"Yellowstone is the navel of the conservation universe."

encapsulates the vision that dominated the nineteenth century. It was originally printed as a handbill that was part of a book that told settlers how to make their way west. In the painting, the concept of Liberty is depicted as a woman floating above the landscape, dressed in a flowing white dress. Close to her breast she holds a large book, a book of knowledge and civilization. She floats westward from the cities in the East embodying progress, carrying a telegraph line in her other hand. She is followed closely by the railways, the stagecoaches, the plow, and the farmers, and before her flee the buffalo, the wild native people, and the wolves. She is going forth and civilizing the landscape. This is *progress*. And if you fattened her up a little bit, put a crabby expression on her face, she could be Queen Victoria, and the vision applies equally to Canadians. This was what was in my ancestors' heads when they came up the Missouri River by steamer in the 1870s, on a boat that had to stop for eight hours while a buffalo herd crossed between them and the end of steamship navigation at Fort Benton, Montana. There they got in a Red River cart and went up to the first settlement in southern Alberta, called Morleyville. So the image in *American Progress* reflects what was going on in people's heads. Such an image or vision is very, very powerful, because it tells us what we ought to do.

But that vision of progress also ran into something else. It ran into magnificence. The nineteenth century was also the period of Romanticism, the intellectual movement that believed that the world was a beautiful place, and that engaged people's passion for Nature. It was a reaction to the ugliness of the industrialization that progress had unleashed. And when people who were imbued with romantic thoughts encountered the incredibly romantic landscape of Yellowstone, it gave rise to the world's first national park. A new approach was created. We had this idea that we could have our Progress and our protected places, too—and thus, the national park, and the protected areas on public land idea, was born.

So by the turn of the nineteenth and into the early part of the twentieth century, we had developed a model that would allow us to have both our progress and our places that were special. We put green boxes on the landscape. We had a hierarchy with wilderness areas and ecological reserves at the top. Next, the least-developed national parks that were all about nature, but also about people getting to see nature. Then we set up wildlife management areas, and managed forests like the U.S. Forest Service's lands. We believed this would give us the range of tools that would allow us to maintain the values

that we wanted while we had our progress. Now it's been a hundred years, and we can evaluate how well that model works.

The Middlesex Fells Reservation in Boston is a case study that's really of quite a bit of interest to me. It was set up in the 1890s, during that great flourishing of conservation, deliberately and specifically to protect wilderness. Because Boston has had good universities for a long time, someone went in and inventoried the plant species in that reserve in the 1890s. Since then, Boston has grown. At establishment, Middlesex Fells was out in the country, a protected area in a rural setting. Now, of course, it is an island in a sea of urban development in the big city of Boston. So someone had the idea to go in there again in the 1990s and say, how are we doing with this island? What's happened? Well, Brian Drayton and Richard Primack found that out of 422 original plant species, 155 species were no longer present in 1993. Sixty-four new species were recorded on the site in 1993, the majority of them exotic species. And the ones that have dropped out are things like the wood lily that reproduces with bulbs, or the things that reproduce with burrs, because there are no animals that can carry them around anymore. The ones that are still working are pollinators. The air is still connected; therefore, they're still flourishing. This is a lesson in island biogeography; this is the cost of isolated green boxes.

Let's think at a bigger scale for a moment. What about big things like grizzly bears? And what about big green boxes like Yellowstone National Park, and the wilderness areas of North America? There's Yellowstone. The Selway-Bitterroot Wilderness Area in Idaho. The Bob Marshall, Waterton-Glacier, and Banff and Jasper. These are big places. And if you add the wilderness areas to Yellowstone Park, Greater Yellowstone gets to be a big chunk of real estate.

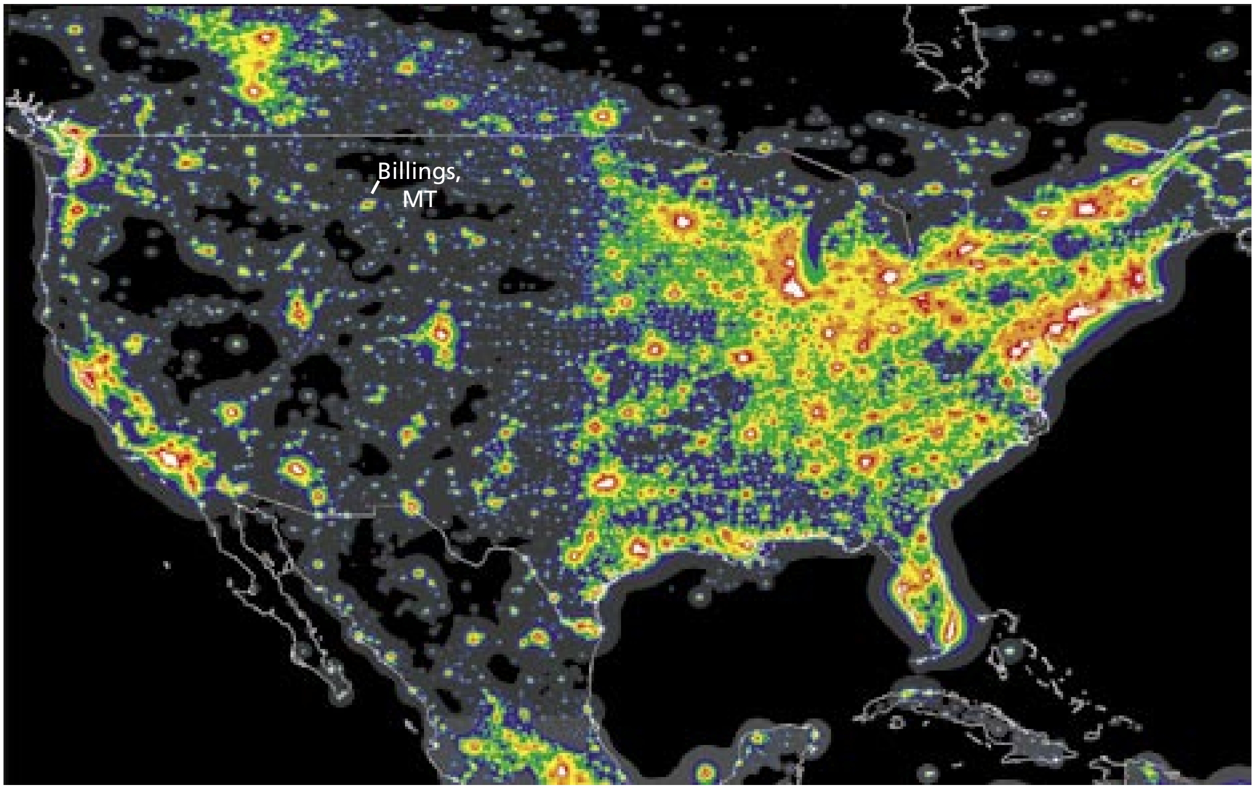
Let's zero in on the Selway-Bitterroot Wilderness Area in Idaho. In addition to the formal wilderness areas, there is a lot of roadless land. In aggregate, there are 8 million acres of unroaded land in that part of Idaho. Is an 8-million acre block big enough to keep grizzly bears?

Well, in a word, no. This can be seen from a map by Canadian biologist Bruce McClellan, which shows the historic distribution of grizzly bears in North America in 1850, where they were in 1922, and where they are today. In the mid-nineteenth century, there were grizzly bears in California. There were grizzly bears in Mexico. By 1922, in the lower 48 there were grizzly bears in little islands all over the United States. Today, there are none left in islands in the United States except the Yellowstone island. There is also a peninsula of life for grizzly bears that runs down the Canadian Rockies into Waterton-Glacier National Park, and into the Bob Marshall Wilderness complex. But the big block of 8 million acres in Idaho has not been large enough to keep grizzly bears, even though it's roadless and 4 million acres of it are managed as wilderness. And I fear, as many others do, that the Yellowstone island is next unless we can reconnect it to the great habitat in Idaho so it can be recolonized by bears, and to the Waterton-Glacier–Bob Marshall area. We need to restore connectivity, and bring the peninsula of life all the way down the system to Greater Yellowstone, where it really belongs.

We've learned a lot in the 1990s, both about these patterns of disappearance and also about how animals actually use the system. A wolf named Pluie, which means rain in French, was radiocollared near Banff National Park in a project led by Paul Paquet. During her life, she traveled an enormous circuit, from Alberta to British Columbia to Idaho to Montana and back again; in all, about 11,000 miles before she was shot. Her ecosystem was that big. Other wolves, radiocollared by Diane Boyd in the Flathead Valley of Montana, found their way all the way down to Yellowstone; another wolf found its way all the way up to Mile Zero of the Alaska Highway near Dawson Creek, British Columbia. These large-scale movements were things we didn't know, but found out about 10 or 15 years ago.

The golden eagle is a species that we've always known was in the system. What we didn't know is that they migrate from Yellowstone to the Yukon every year. Somebody actually discovered this by accident, like a nineteenth-century naturalist discovery in the 1990s. Peter Sherrington had his binoculars on the wrong setting one day and caught some motion above mountaintops in the Kananaskis Valley west of Calgary. And he discovered a migration of eagles—5,000 birds flying overhead every spring like clockwork for about a week-long period. You can set your watch to it. Now there are eagle festivals. Nobody knew this 15 years ago.

A recent study by A. S. Laliberte and W. J. Ripple produced another really interesting graphic. Laliberte and Ripple took a historical look at the historical and current distribution and numbers of species (ungulates and carnivores) in North America. Places with 14 focal species were assigned a hot red color; places with zero of those species were assigned



A "reverse wilderness map": North America at night. Billings, Montana, is identified for reference.

white. What Laliberte and Ripple show is that historically, there were a lot of hot colors representing the distribution of these animals. Today, there are complete whiteouts, for instance in the big farm belts of the Ohio Valley and the Midwest. The only place where the hot colors really still exist in the lower 48 states is in the Yellowstone-to-Yukon region. Well, why is that? It's because there were some good game management policies that came in during the early part of the twentieth century, and because of protected areas: wilderness areas and national parks.

Another way to look at the landscape is by what I call the reverse wilderness map. It's North America at night. It shows all the lights visible form space. Black spots represent how much room we are leaving for nature in North America. There's not much black on the map except in northern Canada and Alaska. But one spot represents the Wind River Range. Another covers the Yellowstone area, another the wild areas of Idaho, another Waterton-Glacier and the Bob Marshall, another covers Banff and Jasper. What we're trying to do is keep that stuff woven together. And it's difficult to conceive a large-scale ambition like Yellowstone-to-Yukon as a big "land grab" when the real facts are that we are leaving very little room for nature. All we're talking about is trying to have humanity coexist with nature instead of swamping it.

And the good news is that we have a lot to work with here. We have one of the greatest systems of protected areas in the world: Yellowstone; the wilderness areas of Idaho; Waterton-Glacier; Banff; Jasper; the new complex in the Muskwa Kechika Management Area of northern British Columbia, and Nahanni. This is a tremendous system to work with. What we need to do is connect them and keep them connected. The idea is to have a core protected area (which is a secure breeding area so the animals can disperse out into the landscape) linked by a corridor or a movement zone to the next core area. The idea of the corridor is not that it's a giant human exclusion zone (i.e., "pass here and be shot"). Rather, it's a permeable landscape through which animals can travel to get to the next place and keep genetic connectivity. It's a simple model, but one that works.

I want to give you a sense of the landscape we have to work with. The Yellowstone-to-Yukon Conservation Initiative commissioned Bill Haskins to create a habitat fragmentation model. It explains the condition of the landscape in regard to linear disturbances—a fancy way of saying roads or rail lines, or seismic lines cut for oil and gas. Where it's green, it's totally intact. There is only one road across the Mackenzie Mountains, and that road is actually de-

commissioned; it's the old Canol Road from World War II. This wild area is many times larger than Yellowstone National Park. As you come south into British Columbia and Alberta, the colors get really hot along the northeast; that's because of oil and gas activity in the Alberta Plain. But in the mountains, it's still pretty darned green. As you get down to Banff and Jasper, it starts to change, with more warm colors. And down at the bottom you can see the green area of Yellowstone all by itself on a sea of hot colors. You can also see in green the Selway-Bitterroot area, the big "island" that the bears have fallen out of. And similarly, you can see green where the Bob Marshall, and the Glacier and Waterton areas stand out. What's really scary is you can see the colors starting to change between Banff and Waterton-Glacier from green to hot, which creates the risk that Waterton-Glacier and the Bob Marshall Wilderness may become an island. We have to do something about that. Part of the advantage of thinking at this Yellowstone-to-Yukon scale is that it allows you to conceive clearly where your problems are and where you need to act.

Gannett Peak, in Wyoming's Wind River Range, is the highest mountain in the whole Yellowstone-to-Yukon system, at 13,800 feet. Past the foot of the Wind River Range, starting in the Green River basin, there occurs an annual migration of pronghorn antelope. Grand Teton National Park has pronghorn for one reason: because it's connected to the upper Green River. Pronghorn cannot winter in Grand Teton; they've tried, and they die off. When, each year in May, the pronghorn, like clockwork, move out of the upper Green and into Grand Teton Park, they have to go through a very narrow course on the Gros Ventre River, and they have to be able to come back out every winter, or there simply won't be any pronghorn in Grand Teton. There are a few things that could choke off that narrow course, including oil and gas development. A lot of very thoughtful people are working on keeping that corridor open. It's apparently the third-largest migration in the world involving large mammals. And it's a microcosm of the whole Yellowstone-to-Yukon idea. Similarly, in Jackson, Wyoming, people are very preoccupied with the Togwotee Pass road, which if enlarged the wrong way, would also fragment this area for wildlife movements. It would cut big chunks of the landscape in two.

In terms of grizzly bears, our goal is to get them back into contiguous areas of suitable habitat between Yellowstone and the Canadian border. And I'm pleased to tell you that there are at least three grizzly bears that made it actually into the edge of the big wild area in Idaho. This morning I learned about one that was shot by a bow hunter near the Anaconda smelter on the southwest side of I-90. And if you think of the Yellowstone-to-Yukon region, the Clark Fork River all across I-90 and Route 200 is like a big "medicine line" that divides the already-too fragmented from the not-yet-too fragmented landscape. And it is very good news that there are three individual bears that—though none has survived—have made it across that Clark Fork medicine line. This makes our dream of reconnecting the fragmented south to the less fragmented north not a fantasy at all, but a doable reality.

I want to give you a sense of what the landscape is like as you go north in the Yellowstone-to-Yukon area. This is fundamentally a north–south region. Humans may move east–west for commerce, but the grain of the country is north–south, and it has always been that way. The Rocky Mountain Trench begins in Montana, near Missoula, and it runs for 12° of latitude to the Yukon Territory, never varying in elevation more than 1,000 feet. It gives rise to the Columbia, the Fraser, the Peace, and the Liard rivers. It is a lovely place. It's a good wintering area for ungulates, and it's also the way wild things travel. They're not going to go over the mountains; they're going to travel north–south up the parallel valleys. This grain of the country is very well illustrated in a map prepared by Eckhardt Zeidler, a fellow who was actually a currency trader at a big bank and had a passion for this part of the world. He painted it from satellite data. It's the most remarkable map. It takes you from Montana to the Yukon with incredible detail. If you know the landscape, you can pick out a lake you know in it. And it gives you a very good sense of the grain of those north–south valleys. But there are also some east–west breaks. Highway 3 runs through Crowsnest Pass and the Purcell Mountains. Highway 1 runs east–west, crossing the Bow Valley in Banff Park. Another highway crosses Jasper, another crosses through the Peace River, and there are highways just north of Yellowstone—particularly at Bozeman Pass—that some of you would recognize as big east–west breaks against the normal grain of the country.

I want to give you a sense of what's going on in the part of the world along the border just north of the Clark Fork "medicine line." The area where Canada and the United States meet is sometimes referred to as the Crown of the Continent. I'm

going to take you on a little circuit around here to give you a sense of some of the wonderful things that a variety of people are doing to maintain the integrity of the landscape. The eastern slope, or front range, of the Rockies is ranching country. Keeping that country open for ranching is really important for wild animals—not just domestic ones. The Nature Conservancy of Montana, on whose board I have the privilege of sitting, has done an astonishing job of working with local landowners to keep grizzly bears on open ranches on the front of the Rocky Mountains. On the Canadian side, so has The Nature Conservancy of Canada, which has prevented ranchland from being subdivided on the edge of Waterton Park.

The contrast is striking between Estes Park, Colorado, which is close to Denver, a city of about 1.5 million people, and at Waterton Lakes National Park in Canada, two and a half hours from Calgary, a city of 1 million people. The Estes Park area is built up with houses, gas stations, and miniature golf courses right up to the park boundary. The fringe of Waterton is open ranchland. The different outcome is because the Waterton-area ranchers did not want subdivision and development like that to happen to their place, and so they worked with The Nature Conservancy of Canada to get 28,000 acres of land adjacent to the park either owned by The Nature Conservancy or under easement to them. And today you can see grizzly bears in among the hay bales when you travel in that country.

So there are some good things happening. But there's also a challenge. The Waterton-Glacier country has got wonderful, wonderful floral diversity. It's in fact a great mixing point of species that come from the north–south and east–west, making it a real biological diversity hotspot. I recently did a chapter for a book on transboundary protected areas whose coauthor had done most of his work in Africa, and he said to me, did you know the Waterton-Glacier area has more vascular plant species than the Serengeti?

It also has enormous significance because of that breakup zone for grizzly bears coming down the peninsula of the Canadian Rockies that I spoke of earlier. In the words of Chris Servheen, who leads the U.S. Fish and Wildlife Service Grizzly Bear Recovery Office, what happens on the Canadian side determines the future of large carnivores in the United States. Let's start with the Waterton-Glacier Park. Glacier is a nice big park, almost a million acres; Waterton is 110,000 acres attached to Glacier on the Alberta side of the Rockies. But there is a big anomaly: a missing piece on the British Columbia side of the Rockies. It's not part of the park because there are historic, constitutional reasons why it wasn't included. The consequence of that failed inclusion is a clearcut extending to the Canada–U.S. border on the B.C. side that abuts Glacier on the U.S. side. This is goofy. Animals are protected species on the American side; they're hunted on the Canadian side. Wolves, for example, an endangered species south of the borderline, can be shot just north of it. We need to fix this, round it out, and make it a proper core reserve of Waterton-Glacier. It's not a new idea. John George "Kootenai" Brown, who was the first superintendent of Waterton Park, said in his first report in 1911, we need to have a larger park so that we have a breeding ground that's consistent in conjunction with Glacier.

The area we are talking about is the North Fork of the Flathead River. It is the wildest river valley left in the United States. It rises on the Canadian side, where we just call it the Flathead. Dr. John Weaver of the Wildlife Conservation Society recently completed a study to answer the question, how does this thing hang together as a whole? Never mind the border; what is the Flathead really like as a unit? This study was a compilation of many, many other studies done by many other people. (John Weaver will be a name you might know because he's the fellow who did the study that set up the wolf reintroduction in Yellowstone 20 years ago.) So John did this synthesis, and he said, holy smokes, the Flathead, from the river to the Continental Divide, is the most important area for large carnivores in North America. It has the greatest abundance [of] any grizzly bear area in the interior of North America, because it's so productive, but it also has all the other carnivores. The lynx come to the south, the bobcat to the north; everything comes together there. This is an astonishing place, and the boundaries of the reserve are not adequate to protect those values.

So we've been advancing the idea that we should protect not only from the middle of the Flathead River, as is the case in Glacier National Park, but also from the far side of the riparian valley bottom over to the Continental Divide—an area of about 110,000 acres—to add to the park to round it out. This is the low-elevation riparian area on the North Fork of the Flathead on the Canadian side. It is the only place left in this part of the world where there are no houses beside a river. Think of Paradise Valley with no houses in it. That's what the North Fork of the Flathead on the Canadian side is. On the

American side there are houses on the west bank of the river. On the Canadian side, none. We (the Yellowstone-to-Yukon Conservation Initiative and The Nature Conservancy of Canada, with the support of the The Nature Conservancy–Montana chapter) secured the only piece of private land on the Canadian side already. The goal of the Yellowstone-to-Yukon Conservation Initiative is to roll the whole thing into a national park from the riparian area to the Continental Divide—a tremendously exciting thing. And one of the great days in my life was in October 2002, when the prime minister of Canada rolled out the action plan for Canadian national parks and said, we will expand Waterton-Glacier International Peace Park if the government of British Columbia and the K'tunaxa [Kootenai] First Nation agree. That was a very, very joyous day for me. It was based on all this stuff.

But life has a way of bringing you back down to Earth. Not everybody would see this as an obvious thing to do. There's a regional economy there that has been very resource-based over time. It's been a bit of a cultural backwater in the sense that although there are national parks nearby, nobody goes to them. And we have had a very interesting time introducing the concept of a national park to a community that has no connection with a national park. One locally generated idea in opposition was that the park expansion was an American conspiracy to steal Canada's water, which was not that hard to debunk, because the Flathead River already flows south. So we did okay on that one. But we've had to do one hell of a lot of work at the field level in these communities to get people to see an opportunity instead of a problem. And we've done that field-level work by reaching out to the different demographics of the Fernie community in particular, and by bringing in people from your part of the world to talk about what a great thing a national park is. People like Steve Duerr, Executive Director of the Jackson Hole Chamber of Commerce, who says the best thing you could possibly do for business in your community is to have a national park. It's not bad for business; it's good for business.

And we've released an economic report, which does a jobs lost vs. amenities migration gains analysis that's quite thorough; you can find it at <www.peaceparkplus.net> if you want to see it. It shows that the park would actually be a net economic benefit, and this idea is starting to have traction. We've also worked with the K'tunaxa First Nation (you call them Kootenai); they have a land claim and they're interested in the broad values. And they have recently, at our request, issued a call for a park expansion feasibility study, which is one of the two preconditions to the park proceeding. The other problem is that so far we don't have the local member of the legislature on board, but I'm very pleased to tell you that we recently had 12 out of the 14 municipalities in the regional district of East Kootenai ask for a park expansion feasibility study formally on behalf of the regional district of East Kootenai. And we're taking this to the streets.

One of the most fun days I've had as a conservation activist was on this campaign: John Weaver's study was featured on the front of the July 16, 2002 *New York Times: Science* section, "Where the Bears and the Wolverines Prey: America's Wildest Valley." And after a big public forum in Fernie which was actually organized to run us out of town on a rail but didn't go the way the organizers planned, there were headlines in the *Fernie Free Press* and the *Elk Valley Miner,* "local support for the park expansion heard at forum." That was a great week.

We will get this park expansion done. It's a lot of hard work. But it was a lot of hard work to make Grand Teton Park happen, too. It's the nature of our business. We're in about the only business where everything has to be perfect. Everybody else gets to do close-enough; we have to do perfect. But that's why we're such good people, right?

Another issue is Highway 3, which runs east–west just north of the U.S.–Canada border. We may get the park expanded, but will the highway cut it off? We're also working to have a wildlife management area established of about three-quarters of a million acres to provide primarily for connectivity while allowing for some careful forestry and other activities. And then we've been trying to work on acquiring the remaining blocks of private land that keep the carnivore populations of the United States connected to the big gene pool in Canada. There's only six of these linkages left, folks. If they go, it's bye-bye Glacier and Bob Marshall for these species over time.

Happily, we've been able to secure the biggest block of them through a deal with Tembec, a timber company that's quite progressive. I sat down with their senior vice president and some colleagues and we explained the Yellowstone-to-Yukon context to them. They're a very large company—one of the largest pulp and paper producers on Earth, operating in six countries. They owned all the riparian river bottom along the Elk River along Highway 3, which is still used by male grizzly bears as a connectivity

corridor. They also owned the logging rights in the Flathead in the park expansion area. We reached an agreement: they would back out of the park expansion area and their public rights to timber if they could be kept whole economically, and working through The Nature Conservancy of Canada, they sold us all of the low-elevation valley bottomlands, 1,400 acres along the river. In addition, there are conservation easements on the 6,000 acres adjoining it on the hillside so it doesn't just get fragmented on the edge. Tembec also has 90,000 acres of private land at the head of the Flathead on the other side, which is in a voluntary 10-year moratorium while they consider whether they'll give us easements on the rest. This is the largest private land deal ever done in Canada, and it happened only for one reason: because of context. These people could see there was a strategic issue, they wanted to be aligned with it, and we got this outcome. At the local level they actually weren't even talking to The Nature Conservancy about it. It shifted when the context shifted.

I'd like to take you north to Banff, which is our Yellowstone in terms of iconography. It's actually a busier park than Yellowstone. It has more visitors than Yellowstone, in addition to the busiest highway in western Canada, **and** the busiest rail line. Add three world-class ski hills, and you've got a really busy place. The town of Banff sits in the Bow Valley, one of the east–west valleys. Banff had a big development boom in the late 1980s, when it appeared clever to try to create more jobs from tourism. The federal government sponsored an incentive program for building in Banff Park and gave away a bunch of money to people to develop, and we ended up with a half-billion dollars worth of new commercial development in Banff Park. The consequences were a change to the landscape, because it happened without thinking about context and connectivity. Between 1982 and 1992 the Banff Springs Hotel—the famous "castle in the wilderness" that was often advertised in *National Geographic* a while back—went from being a castle in the wilderness to being a castle in the suburbs. The consequences of that were, of course, to block the wildlife movement areas around it, and the overall consequence was to make Banff a cork sitting in the mouth of the Bow Valley. As a result, the wolves would stay west of town, and the elk would stay east of town. In fact, they wouldn't even just stay east of town, they'd stay right **in** town, and they'd calve. And we had interesting posters or warning signs, kind of like you do, except in Japanese with a kickboxing elk and a person falling backwards with a camera dangling in mid-air. This was a really big problem, and it was killing the aspen trees, as there were too many elk eating the young shoots.

We had this big dysfunction in a national park. We had a big hue and cry about this, a big public fight about what national parks are and aren't, and it went well. The federal government appointed a task force called the Banff Bow Valley Study, and they did a seminal study—a couple-million-dollar study, with massive public engagement, that took several years. It said Banff was off-course, that this place was going to be in trouble, and we needed to change course completely. Our national parks changed direction as result of that study. Our statute used to say only that parks were to be maintained unimpaired for future generations, very similar to your National Park Service Organic Act. It now says that ecological integrity is the first consideration in all aspects of park management decisions. We had all of the town sites surveyed, and the town site of Banff was actually reduced in size; the obstructions in the movement corridor were removed. Now it's the great case study in connectivity that was given at the 2003 World Parks Congress in Durban, South Africa, that Gary Machlis spoke of [earlier at the conference], because it's the one case where a corridor was obstructed by development, we pulled some of that development out (closed an airstrip and a cadet camp), and now the whole system functions, the wolves flow around the town, and the elk numbers are down—and the grizzly bears are even using an area they weren't using before. This connectivity theory stuff actually works. It's kind of encouraging.

But Banff still does have both a big highway and railway: picture Interstate 90 running through Yellowstone. What do you do about it? Well, there's been a lot of construction done on overpasses and underpasses for animals. Initially, the mitigations were fences and culverts, just like we have for cattle on I-90 on Bozeman Pass. It wasn't working for carnivores, and the plan was to go ahead with business as usual. We called that the Berlin Wall of Biodiversity, because it snipped this Yellowstone-to-Yukon region in two. There was a big public response to that, some more money was found, and the result was overpasses, built over the road, that are 50 yards wide, designed for carnivores to go over the road. And do they work? . . . They work. They're not as good as not having the highway, but they do work. So we can mitigate our effects if we think about it. The same mitigations were insisted on by the Kootenai-Salish people on Highway 93 north of

Missoula. When the Montana Department of Transportation said they wanted to go through their reservation, the Kootenai-Salish said, only if you build the things they have in Banff, and guess what, the Department of Transportation agreed. So these mitigations will be built for the same reason on the Kootenai-Salish reservation north of Missoula very soon.

There's one other lesson from Banff before I move on. There's a painting of Crowfoot Glacier by Carl Rungius, who painted the Yellowstone to the Yukon area. He painted in Cora, Wyoming, and had a studio in Banff; he traveled the system long before we thought of calling it the Yellowstone-to-Yukon. Rungius was known for being very accurate; although impressionistic, his detail was legendary. The three fingers of the Crowfoot Glacier are visible in his painting, which is about 90 years old. When I took a picture of the Crowfoot Glacier two years ago, the fingers were melting back and had dropped off; you can see old terminal moraines far below the current ice. This is climate change.

We need to do two things about climate change. One, we need to stop fouling the air with all the $C0_2$ that we're releasing. Second, we need to adapt to it. To do that, one of the things the climate scientists and biologists who study climate change tell us is that we need north–south connectivity to allow temperature-sensitive species to adapt, because the temperature's cooler as you go north. And we need up–down connectivity—vertical connectivity—because the temperature's cooler as you go up. And another thing that I just learned from a plant ecologist at the Provincial Museum in Victoria, British Columbia, is that we also need aspect, because the moisture gradients and temperature are very different on a south-facing than a north-facing slope. And so although we've sometimes called mountains—pejoratively—rocks and ice, and thought them unimportant to biodiversity, Richard Hebda, at the Provincial Museum of Victoria, told me that the Yellowstone-to-Yukon region is the future of the life of vascular plants on this continent in the face of rapid climate change.

We also had a workshop with people who had worked on an Arctic assessment who said, "You misunderstand why the Yellowstone-to-Yukon region matters. It's not about bears and plants. It's about the future of fresh water in North America, because there aren't going to be many places where it comes from anymore with the climate warming." So we really have something here that matters at a whole bunch of scales, some of which we didn't even understand when we started.

So I've taken you through the "islands" and how to reconnect them, and I've taken you through avoiding fragmentation. Now I want to take you here to the big wild north, just so we can dream a little bit about what wilderness really can still be. I'm going to take you to the Nahanni. Nahanni is in the Northwest Territories, near the 60th parallel. It's a forested landscape, and the land of the Dehcho Dene. Dehcho means big river, for the Mackenzie River, and Dene, of course, means native people, for the Athapascan speakers. These people still have their culture related to the land, and for them the Nahanni River is a very special and sacred place—as it is for anyone who loves wild nature. Because Rabbit Kettle Hot Springs, in Nahanni National Park Reserve, looks a lot like Mammoth Hot Springs, the Nahanni is sometimes referred to as Canada's Yellowstone. If you're a rock climber, the Cirque of the Unclimbables' Lotus Flower Tower in the Nahanni watershed is one of the most impressive places on earth for climbing. It is Canada's Yosemite. These are karst lands on the edge of the Nahanni—the most developed subarctic karst in the world. This area's part of Beringia (the area that wasn't glaciated during the last few ice ages when the Bering Land Bridge was exposed), so for 200,000 years this karst has been forming. The Nahanni has absolutely exquisite canyons—four of them—entrenched meanders just like the San Juan and the Colorado rivers, where the land rose around the river instead of the river down-cutting. The deepest canyon on the Nahanni is 4,500 feet deep.

So imagine a place with no roads, 9.5 million acres in size, with the granite qualities of Yosemite, the canyon qualities of the Colorado plateau, and the thermal qualities of Yellowstone (without the geysers), and it's all big boreal wilderness, on top of which is the best development of subarctic karst in the world. Expanding the park is part of the federal government's action plan for the expansion of national parks in Canada. But there's a mining company that would like to put a mine right in the middle of the Prairie Creek drainage inside that watershed. So we are working our tails off to prevent that. We want Nahanni National Park Reserve to be expanded to take in the whole watershed, which would be 35,000 km^2, 9.5 million acres. The park now covers only a part of the river, and it's about one and a half times the size of Glacier [National Park]. We are about to start a big speaking tour of Canada to try to bring the message that the park's current size, and the extractive threats to it, are not good enough public policy. Instead, we have a dream: picture if you were to put a

park in at Yellowstone Lake and took it down to Big Timber, Montana. That's the opportunity we have here, and we're going to succeed.

And when we succeed, we will have fulfilled the original vision for national parks in North America from George Catlin: creating a nation's park with all the wild animals and the people who live on them, working with aboriginal people instead of excluding them—that's the way we're going with these things up north, where the opportunity still exists and, frankly, where the culture still exists in the aboriginal people. To have this passion for the landscape—the Nahanni for the Dehcho people is the source of their creation stories. That hot spring I showed you is called Umoria's Dinner Plate; he's the sort of monster in their creation myth. They still feel this powerful connection to place. It's an amazing thing. When mist rises on the river, Dehcho Grand Chief Herb Norwegian would say, that's the spirits of the people of the Nahanni. It's a place they didn't live, [but rather] just went into—a magic place just like Yellowstone.

In fact, this whole Yellowstone-to-Yukon idea makes a lot of sense to native people. When we first rolled it out, the response wasn't, "you're crazy;" the response was, "what took you so long?" Because they already have a name for the region. For the Dehcho Dene and all the other people in the north, it's called "The People's Trail." It came down between the ice sheets of the last big glacial period. For the Blackfoot people, or Blackfeet, as you call them here, it's called the Old North Trail, if you spend time in Glacier. So when we talk to aboriginal people about this, they say, of course—this is the way the land works, [and] this is how it should work.

Of course, at the foot of the People's Trail, we are back in the national parks of Waterton-Glacier and Yellowstone, and we are also brought back to the world. What we're doing here is part of a global movement. In 2004, Y2Y (Yellowstone-to-Yukon) organized a conference called, "Protecting the World's Mountain Corridors and Peace Parks." In attendance were people from all over the world. For example, a fellow from Nepal, Mingma Sherpa, spends his days working for the World Wildlife Fund on connecting the parks in the Terai Arc in the Himalayan foothills of Nepal and India for rhinoceros, elephant, and tiger. A young woman from Venezuela works on trying to keep connectivity for bears in the Andes. A fellow from Australia works on connecting corridors up the eastern mountains of Australia. And men from Spain and from Cantabria are having a conference next week [October 24–30, 2005] at which they are launching the Cantabrics/Alps/Pyrenees Initiative, which they describe as the baby of Y2Y, designed to keep carnivores like wolves and grizzly bears in the mountains of Europe. That's where I'm going on Saturday next to give my next talk. Lots of travel. But it's very cool. That project is the baby of Yellowstone-to-Yukon, as they put it. And of course, Yellowstone-to-Yukon is a baby of Yellowstone. All conservation is a baby of Yellowstone.

As we go forward in the twenty-first century, I'd like to invite you citizens of Yellowstone to reconceive your role in the world. You're the center of a global movement in an interdependent world. No park, no country is an island unto itself. The twentieth century was a lousy one for nature, and a lousy one for people, although we prosperous North Americans sometimes ignore that. It was a century of horrifically violent wars. It was a century of horrific genocides. It was the century when we changed the climate. It was the century in which we set in motion a biodiversity extinction crisis. It was the century in which we emptied out the oceans of fish. And it was the century whose forward motion is disastrous if we don't change it. But we *can* change it. All through that century, Yellowstone stood as a symbol of a different kind of world, one of generosity of spirit, humility, sharing the land with other species, and understanding there's magic in the world that comes from nature. Yellowstone has meant all of that to everyone in the world. The Yellowstone-to-Yukon vision is an effort to set the world in a new way. So are all the other things I talked about. And I believe profoundly that as we go forward in the twenty-first century, Yellowstone, conceived of as a symbol of hope in a saner world, will be more important than it has ever been.

Thank you.

Insect–Fire Interactions in Yellowstone National Park: The Influence of Historical Mountain Pine Beetle (*Dendroctonus ponderosae*) Activity on the Spatial Pattern of the 1988 Yellowstone Fires

Heather J. Lynch

Department of Organismic and Evolutionary Biology, Harvard University, Harvard University Herbaria, 22 Divinity Avenue, Cambridge, MA 02138 (617-495-1621, hlynch@fas.harvard.edu)

Roy A. Renkin

Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (307-344-2161, roy_renkin@nps.gov)

Robert L. Crabtree

Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59715 (406-556-1414, crabtree@yellowstoneresearch.org)

Paul R. Moorcroft

Department of Organismic and Evolutionary Biology, Harvard University, Harvard University Herbaria, 22 Divinity Avenue, Cambridge, MA 02138 (617-496-6744, moorcrof@fas.harvard.edu)

Abstract

We examined the historical record of mountain pine beetle (*Dendroctonus ponderosae* Hopkins) activity within Yellowstone National Park, Wyoming, for the 25-year period leading up to the 1988 Yellowstone fires (1963–1986) in order to determine how prior mountain pine beetle activity and resulting tree mortality affected the spatial pattern of the 1988 Yellowstone fires. To obtain accurate estimates of our model parameters, we used a Markov Chain Monte Carlo (MCMC) method to account for the high degree of spatial autocorrelation inherent to forest fires. Our final model included four statistically significant variables: drought, aspect, moderate mountain pine beetle activity in 1975, and heavy mountain pine beetle activity in 1975. Of the two major mountain pine beetle outbreaks to precede the 1988 fires, the older outbreak (1971–1976) was significantly correlated with the burn pattern, whereas the more recent outbreak (1980–1983) was not. Although regional drought and high winds were responsible for the overall scale of the event, we concluded that mountain pine beetle activity in the mid-1970s increased the odds of burning ~13.0–15.0% and, along with aspect and spatial variation in drought, contributed to the spatial pattern of burned and unburned areas.

Introduction

Both insect outbreaks and forest fires constitute important disturbance processes in the Greater Yellowstone Ecosystem (GYE), and research suggests that both insects and fire play a crucial role in the continuation and healthy functioning of the ecosystem (Despain 1990; Parker and Stipe 1993). Several authors have directly addressed the role of fire in promoting or inhibiting certain forest insects in the GYE (Amman 1991; Amman and Ryan 1991; Rasmussen et al. 1996). The converse question (Does insect activity promote or inhibit forest fire in the GYE?) has received surprisingly less attention, with no scientific consensus having yet been reached. With regard to mountain pine beetle (mpb), Parker and Stipe (1993) concluded that "[there] is no question . . . that the increased fuel loading from the beetle-killed trees has made the remaining lodgepole pine forest more susceptible to wildfires," while Despain (1990) argued that "[f]uels suitable for crown fires may be reduced by the beetles to the point of retarding fires."

Table 1. Datasets used in the analysis of the 1988 Yellowstone fires.

	Data layer	Abbreviation	Original data type	Source
Climate data[a]	Min. daily temp (°F)	tmin	text	NCDC[b]
	Max. daily temp (°F)	tmax	text	NCDC
	Ave. daily wind speed (mph in tenths)	wind	text	NCDC
	Total precip. (hundredths of an inch)	prcp	text	NCDC
	Palmer Drought Severity Index	pdsi	text	NCDC
Geographic data	Elevation (meters)	elev	30-m raster	NPS[c]
	Slope (degrees)	slope	30-m raster	NPS
	Aspect	see footnote[d]	50-m raster	derived from elevation
	Pre-1988 fire cover type	see footnote[e]	50-m raster	NPS
	Previous fire history	previous burn	polygon shapefile	NPS
Historical data	Mountain pine beetle activity (1963–1986)	mpbyy(severity)[f]	polygon shapefile	digitized from aerial survey

[a]An inverse-distance weighting was used to extrapolate climate variables from the three nearest weather stations available through the National Climate Data Center (Yellowstone Lake, West Yellowstone, and Yellowstone Park, Mammoth). This accounts for broad-scale patterns of climate variability. Factors affecting microclimatic conditions (slope, aspect, elevation) were included as separate variables.
[b]NCDC = National Climatic Data Center
[c]NPS = National Park Service
[d]Aspect was divided into eight categories: North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W), and Northwest (NW). Areas of zero slope were designated as "flat"; flat areas were used as the basis of comparison for the other aspect factors.
[e]Pre-1988 cover types were grouped into the following categories: aspen (As), Douglas-fir (early (DF0), mid- (DF1), or late-successional (DF2)), Engelmann spruce/subalpine fir (late-successional (ESSF2)), Krumholtz (Kr), lodgepole pine (early (LPP0), mid- (LPP1), or late-successional (LPP2)), pygmy lodgepole pine (PyLPP), whitebark pine (early (WBP0), mid- (WBP1), or late-successional (WBP2)), and non-forested.
[f]Severity classes were based on the original datasets and were grouped into the following categories: vl=very light, l=light, m=moderate, h=heavy, and vh=very heavy.

Mountain pine beetle (*Dendroctonus ponderosae*) activity in a stand initiates a long and complex cascade of ecological changes. In the short term (up to a year), needle death may increase canopy fuel loads, but subsequent needle drop and decomposition may actually eliminate much of the flammable fuels in the stand. Over longer timescales, fire risk will depend on both dead and downed coarse woody debris and on new growth, which may arise via the release of understory trees or through recruitment of new individuals. As noted by Despain (1990), most of the dead and downed trunks in the GYE are larger than three inches in diameter, and the bulk of this downed biomass will not burn even under the most intense fire conditions. Additionally, a study in northwestern Colorado (Kulakowski et al. 2003) suggested that the opening of the canopy may lead to a proliferation of moist understory vegetation that may prevent low-severity fires from burning. On the other hand, vertical heterogeneity arising from rapid release of understory trees combined with surviving mature individuals may provide ladder fuels sufficient to increase fire risk. It is almost certain that both fire-promoting and fire-inhibiting changes have occurred simultaneously, to varying degrees, over the decades following substantial insect activity in the GYE. Nevertheless, by analyzing the historical record of insect activity and fires in Yellowstone National Park (YNP), we can hope to identify the net effect of these concurrent, stand-level changes on the future risk of forest fire.

Historical data indicate that very large fires occur naturally in the GYE every 200–300 years (Romme and Despain 1989). It has been suggested that under these extreme circumstances, landscape heterogeneity arising from site-specific canopy and fuel load conditions plays no significant role in determining fire risk (Turner et al. 2003). In this analysis, we used an extensive and largely unexploited dataset of insect outbreaks in YNP to answer the question: Did the previous decades of mpb activity in YNP have a measurable influence on the spatial pattern of the 1988 Yellowstone fires?

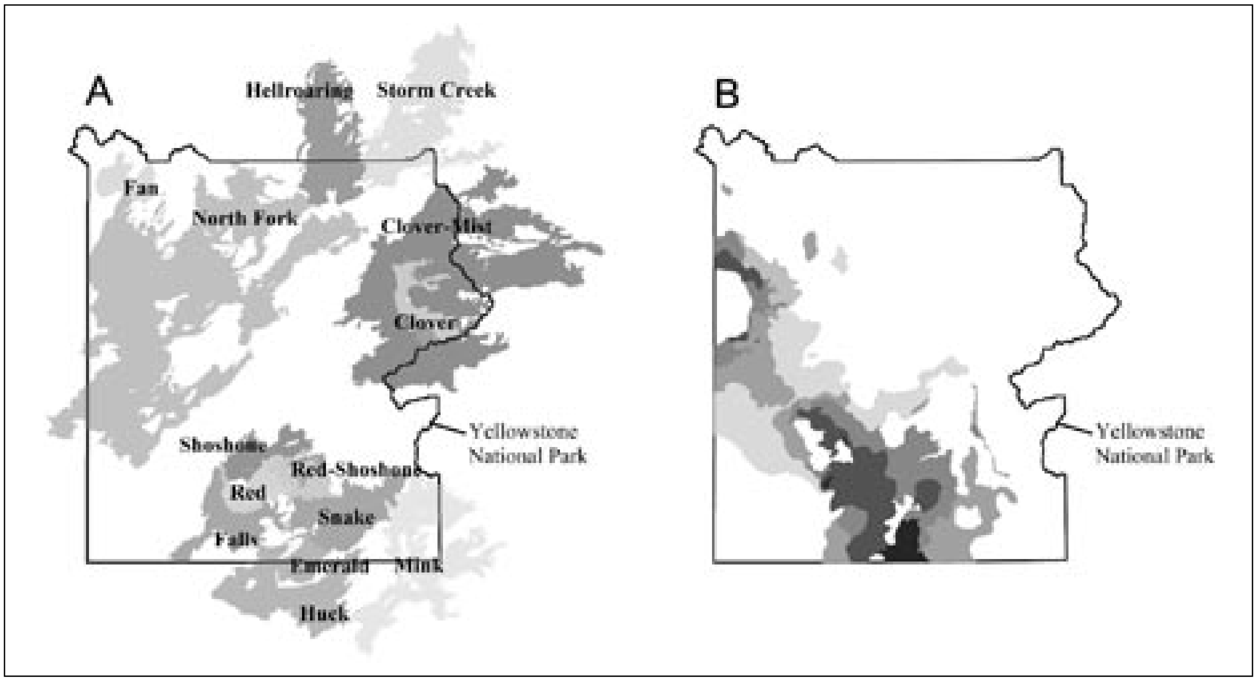


Figure 1A. Major fire complexes that comprised the 1988 Yellowstone fires.

Figure 1B. Tree mortality due to mountain pine beetle activity in 1975 (darker shades of gray represent more intense activity).

Methods

Analytical approach

The forestry and fire communities have long embraced the notion that insect outbreaks may affect both the occurrence and intensity of extreme fire events. In this analysis we considered only the final pattern of burned areas in Yellowstone following the 1988 fires in order to understand why some areas burned and some did not, conditional upon pre-existing conditions being amenable to an extreme fire. In addition to the spatial extent and intensity of mpb activity from 1963 to 1986, we included information on a number of variables that potentially played a role in promoting fire. These variables fell into several broad categories (see Table 1): climate/environmental factors, geographic factors, and previous fire history. By including all of these factors, we ascribed as much variability as possible to non-insect-related variables, and the resulting analysis of the role of mpb in promoting fire was conservative.

Data

The 1988 Yellowstone fires (Figure 1A) were one of the most well-documented large-scale disturbances in American history (Franke 2000; Turner et al. 2003; Wallace 2004). A complete GIS database is available with a daily record of fire extent and fire type (crown vs. ground vs. non-forested fire) for the entire duration of the fires (Despain et al. 1989; Rothermel et al. 1994).

To understand the influence of previous mpb activity on the 1988 Yellowstone fires, we compiled all available aerial detection surveys of forest insect activity within the park covering the years 1963–1986. Hardcopy maps (1:125,000 scale), initially provided by the U.S. Forest Service's Northern Region Forest Health Protection Group and archived in Yellowstone National Park, were digitized using a high-resolution scanner and integrated into a complete GIS database by a process of manual (on-screen) digitization. This geographic database was georeferenced using existing (on-image) map grid points and given attributes (insect agent, intensity of tree mortality) according to the information provided in the original maps.

From 1962 to 1986, two different insect intensity scales were used in the aerial detection surveys: an ordinal scale with five categories ranging from "very light" to "very heavy" (1964, 1970–1976, 1980, 1986) and a cardinal scale indicating the approximate number of trees affected by insect activity (1969, 1977–1985). Two years used both scales (1962 and 1967), and in 1965, no intensities were indicated. Fortunately, in some cases, both scales were used, allowing us to develop an approximate conversion between the two scales of measure in order to treat insect activity intensities uniformly across the entire

database. This conversion is included in Table 2.

The aerial surveys and the corresponding database included all pests or pathogens that could have been detected by aerial survey, including mpb, Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins), spruce beetle (*Dendroctonus rufipennis* Kirby), western balsam bark beetle (*Dryocoetes confuses* Swaine), and defoliating species such as the western spruce budworm (*Choristoneura occidentalis* Freeman). The insects whose activity was detected and recorded in this database are listed in Table 3. Repeated outbreaks, widespread activity, and the broad distribution of host species (primarily lodgepole pine [*Pinus contorta* Dougl. var *latifolia*] and whitebark pine [*Pinus albicaulis* Engelm.]) of the mpb complemented the broad spatial extent of the 1988 Yellowstone fires, making the mpb the choice insect agent for this analysis. Figure 1B represents the spatial extent of tree mortality due to mountain pine beetles in 1975, a year of extensive insect activity and one that was ultimately significant in our analysis.

Table 2. Conversion table for the cardinal and ordinal scales for reporting insect activity intensity.

Cardinal category	Ordinal range (n = # trees affected per hectare)
Very light	n ≤ 0.5
Light	0.5 ≤ n ≤ 5
Moderate	5 ≤ n ≤ 10
Heavy	10 ≤ n ≤ 50
Very heavy	n ≥ 50

To account for other potentially important risk factors, we compiled spatial datasets of geographic, topographic, and climatological factors that may also have played a role in determining which areas burned in 1988 and which did not (Table 1). These data layers were re-sampled or digitized as appropriate on a common 100-m-resolution raster grid. This dataset was then exported to the statistical software package

Table 3. Historical data on the presence or absence of various insect and fungal pathogens as represented in the aerial survey maps discussed in the text.*

	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Comandra rust (*Cronartium comandrae*)	X			X								X													
Douglas-fir beetle (*Dendroctonus pseudotsugae*)	X	X	X			X							X						X		X	X	X	X	X
Fir engraver (*Scolytus ventralis*)	X	X	Y	Y																					
Lodgepole needle miner (*Coleotechnites milleri*)	X																								
Mountain pine beetle (*Dendroctonus ponderosae*)	X		X	X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pine engraver (*Ips pini*)													X												
Spruce beetle (*Dendroctonus rufipennis*)								X																	
Western balsam bark beetle (*Dryocoetes confuses*)			Y	Y		X		X								X	X	X			X		X	X	X
Western spruce budworm (*Choristoneura occidentalis*)	X	X	X	X		X		X		X	X	X	X	X		X	X	X	X	X		X	X	X	X

*X represents presence; Y represents potential presence.

R (R Development Core Team 2005) and re-sampled every 500 m so that each data point represented a 100 × 100-m pixel from the original dataset, spaced 500 m apart. The re-sampling was necessary to reduce the size of the dataset for computational speed. The final dataset was a 219 × 209-pixel grid (45,771 pixels), from which pixels with no data (inside the YNP bounding box but outside the park boundary), pixels representing water cover types, and pixels identified as non-forest were removed. There were 28,748 pixels in the final dataset.

Data analysis

In this analysis, the independent variable of interest was the binary (0,1) variable indicating whether or not a particular area burned in the 1988 Yellowstone fires. Accordingly, we transformed the original dependent variable y_i to regress the log-odds of burning in 1988 against its potential covariates as follows (Equation 1):

in which y_i represents the burn status of the pixel (y_i = 1 if the pixel burned), β_0 represents the intercept,

$$\mathrm{logit}(y_i) = \log\left(\frac{y_i}{1-y_i}\right) = \beta_0 + \sum_i \beta_i x_i$$

and the β_i represents the regression coefficients for the covariates x_i.

Ordinary logistic regression implicitly requires that individual data points are independent; this basic requirement is immediately violated in any analysis involving a spatial context. This is particularly true in the analysis of "contagious" forest disturbances; the underlying contagious nature of fire spread dictates that neighboring regions are not independent. Accurate determination of the regression coefficients requires one to account for the non-independent nature of the independent variable. Several schemes have been developed to account for autocorrelation in logistic regression analysis. Besag's (1972, 1974) coding method divides the pixels into two interlocking sets of points arranged like the red and black tiles on a checkerboard; the two sets depend on each other, but the points within each set are assumed to be independent. The pseudolikelihood approach simply adds the sum of nearest-neighbor values as an additional covariate to the regression model; this technique has been studied by many authors (Besag 1975; Ripley 1988) and can be easily applied using standard regression software. More recently, a spatial filtering approach has been suggested (Griffith 2004) by which the eigenvectors of a modified spatial weights matrix are added as additional regression covariates; these eigenvectors serve as surrogates for unknown latent factors underlying the spatial autocorrelation. Finally, a Markov Chain Monte Carlo (MCMC) approach (Wu 1994; Wu and Huffer 1997; Huffer and Wu 1998) has been developed that can approximate the maximum likelihood function for probability densities known up to a constant of proportionality.

In this analysis, we use the MCMC approach as developed by Huffer and Wu, who used the technique to understand the underlying environmental factors responsible for plant species distributions. As shown in several case studies (Huffer and Wu 1998; Hubbell et al. 2001), the MCMC approach more accurately captures the latent spatial autocorrelation of these types of ecological problems and has been shown to more accurately represent the estimate errors. Although the details of our analytical technique have been reported elsewhere (Lynch et al. in press) and will not be described here, it is sufficient to note that ultimately, our regression analysis involves estimating the maximum likelihood function (Equation 2):

where y_i, x_i, β, and γ represent the burn state at pixel i, the covariate values at pixel i, the transpose of

$$\ell(\beta,\gamma) = \frac{e^{\beta'\sum_i x_i y_i + \gamma \sum_i \sum_{j^*} x_i y_i y_j}}{\sum_{\text{all map possibilities}} e^{\beta'\sum_i x_i y_i + \gamma \sum_i \sum_{j^*} x_i y_i y_j}}$$

the covariate regression coefficients, and the nearest-neighbor regression coefficient, respectively. Note that the denominator involves a sum over all possible permutations of burned and unburned pixels; this intractable normalizing constant cannot be evaluated analytically and must be estimated using MCMC methods. Further details on the general technique may be found in the papers by Huffer and Wu (Wu and Huffer 1997; Huffer and Wu 1998). A clear and straightforward overview of this technique as applied in an ecological context may be found in Hubbell et al. (2001).

Model selection

Because of their computational complexity, MCMC methods are not suitable for model selection (for example, by means of forward step-wise regression), and an appropriate set of models was chosen based on the pseudolikelihood approach described above. In the first step, all 80 variables

were put into the model, and a combination of forward and backward step-wise regression (using the R function "step") was used to select the best model according to Akaike's Information Criterion (a criterion used for selecting among nested models). To further simplify the model, variables that were not significant at the 5% confidence level (slope, mpb85(l), mpb74(m), and mpb73(m)) were eliminated (see Table 1), and the four significant aspect variables (which spanned the continuous range from northwest–north–northeast–east) were combined into one variable, which we called "northeast." Finally, we narrowed our focus to consider only insect activity in 1975, which had the most robust effect on the fire model independent of the particular formulation of the model.

Because the MCMC approach takes into account neighboring burn states to determine the probability of burning, pixels that were not included in the model (such as the boundary of the park, non-forested areas, and water) required (fixed) predefined burn states. Our approach was to assign the park border and interior non-forested areas a burn state according to a binary random variable with probability of burning equal to the actual probability of burning over those pixels (p_{burn}=0.415). The model, therefore, gets no spatial information from these pixels. Areas of water were set to burn=0, because under no circumstances would those have burned. In reality, the final burn pattern in 1988 was informed to some extent by the actual burn pattern along the boundary and in non-forested areas, and our approach was therefore conservative. We excluded from our final model covariates that were not robust to the random values of the border pixels (ESSF2 and mpb75(vh) (see Table 1). Our final statistical model,

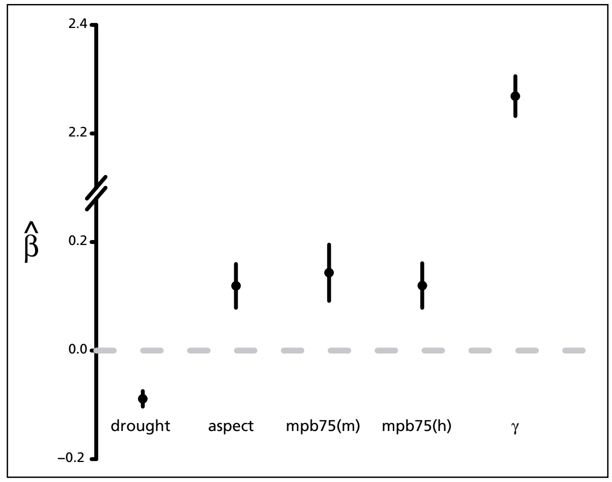


Figure 2. Graphic summary of the results of this analysis. The x-axis represents the various covariates included in the final model. Error bars represent 95% confidence limits for the value of $\hat{\beta}$.

represented in Equation 3 (below), contained only four variables: pdsi (Palmer Drought Severity Index), northeast (representing all aspects within 90° of 22.5° northeast), mpb75(m) (moderate mountain pine beetle intensity in 1975), and mpb75(h) (heavy mountain pine beetle intensity in 1975).

$$\text{logit}(y_i) \sim pdsi + northeast + mpb75(m) + mpb75(h)$$

Results

The results of the analysis are summarized in Figure 2 and Table 4. Figures 3A and B represent the burn probabilities as modeled either when no autocorrelation was accounted for (see Table 4) or when only autocorrelation was included (i.e., when the model consisted of only an intercept and an

Table 4. Best-fit model estimates (and standard errors) discussed in the text.

	ß0	pdsi	northeast	mpb75(m)	mpb75(h)	λ	Fig. 3
Logistic (site-specific only)[1]	–4.96(0.16)	–0.90(0.03)	0.25(0.02)	1.37(0.06)	1.77(0.06)		A
MCMC (autologistic only)[2]	–4.47(0.04)					2.25(0.02)	B
PSE (site-specific+ autocorrelation)[3]	–6.46(0.49)	–0.20(0.09)	0.28(0.08)	0.46(0.16)	0.72(0.21)	2.67(0.04)	
MCMC (site-specific +autocorrelation)[3]	–5.05(0.06)	–0.09(0.01)	0.12(0.02)	0.14(0.03)	0.12(0.02)	2.27(0.02)	C

[1]The top line represents the best-fit estimates using standard logistic regression with no autocorrelation variable.
[2]The second line represents the results of MCMC maximization for the gamma-only model.
[3]The last two lines represent the pseudolikelihood estimates and MCMC estimates (respectively) for the full model, which includes both site-specific variation in the covariates and autocorrelation. Estimated errors for the MCMC-derived estimates are calculated from the Fisher information matrix, as detailed in Huffer and Wu (1998). Monte Carlo variability is not reported, but is typically a factor of ten smaller than the reported estimated error.

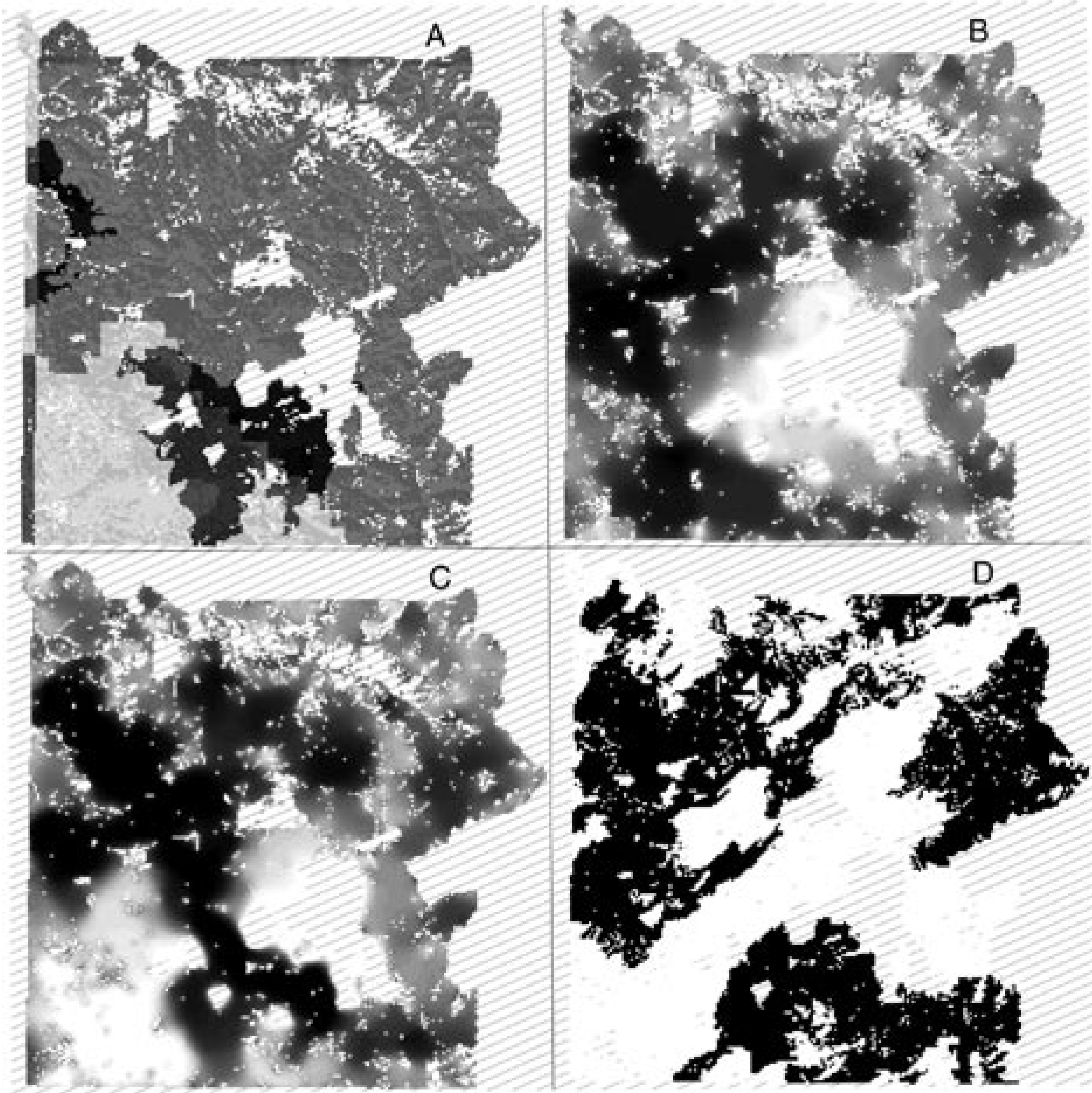


Figure 3. Figures 3A–C illustrate the probability of burning from the best-fit models, and Figure 3D illustrates the actual 1988 burn map (black=burned). Maps A–C correspond to the models incorporating no autocorrelation (A), only autocorrelation (B), and the full model (C) as indicated in Table 2. Map A represents the probability of burning according to the best-fit standard logistic model. Maps B and C represent the probability of burning (with darker shades of gray representing increasing probability of burning) over 20,000 MCMC iterations following an initialization period of 2,000 iterations starting with all forest pixels initially unburned. As discussed in the text, boundary pixels and non-forested areas (pixels left blank in the map) were drawn from a binary random variable. These maps represent an average over ten different simulations representing ten different randomly drawn boundaries. The grayscale ranges from zero probability of burning (white) to unity probability of burning (black).

autocorrelation parameter, see Table 4). As seen in Figure 3A, the simple auto-logistic model, which ignores spatial autocorrelation in fire spread, does not capture the spatial scale of the 1988 fires, and shows both very small-scale variation in the log-odds of burning (due to the aspect variable) and very large-scale variation (due primarily to drought). This model is also strongly biased, and overestimates the overall amount of burning. A model including only nearest-neighbor interactions (Figure 3B) accurately captures the overall scale at which burning occurs, but with no spatial information (other than the locations of the water bodies, which biases neighboring pixels in the direction of not burning), this model

cannot identify which areas are more likely to have burned than others.

Our final (site-specific+autocorrelation) model (Figure 3C) captures both the spatial scale of the 1988 fires and their placement across the park. All four covariates in our final model are statistically significant, including moderate and heavy mpb activity occurring in 1975. The model correctly classifies 64.7% of all pixels. The number of misclassified burned pixels (5,556 of 15,749) is approximately equal to the number of misclassified unburned pixels (4,605 of 12,999); the model, therefore, produces approximately unbiased predictions of burn risk. Figure 3C illustrates the fit of our model, which captures both the large-scale pattern and many of the finer-scale details of the final burn pattern (Figure 3D). This highlights the interaction between site-specific fire risk and the strong autocorrelation inherent to fire spread; both components are necessary to generate a reasonably accurate statistical model for the event.

The vertical error bars in Figure 2 represent the 95% confidence envelope of the value presented, and are associated with the probability that a particular variable is different than zero. This leads us to investigate the statistical probability that both of the insect-related βs are zero; that is, what is the probability that mpb activity played no role in the 1988 Yellowstone fires? The multivariate Wald statistic Z_0^2, which under the null hypothesis of zero insect activity effect is distributed as χ^2(df=2), is 146.0. Therefore, the probability that both β_{insect} values are actually zero is effectively nil.

The variables "northeast," "mpb75(m)", and "mpb75(h)" are all 0/1 factors; therefore, the relative strengths of each can be compared using the magnitudes of their coefficients. The range of the variable "pdsi" was 2.01, making the overall impact of that variable on burn risk similar to that of the other three factors. All four variables are approximately equal with regard to their impact on the log-odds of burning, and we can use Equation 1 to calculate the change in fire risk associated with any of these variables. For example, moderate mpb intensity in 1975 ($\bar{\beta}$ =0.14) is associated with a 15.0% increase in the odds of burning during the summer of 1988. Although it may seem counterintuitive that each of the four variables has such a small effect on the fire risk and yet the full model fits the actual burn pattern so well, the overwhelming spatial autocorrelation inherent to forest fires dominates the actual pattern of fire spread, and the underlying factors identified in our model function primarily to break the isotropy of the landscape in regard to fire spread.

Therefore, mpb activity some 10–12 years previous to the 1988 fire event served to increase fire risk and ultimately may have influenced the spatial patterning of burned areas. The effects of previous moderate- and high-intensity beetle activity are comparable in magnitude to other factors affecting fire risk, such as drought and aspect, in our model.

Discussion

As noted by other authors (Knight and Wallace 1989), the pre-1988 Yellowstone landscape was a patchy mosaic representing the accumulated history of biological and geological processes. The 1988 Yellowstone fires proceeded across the landscape under the constraints of this heterogeneity, and the final pattern of burned areas represents a complex mixture of site-specific flammability and the contagious nature of fire itself. Using the MCMC technique described above, we were able to untangle these two components in order to understand which site-specific characteristics, such as previous insect activity, may predispose some patches to burn while other patches are left untouched.

Before considering the main question of mpb activity and fire risk, it is important to consider the biological relevance of the other two variables that remained significant in the final model: average drought and northeastern aspect. It is not surprising that fine-scale spatial variation in drought was significant in our model, because others have demonstrated the role of drought in promoting the extreme fire conditions present in 1988 (Christensen et al. 1989; Renkin and Despain 1992; Schoennagel et al. 2004). The second factor, aspect, is also known to affect fire spread. Southward-facing slopes experience the most incident sunlight, and the subsequent drying is known to increase fire risk. Northern aspects, on the other hand, tend to support higher fuel loads because they retain moisture more effectively than southern aspects. Fires typically spread more quickly upslope, and because 1988 fire spread was generally in a southwest-to-northeast direction, the northeast aspects were typically on the leeward side of the mountains from the advancing fire front. The fires, then, would have spread most slowly on the northeast-facing slopes, generally backing downslope. We hypothesize that this slow burning on northeastern-facing slopes, coupled with increased fuel loads, may have allowed for relatively slower, but more, fire spread in these areas. It is important to note that because cover type was included in the original set

of covariates, the effect of aspect is independent of any differences in cover type, and must result from something other than differences in stand composition or stand age.

The results of this analysis demonstrate that even when considering a wide range of potential variables, mpb activity remains a statistically significant factor when choosing models to explain the final pattern of burned areas for the 1988 Yellowstone fires. Moderate- to high-intensity mpb activity is particularly correlated with the risk of burning, and represents a factor that increased the odds of burning by 12.7–15.0%. Consistent with this conclusion, we note that in the period 1974–1986, areas that eventually burned in 1988 had consistently higher average mpb activity than those that did not burn in 1988. It is interesting to note that in the 25 years prior to 1988 for which we have complete insect activity records, there were two major outbreaks of mpb: one during the period 1971–1976, and the other during 1980–1983. Whereas beetle activity during the first outbreak is correlated with an increase in fire risk, activity during the second outbreak was either uncorrelated or negatively correlated with the log-odds of burning in 1988, once spatial interaction effects had been accounted for. This result—that mpb activity increases fire risk only after a period of 10–12 years—was unexpected, but is consistent with earlier work pointing to a strong time-dependence in the strength of insect–fire interactions (Lynch and Moorcroft in review). The biological mechanisms leading to this delayed increase in fire risk require further study, although the timescale of the process would be consistent with the time required for significant release of understory vegetation.

In this analysis, we considered each category of beetle-induced tree mortality (very light, light, moderate, heavy, and very heavy) as separate and independent binary factors in order to avoid making any assumptions about the relative impact of varying levels of insect activity. For example, high levels of insect activity may cause widespread mortality and changes in stand structure and composition, whereas light damage may cause only scattered mortality with no widespread recruitment from the understory. There is no obvious ordinal relationship in the fire risk associated with these different ecological changes, and it was more appropriate to consider each activity level independently. Our results consistently demonstrated that moderate and heavy mpb activity were most strongly associated with fire risk, whereas very light, light, and very heavy activity were not significantly correlated with a change in the log-odds of burning. More field work will be required in order to understand why areas experiencing such intermediate activity are at the highest risk of future burning.

This analysis focused specifically on the influence of mountain pine beetles in landscape-level heterogeneity in fire risk. There are several other forest pests of concern in the Yellowstone region, including other bark beetles such as Douglas-fir beetle, spruce beetle, and western balsam bark beetle, and defoliating species such as the western spruce budworm. A previous study has shown that defoliating insects may actually inhibit forest fires (Lynch and Moorcroft in preparation), and it seems likely that the influence of insects in affecting fire risk differs according to feeding guild. Preliminary analysis suggests that western spruce budworm activity in the period studied is associated with decreased risk of burning in 1988, although this requires further study.

Conclusion

In this analysis of the 1988 Yellowstone fires, we found a measurable influence of mpb activity in increasing the odds of burning in 1988, by 15.0% and 12.7% for moderate and heavy insect activity in 1975, respectively. More recent insect activity was not significantly correlated with increased risk of burning, and mechanisms underlying this delayed increase in fire risk will require further research. Plot studies of fuel load changes following insect activity are now being planned (M. Simard, pers. comm.) and it is likely that studies such as these will help illuminate the underlying biological changes involved in the delayed increase in fire risk we report here.

Finally, the results of this study highlight the importance of regular, long-term, and spatially explicit mapping of insect and pathogen activity within the park. Yellowstone National Park, under the current wildland fire program, is a unique natural laboratory for understanding the spatial and temporal dynamics of these complex phenomena. Ongoing efforts toward a complete digital database of park terrain, biogeography, and forest disturbance within the park will continue to spur important developments in both basic and applied research.

References

Amman, G. D. 1991. Bark beetle-fire associations in the Greater Yellowstone Area. Pages 313–320 *in* S. C. Nodvin and T. A. Waldrop, eds., *Fire and the environment: ecological and cultural perspectives*. Proceedings of an International Symposium, Knoxville, Tenn., March 20–24, 1990. Asheville, N.C.: USDA Forest Service, Southeastern Forest Experimental Station.

Amman, G. D., and K. C. Ryan. 1991. Insect infestation of fire-injured trees in the Greater Yellowstone Area. Technical Report, USDA Forest Service Research Note INT-398.

Besag, J. 1972. Nearest-neighbor systems and the autologistic model for binary data (with discussion). *Journal of the Royal Statistical Society, Series B* 34:75–83.

______. 1974. Spatial interaction and the statistical analysis of lattice systems (with discussion). *Journal of the Royal Statistical Society, Series B* 36:192–236.

______. 1975. Statistical analysis of non-lattice data. *The Statistician* 24:179–195.

Christensen, N. L., J. K. Agee, P. F. Brussard, J. Hughes, D. H. Knight, G. W. Minshall, J. M. Peek, S. J. Pyne, F. J. Swanson, J. W. Thomas, S. Wells, S. E. Williams, and H. A. Wright. 1989. Interpreting the Yellowstone fires of 1988. *BioScience* 39(10):678–685.

Despain, D. G. 1990. *Yellowstone vegetation: consequences of environment and history in a natural setting*. Boulder, Colo.: Roberts Rinehart Publishers.

Despain, D. G., A. Rodman, P. Schullery, and H. Shovic. 1989. Burned area survey of Yellowstone National Park: the fires of 1988. Unpublished report on file in the Yellowstone Center for Resources, Yellowstone National Park.

Franke, M. A. 2000. Yellowstone in the afterglow: lessons from the fires. Technical report, National Park Service, Mammoth Hot Springs, Wyoming, YCR-NR-2000-03.

Griffith, D. A. 2004. A spatial filtering specification for the autologistic model. *Environment and Planning A* 36:1791–1811.

Hubbell, S. P., J. A. Ahumada, R. Condit, and R. B. Foster. 2001. Local neighborhood effects on long-term survival of individual trees in a neotropical forest. *Ecological Research* 16:859–875.

Huffer, F. W., and H. Wu. 1998. Markov Chain Monte Carlo for autologistic regression models with application to the distribution of plants species. *Biometrics* 54(2):509–524.

Knight, D. H., and L. L. Wallace. 1989. The Yellowstone fires: issues in landscape ecology. *BioScience* 39:700–706.

Kulakowski, D., T. T. Veblen, and P. Bebi. 2003. Effects of fire and spruce beetle outbreak legacies on the disturbance regime of a subalpine forest in Colorado. *Journal of Biogeography* 30:1445–1456.

Lynch, H. J., and P. R. Moorcroft. Extending Ripley's K-function for the analysis of insect–fire interaction in British Columbia. In preparation.

Lynch, H. J., P. R. Moorcroft, R. A. Renkin, and R. L. Crabtree. The influence of previous mountain pine beetle (*Dendroctonus ponderosae*) activity on the 1988 Yellowstone fires. *Ecosystems*, in press.

Parker, D. L., and L. E. Stipe. 1993. A sequence of destruction: mountain pine beetle and wildfire. Technical Report, USDA Forest Service, Southwest Region.

Rasmussen, L. A., G. D. Amman, J. C. Vandygriff, R. D. Oakes, A. S. Munson, and K. E. Gibson. 1996. Bark beetle and wood borer infestation in the Greater Yellowstone Area during four postfire years. Technical Report, USDA Forest Service, Research Paper INT-RP-487.

R Development Core Team. 2005. R: a language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. ISBN 3-900051-07-0.

Renkin, R. A., and D. G. Despain. 1992. Fuel moisture, forest type, and lightning-caused fire in Yellowstone National Park. *Canadian Journal of Forest Research* 22(1):37–45.

Ripley, B. D. 1988. *Statistical inference for spatial processes*. Cambridge: Cambridge University Press.

Romme, W. H., and D. G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. *BioScience* 39(10):695–699.

Rothermal, R. C., R. A. Hartford, and C. H. Chase. 1994. Fire growth maps for the 1988 Greater Yellowstone Area fires. Technical Report, USDA Forest Service, General Technical Report INT-304.

Schoennagel, T., T. T. Veblen, and W. H. Romme. 2004. The interaction of fires, fuels, and climate across Rocky Mountain Forests. *BioScience* 54(7):661–676.

Turner, M. G., W. H. Romme, and D. B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment* 1(7):351–358.

Wallace, L. L., ed. 2004. *After the fires: the ecology of change in Yellowstone National Park*. New Haven: Yale University Press.

Wu, H. 1994. *Regression models for spatial binary data with application to the distribution of plant species*. Ph.D. thesis, Florida State University.

Wu, H., and F. W. Huffer. 1997. Modelling the distribution of plant species using the autologistic regression model. *Environmental and Ecological Statistics* 4:49–64.

Recreation on the Upper Yellowstone River: A Study of Use and Place

Megan McBride

1525 Olive Street, Denver, CO 80220 (406-531-6146, meganmcbride@yahoo.com)

Norma P. Nickerson

32 Campus Dr. #1234, University of Montana, Missoula, MT 59812
(406-243-2328, norma.nickerson@umontana.edu)

Abstract

The concept of place and how individuals relate to recreation areas has been an aspect of considerable interest within recreation literature. Past research has used this concept to unify groups of people through their attachment to place. However, there is a push within research to recognize that multiple interpretations of space exist, and therefore, how individuals view a particular place may differ from person to person. The study area for this paper was the upper Yellowstone River between Gardiner and Springdale, Montana. The purpose of this study was to investigate recreation use, recreationists' attachment to place, and common and divergent views of the river. During the summer of 2004, 307 individuals completed a quantitative survey looking at individuals' recreation activities, levels of satisfaction, attachment to place, and level of concern regarding growth along the upper Yellowstone River. Additionally, 20 recreationists participated in in-depth interviews to shed further light on place attachment. Results show that recreationists participate in a variety of activities and are very satisfied with their recreation experiences. The place attachment dimension was described as a combination of two factors: place identity and place dependence. Place identity was the stronger factor, indicating a sound emotional attachment to the river. Further analysis revealed concern among recreationists about development. Findings indicated that individuals' emotional connection to the watershed is being changed and challenged by increasing development along the banks of the upper Yellowstone River. This study proposes that the issue of development and its effects on recreationists' attachment to place be further studied.

The Yellowstone River is the longest free-flowing river in the lower 48 United States, and is habitat for diverse wildlife and fish populations. After the river leaves the boundaries of Yellowstone National Park, it heads north through Paradise Valley (Park County, Montana). The upper Yellowstone River ecosystem (Figure 1) is currently experiencing rapid development of small ranchettes that dot the horizon for miles. Additionally, more river users are seen along the banks and in the river than ever before. The upper Yellowstone River has been "discovered."

This "discovery," and recent floods, have prompted research questions related to the upper Yellowstone River. In November 1997, after 100-year floods in 1996 and 1997, former Montana governor Marc Racicot created a task force of diverse stakeholders to develop a set of recommendations for management of the upper Yellowstone River Valley (GUYRTF 2003, 13). Over the seven years in which the task force met, the members used information from a variety of studies on and around the upper Yellowstone River to develop its recommendations. Recommendation VI.d, which stated, "A study should be funded to identify the current conflicts and potential future conflicts arising from changing uses of the upper Yellowstone River," pointed to the need to further study the human dimensions at work within the upper Yellowstone River Valley (Harvey 2002).

Additionally, in 2004, Montana Fish, Wildlife and Parks (FWP) conducted an internal review of rivers in the state to assess the level of social conflicts occurring, and to determine where the department might need to initiate further analysis and management actions. Although the review was not a rigorous scientific study, the results labeled the river as a high conflict area where the department needs to acquire more information on the issues and the amount and types of use that are occurring.

With the above needs stated, this paper examines use and place attachment on the upper Yellowstone River. To date, most of the studies conducted

on the Yellowstone have related to the ecology of the system, focusing on riparian management, fisheries, bank stabilization, and river modification. Humans, however, cannot be left out of this equation, as human modifications profoundly impact and change the river. Thus, in order to best manage the upper Yellowstone, there is a need to understand the people using the river.

The purpose of this study was to establish a baseline of recreation use on the upper Yellowstone River and to gain an understanding of recreationists' attachment to place—both the shared understandings of a recreation area and the divergent views of this shared space.

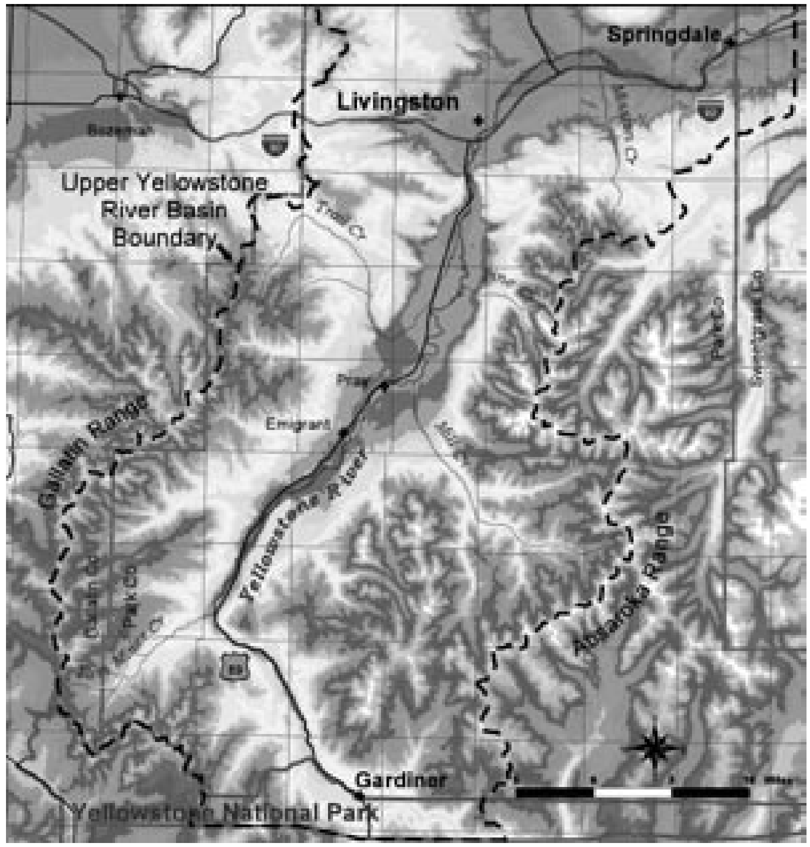


Figure 1. Upper Yellowstone River study area.

River recreation and place attachment

With increasing numbers of people heading to public lands and waters for leisure pursuits, the field of recreation management continues to expand. Sun and Walsh (1998) define recreation as "a means by which people achieve desired objectives for their leisure life." Other research has identified the different aspects of recreation. Sherif, along with other researchers, focused on the idea of activity involvement within recreation, noting cognitive linkages between an individual and her chosen leisure activity (Sherif and Cantril 1947; Sherif and Howland 1961; Sherif et al. 1965).

More recently, a variety of research specifically related to river recreation has been conducted. Taylor and Douglas (1999) integrated economic and social value information as a means of establishing "greater depth of understanding of [a] resource's value." Issues such as crowding have been studied in relation to encounter norms among whitewater recreationists (Roggenbuck et al. 1991; Shelby and Vaske 1991). Heywood (1987, 3) cited the importance of realizing the diversity of social groups involved in recreation activities on the same stretch of river.

Much of the research on recreation in general, and river recreation specifically, has focused on the concept of recreation experience. Recreation experience deals with recreationists' characteristics related to preferences (Iso-Ahola 1980). Experience has been found to be affected by the naturalness of a setting, the aesthetic appeal of an area, and the innate value of instream flows (Taylor and Douglas 1999, 332). Thus it is essential, when conducting research, to identify and gauge not only the importance of general aspects of recreation, but also aspects of the experience unique to the area in which individuals are recreating.

Unique aspects of an area tie into the concept of place attachment. Place, and how individuals relate to recreation areas, have been of considerable interest within recreation literature. Past research has used this concept to unify groups of people through their attachment to place. The basis of the concept of place was nicely stated by Williams (1995): "From the human experience, an ecosystem is foremost a place—a place to extract a living, to play, to affiliate, to appreciate, to define self, and to become acquainted with one's origins be they biological or spiritual" (7). Thus, whether in terms of work or play, the locations where these activities take place are imbued with human meaning, leading to the development of individuals' attachments to specific places, which hold value and meaning (Warzecha and Lime 2001, 60).

While the different aspects of place vary, be they a couch in one's living room, a neighborhood, a continent, or anywhere in between (Williams et al. 1992, 31), the affective and emotional components of the concept of place attachment are present in most analyses of place (Altman and Low 1992; Williams et al. 1992; Moore and Graefe 1994; Bricker and Kerstetter 2002; Tuan 1974). According to Altman and Low (1992, 4–5), "A number of writers state that emotional qualities are often accompanied by cognition (thought, knowledge, and belief) and practice (action and behavior). That is, place attachment involves interplay of affect and emotions, knowledge and beliefs, and behaviors and actions in reference to a place."

There is a push within research to recognize that multiple interpretations of space exist, and therefore, how individuals view a particular place may differ from person to person. In this study, therefore, it was important to understand how recreationists

Table 1. Demographics of river users.

	n	%
Gender		
Male	170	56%
Female	132	44%
Mean age	39.9	
Residence of respondents		
Outside Montana	114	37%
Montana	193	63%
Gallatin County	83	27%
Park County	58	19%
Own property adjacent to river	6	2%
Group type		
Friends	105	35%
Family	87	29%
Friends & family	50	17%
Guided group	45	15%
Self	16	5%
Group size		
Mean	6.3	
Median	4.0	
Education		
College graduate	136	45%
Post graduate	73	24%
Some college	60	20%
High school	27	9%
Technical school	7	2%
Income		
<$20,000	38	13%
$20,000–$39,999	59	21%
$40,000–59,999	54	19%
$60,000–$79,999	42	15%
$80,000–$99,999	28	10%
≥$100,000	63	22%
Repeat visitors	**238**	**78%**
Mean # of years of river use	**13.28**	
Primary reason for visiting*		
Close to home	103	36%
Fishing	65	22%
Scenic beauty	54	19%

*top three

Table 2. Activity participation.

	n	%
All activities		
Viewing nature	187	62%
Viewing wildlife	167	56%
Rafting	145	48%
Boat angling	128	43%
Wade angling	92	31%
Picnicking	86	29%
Bank angling	80	27%
Tent camping	70	23%
Driving for pleasure	66	22%
Nature photography	56	19%
Other	52	17%
Swimming	13	4%
Activities with dogs	7	2%
Day hiking	51	17%
Canoeing	49	16%
Birding	44	14%
Tubing	40	13%
Walking/jogging	39	13%
Kayaking	36	12%
Auto/RV camping	23	8%
Biking	10	3%
Primary activity		
Boat angling	83	29%
Rafting	83	29%
Other (write-in): Swimming and activities with dogs	28	10%
Kayaking	19	7%
Canoeing	15	5%
Wade angling	15	5%
Bank angling	8	3%
Tubing	7	2%
Viewing nature	7	2%
Day hiking	6	2%
Driving for pleasure	6	2%
Viewing wildlife	4	1%
Walking/jogging	3	1%
Auto/RV camping	3	1%
Tent camping	2	1%
Nature photography	1	0%
Birding	1	0%
Biking	0	0%
Picnicking	0	0%

on the upper Yellowstone River use and define the watershed.

Methods

Both quantitative and qualitative survey methods were employed to understand river use and attachment. During the summer of 2004, recreationists at 22 fishing access sites were asked about their use along the river. Interviews were requested with those who had been recreating along the river for five years or longer. Of those asked for an interview, 96% agreed to the taped interview (qualitative method). After 20 interviews were conducted, it was believed that all information was being repeated; therefore, the interviewing came to an end. In addition, a two-page written questionnaire was completed by 307 respondents as they recreated along the river (quantitative method).

Results

To understand recreation use along the upper Yellowstone River, questions about demographics, type of use (activities), attachment, and concerns appeared on the written survey. In-depth interviews were used to clarify attachment and concerns. Demographic results showed that the upper Yellowstone River was used largely by Montanans with college degrees who used the river quite often (Table 1). Recreationists participated in a variety of activities, with viewing nature, viewing wildlife, rafting, and fishing being the activities engaged in by most respondents. When asked to identify their primary activity, boat angling and rafting came out as the most predominant activities, with 29% of those surveyed identifying one of these as their primary activity (Table 2).

The place attachment dimension comprised two factors: place identity and place dependence. The place identity factor was stronger than place dependence among recreationists, indicating a strong emotional attachment to the river, but less dependence on it for the activity (Table 3). The quantitative survey results showed that most recreationists were more concerned with development along and access to the river than they were about the number and activities of users (Table 4). The qualitative interviews revealed a wide range of river descriptions, views of change along the river, special places identified, and ideas for management (Table 5). Change was mentioned by respondents more often than any other type of descriptor. Most concerns about change were related to growth, as well as to users' unease about housing developments obscuring views from the river. Where one once viewed animals and scenic vistas of mountains, one now sees houses dotting the river banks.

In describing the river, recreationists discussed aesthetics such as the river's "magic" and beauty. Some mentioned the physical attributes of a wild and

Table 3. Place attachment factor analysis dimensions and means.

Factor	Mean*
Identity	
The upper Yellowstone River (UYR) means a lot to me	4.66
The UYR is very special to me	4.56
I feel the UYR is a part of me	4.41
I identify strongly with the UYR	4.21
I am very attached to the UYR	4.17
Visiting the UYR says a lot about who I am	4.02
Eigan value	6.50
Variance explained	64.5%
Dependence	
The UYR is the best place for what I like to do	3.80
No other place can compare to the UYR	3.52
I get more satisfaction from the UYR than any other place	3.49
Doing what I do on the UYR can't be substituted elsewhere	3.26
Eigan value	1.03
Variance explained	10.3%

*Scale: 1=strongly disagree; 6=strongly agree

Table 4. Level of concern.

	Mean
Appropriateness of development along the river	4.55
Amount of development along the river	4.52
Residential development visible from the river	4.52
Ability to access the river	4.11
Feeling crowded on the river	3.98
Number of river users observed	3.49
Number of watercraft observed	3.46
Overall	4.09

Note: Scale: 1=not at all concerned; 6=extremely concerned

free-flowing river and the sense of power or peace it provided them. Others described the river in terms of the atmosphere it provided for family time or solitude. Respondents varied in their thoughts about use; while some believed the river was over-fished and over-rafted, others saw it as providing great recreation opportunities to all.

People's ideas about special places revealed the multi-dimensional nature of what makes a place special. Many respondents easily identified a special spot either because there was great fishing there, they had great memories associated with it, it was remote, or it was a family gathering spot. Most, however, viewed the entire river as special because of its scenic beauty between two mountain ranges.

Respondents suggested various management ideas, but most agreed that development policies needed to be carefully planned, and that the public should be included in discussions about the river.

Conclusions and recommendations

Recreationists who responded to this study were diverse, experienced, and concerned about the future of the upper Yellowstone River. Types of river use ranged from sitting and viewing the water and mountains to rafting and fishing activities. All users expressed concern about the landscape changing from river and mountains to river and houses. In regard to place attachment, identity was stronger than dependence, meaning that most activities in which people took part along the upper Yellowstone River could have been done in similar environmental

Table 5. Summary of in-depth interviews.

When asked to describe the river, respondents used four distinct descriptions:

Aesthetic descriptions. It's a magical place; closeness of mountains to river; pristine beauty; beautiful valley and river; perfect; changing color of the river; great storms; visually amazing.

Physical properties. The river ties the valley to mountains; it's the longest free-flowing river; it's wild and variable; the flood potential is always there; it's a powerful river; it's a relaxing river.

Atmosphere. It's . . . an incredibly social river; it still feels fairly remote even though there are a lot of homesites.

Use. It's over-fished; it's over-rafted; there are lots of recreational opportunities; it's great fishing.

Change was a theme that emerged from the respondents.

Positive. People care about this river; it's good to have use so it will always be available to us; I love it and couldn't deny others use.

Ecological. Flooding has changed the channels; drought has reduced fish; rip-rap is changing river flow and impacting wetlands.

Growth. Parking spaces are limited; more users and more litter; more guides; more commercialization, more houses along river taking away from the view; multi-million dollar residences popping up; there's lots of dividing up of real estate; it's losing aesthetic appeal; access from private lands is limited now.

Special places were discussed by respondents.

Special place. Identification of special places was easy for some to answer such as a favorite fishing spot, favorite beach, or favorite rock. Most however, said the entire river was special.

Reasons places are special: It's a place for family/friends to gather; good memories; best fishing; accessible for wade fishing; it feels remote; safe beach area for kids.

Various management suggestions were provided.

Balance. All users should have a voice in river planning; we need to assure fish and wildlife as well as people access and use of the river; we need social spaces along the river.

Use. Educate fishermen about types of fish; educate public about responsible use of river; restrict who can guide by making sure they know what they are doing; designate access sites for type of use; manage use and user groups.

Planning. Work with all stakeholders but don't forget the private recreationist who is likely to not affiliate with any particular group; manage the building along the river; manage for a healthy river; manage for the long term.

Accepting current practices. Use of the river is good as it will ensure that we can use it in the future; improvements at access sites have been beneficial.

settings elsewhere (except for fishing, which was the most place-dependent variable). Individuals' attachments appeared to take the form of emotional ties to the river and the surrounding area. Any changes to their perception of the landscape could easily alter recreationists' attachment to and use of the area. In addition, special places ranged from the entire river to specific spots, and of course were more place-dependent than activity involvement. Perhaps the most common theme that emerged from this study was that everyone agreed the river was important to them, and the majority was concerned with development from mostly an aesthetic perspective, coupled with the potential for conflicts between users.

Recreationists have strong attachments to the upper Yellowstone River. It is important that managers recognize the emotional ties recreationists have to the river because, as previous research has suggested, individuals who are emotionally attached to a recreation place typically will have an "increased level of concern regarding how a place is used and managed" (Williams et al. 1992, 32–33). This is where it becomes crucial for managers to recognize that for users, place identity ranks above place dependence. As Kyle et al. (2004, 138) stated, "To manage recreation resources based solely on the activities enjoyed in the setting may be inappropriate if in doing so we ignore the more abstract elements of the experience such as values, beliefs, and feelings about specific recreation settings." It appears, in the case of the upper Yellowstone River, that people emotionally align themselves with the river, and often perceive their sense of self as intertwined with the place. This can complicate the process of managing public recreation areas, because the place may mean different things and hold different values for each of the individuals who use it.

As it stands now, there is a preoccupation among recreationists regarding how the river will be managed in the near future, as it is perceived that more and more people will use the river. Long-time users fear that their ability to access and use the river may be jeopardized or regulated. This is not currently leading to overt conflicts between individuals or user groups, but rather to an overall concern about the future of the river. It is recommended that managers and all those involved in decisionmaking along the upper Yellowstone be aware of the influence that river corridor development is having on individuals' recreational and aesthetic experiences.

Acknowledgements

This study was funded in part by the Montana Water Center at Montana State University, Montana Fish, Wildlife and Parks (Parks Division), and The Institute for Tourism and Recreation Research at the University of Montana. It was conducted as a master's thesis by Megan McBride. For a complete review of the thesis, see <www.itrr.umt.edu>.

References

Altman, I., and S. M. Low. 1992 Place attachment: a conceptual inquiry. Pages 1–12 *in* I. Altman and S. M. Low eds., *Place attachment*. New York: Plenum Press.

Bricker, K. S., and D. H. Kerstetter. 2002. An interpretation of special place meanings whitewater recreationists attach to the South Fork of the American River. *Tourism Geographies* 4(4):396–425.

Governor's Upper Yellowstone River Task Force (GUYRTF). 2003. *Governor's Upper Yellowstone River Task Force final report* (December 15). <http://upperyellowstonerivertaskforce.org>.

Harvey, E. 2002. *Socioeconomic assessment of the upper Yellowstone River Valley*. Denver, Colo.: BBC Research and Consulting.

Heywood, J. L. 1987. Experience preferences of participants in different types of river recreation groups. *Journal of Leisure Research* 19(1):1–12.

Iso-Ahola, S. E. 1980. *The social psychology of leisure and recreation*. Dubuque, Iowa: William C. Brown.

Kyle, G., K. Bricker, A. Graefe, and T. Wickham. 2004. An examination of recreationists' relationships with activities and settings. *Leisure Sciences* 26:123–142.

Montana Fish, Wildlife and Parks (FWP). 2004. *River evaluation*. Unpublished river evaluation report. Helena, Mont.: Montana Fish, Wildlife and Parks.

Moore, R. L., and A. R. Graefe. 1994. Attachments in recreation settings: the case of rail-trail users. *Leisure Sciences* 16(1):17–31.

Roggenbuck, J. W., D. R. Williams, S. P. Bange, and D. J. Dean. 1991. River float trip encounter norms: questioning the use of the social norms concept. *Journal of Leisure Research* 23(2):133–153.

Shelby, B., and J. J. Vaske. 1991. Using normative data to develop evaluative standards for research management: a comment on three recent papers. *Journal of Leisure Research* 23(2):173–187.

Sherif, M., and H. Cantril. 1947. *The psychology of ego-involvements: social attitudes and identifications*. New York: Wiley.

Sherif, M., and C. I. Hovland. 1961. *Social judgment: assimilation and contrast effects in recreation to communication and attitude change*. New Haven, Conn.: Greenwood.

Sherif, C. W., M. Sherif, and R. E. Nebergall. 1965. *Attitude and attitude change: the social judgment involvement approach*. Philadelphia: W. G. Saunders.

Sun, D., and D. Walsh. 1998. Review of studies on environmental impacts of recreation and tourism in Australia. *Journal of Environmental Management* 56:323–338.

Taylor, J. G., and A. J. Douglas. 1999. Diversifying natural resource value measurements: the Trinity River study. *Society and Natural Resources* 12:315–336.

Tuan, Y.-F. 1974. *Topophilia: a study of environmental perception, attitudes, and values*. Englewood Cliffs, N.J.: Prentice-Hall.

Warzecha, C. A., and D. W. Lime. 2001. Place attachment in Canyonlands National Park: visitors' assessment of setting attributes on the Colorado and Green rivers. *Journal of Park and Recreation Administration* 19(1):59–78.

Williams, D. R. 1995. Mapping place meanings for ecosystem management: a technical report submitted to the Interior Columbia River Basin Ecosystem Management Project.

Williams, D. R., M. E. Patterson, J. W. Roggenbuck, and A. E. Watson. 1992. Beyond the commodity metaphor: examining emotional and symbolic attachment to place. *Leisure Sciences* 14:29–46.

From Microscope to Telescope: Viewing Yellowstone from a Global Perspective

Judith L. Meyer

Department of Geography, Geology and Planning, Missouri State University, 901 South National Ave., Springfield, MO 65897 (417-836-5604, JudithMeyer@missouristate.edu)

Abstract

The Greater Yellowstone Ecosystem (GYE) is a major presence in any discussion of U.S. wildlands management. For better or worse, the Yellowstone model is the standard by which we measure or evaluate many public lands. But for all its superlative and singular characteristics, the GYE is really just one of many places on the planet where many different people have tried to balance many different needs at the same time in the same place. Other countries' parks and preserves must deal with the same issues that challenge the GYE, and valuable lessons can be learned by all parties from even a general comparison. Using an example from a protected, natural area in Iceland, this paper examines how identifying and understanding similarities and differences with the GYE provides insight into long-range planning. Both areas serve as economic growth poles for the local and/or regional communities, and all share management goals of providing for nature protection and public accessibility. But the differences are striking and revealing. This paper focuses on three distinct but interrelated topics revealed in a comparison: the role of personal responsibility, the viability of ecotourism, and expectations of comfort and risk as integral to the tourist experience. Rather than debating the merits of exporting the Yellowstone model, it may be useful to consider the merits of importing lessons from other parts of the world and incorporating them into the management of the GYE.

Introduction

For many of us attending this and past Biennial Scientific Conferences on the Greater Yellowstone Ecosystem, Yellowstone National Park lies at the core of our personal and professional universes. The power of this place to attract and intrigue us has led to a huge body of knowledge, both broad and detailed, centered on understanding the park. We have learned much about how this place works: from nutrient cycling and microscopic lifeforms in individual hot springs to the impact of wildfires and climate change over grand scales of time and space. And for many of us, the park itself drives our work and who we are. That is what makes these conferences so rewarding and such fun. They are a meeting of soul mates; they are a time when we pat ourselves on the back and confirm our commitment to knowing and protecting this special place.

There have been many outstanding keynote speakers at these conferences whose views-from-the-outside have given us new perspectives on the park. But Dr. Richard Leakey's keynote speech at the Seventh Biennial Conference in 2003 was, at least for me, exceptional (Leakey 2004). I was profoundly moved, confused, and a bit shaken by his observations, and will use some of them as the basis for my presentation today. For just a moment, I would like us to change our perspective. Instead of looking through a microscope at one bit of the ecological puzzle that is the Greater Yellowstone, I would like us to gaze through a telescope to consider Yellowstone's place in a rapidly globalizing world. Yellowstone is just one place among many around the world where managers have tried to protect nature while still accommodating tourists and all the trappings and comforts that major tourist destinations require if they are to survive economically.

This paper examines one such experiment in Iceland and considers what we might learn from it in light of Dr. Leakey's comments when we last met. Iceland's volcanic landscape offers tourists a nature experience very similar to that of Yellowstone's thermal areas, yet in a much less developed and less protective setting. Yellowstone's managers would be well served to consider how places like Iceland are responding to the forces of globalization so that Yellowstone will be in a position to absorb the challenges ahead. Just as other countries look to Yellowstone for guidance in balancing sustainable tourism development with wildlands preservation, so should

Yellowstone be open to looking outward for an understanding of where the future of global nature tourism lies.

Dr. Leakey's message revisited

The theme of our last conference was comparison and contrast of nature protection efforts and ecosystem studies and management (especially for wildlife) in East Africa and Yellowstone. More specifically, much of the conference focused on comparison studies of the Greater Yellowstone with Tanzania and Kenya's Serengeti–Maasai Mara parks. Although Yellowstone and the East African parks do have some similarities, an understanding of basic global geography reveals an ocean of differences. Dr. Leakey pointed out several. First, whereas Yellowstone's migrating ungulates are regulated by a tangle of often-competing national, state, and local governments as well as non-governmental organizations and private individuals, Tanzania's Serengeti and Kenya's Maasai Mara preserves must coordinate wildlife protection efforts between two countries—one capitalist, one socialist—and their respective governments, agencies, and landowners at national, local, and private levels. One speaker with the East African parks contingent mentioned that in his country, wildlife managers can only dream of having problems such as ours.

Another of Dr. Leakey's points was a little more complicated and addressed the differences in economics and status of indigenous people on and around park lands as two parts of a single issue. The United States is the wealthiest country in the world, and its federal coffers pay for Yellowstone's upkeep regardless of how many tourists visit the park or how successful wildlife management policies are. Tanzania and Kenya are poor countries, and tourist dollars generated by their national parks help subsidize their respective governments. Without foreign tourists visiting the Serengeti–Maasai Mara, there would be significantly less money for the Tanzanian and Kenyan governments to spend on social services such as hospitals, schools, water supplies, and roads. Dr. Leakey indicated that as much as 10% of Kenya's total gross domestic product comes from wildlife-based tourism. When American conference participants suggested that monies generated by the Serengeti–Maasai Mara reserves should be "given back" to the indigenous people displaced by the parks, Dr. Leakey opined that such answers to social justice problems are short-sighted and misguided. The very existence of both countries as stable, independent states depends on the integrity of the Serengeti–Maasai Mara ecosystem, because the ecosystem attracts tourists, and tourist dollars fund the government. In terms of economic benefit to the country, Dr. Leakey pointed out, an elephant generates more wealth for Kenya than does the average Kenyan citizen. Balancing the needs of the human population and the needs of the ecosystem cannot be solved by park-profit-sharing payments, opening up the parks to further encroachment by farmers or livestock, or other programs that further stress the arid grassland ecosystem. Further, in Kenya, members of the indigenous population do hold high public office and do make decisions regarding property rights and wildlands protection. Hence, U.S. conservationists who argue that indigenous people should have a voice in national nature protection debates do not really understand the situation in post-colonial East Africa. Dr. Leakey reminded us that we have yet to elect a Native American to serve as president or vice president in the U.S.

Finally, Dr. Leakey pointed out that Tanzania and Kenya do not and cannot exist in the sort of political and economic vacuum that characterizes attempts to balance nature protection and nature tourism in U.S. national parks. The U.S. shares its border with only two countries, and both Mexico and Canada are politically and economically stable. In Africa, refugees of home-grown and neighboring-state political unrest routinely cross international borders, and lands set aside as national parks and game reserves provide a path of least resistance for government officials looking for land to be used for refugee camps or resettlement projects. Regardless of whether the cause is drought, disease, civil unrest, the construction of dams, or the conversion of subsistence farms to commercial agriculture, East African lands set aside for nature protection bear the brunt of the burden. Geographically large, wealthy, politically stable states surrounded by other stable states can approach wildlands management very differently than can the rest of the world. The Yellowstone model is simply not always applicable elsewhere.

The people–nature image

In a brief aside, let us consider the image the United States portrays to the world regarding our relationship to nature. All of us in this room know that Yellowstone is our best example of America's love of nature. It is the oldest national park in the world; the largest intact ecosystem in the lower 48 states;

the place where nature is allowed to run its course; and the crown jewel of the National Park Service, the agency that epitomizes and validates America's world-class reputation for protecting and preserving nature. All this is true. But the commercial side of America's love of nature is also evident. National park scenes are used to market not only health food and outdoor recreation gear but also gas-guzzling sport utility vehicles, credit cards, and pharmaceuticals—products one might consider anathema or at least incongruent with a reverence for wild nature. Consider the car manufacturers who advertise their SUVs as "the answering machine for the call of the wild," or picture a shiny, new SUV in deserted Monument Valley with the caption, "In primitive times, it would've been a god." Better yet, Jeep had a successful marketing campaign showing an astronaut dangling in space with the blue marble of Earth in the background. In the ad, the astronaut is thinking, "I can't wait to get back to Earth, hop into my Jeep, and really get away from it all."

In the U.S., we really can have it all. We can set aside and protect real wilderness areas and at the same time advocate a consumptive lifestyle that destroys or dilutes that very wilderness at home and abroad. We can protect places like Yellowstone, manage them as intact ecosystems, and yet accommodate three million people over the course of a short summer. Visitors are provided a nature experience, but with paved roads, flush toilets, fine dining opportunities, postal services, medical care, and a host of other amenities. The rest of the world is not so lucky. Most other countries are smaller, poorer, have been occupied by humans longer, and therefore have no large tracts of uninhabited lands available to serve as what we consider "national parks." As a result, other countries' approaches to balancing nature and people are very different.

Since 1872, "the best idea America ever had" has spread around the globe, and there are now many different expressions of the national park idea. As the world grows smaller and more interconnected, we are at a point where we can consider Yellowstone's grand experiment alongside others and learn from the comparison. The remainder of this paper is a consideration of how the people–nature interface is managed in parts of Iceland. Like the Serengeti–Maasai Mara, Iceland has some things in common with Yellowstone—enough to allow a comparison—but is perhaps more important and revealing as a result of its differences.

Iceland's geyser basins

Iceland, an island, is an independent country in the north Atlantic Ocean just south of the Arctic Circle between Greenland and the United Kingdom. As yet, Iceland is not a member of the European Union. It is about the size of Kentucky, with a population of approximately 300,000 people, most of whom live in a handful of coastal cities. Iceland shares the following similarities with Yellowstone: both are (1) geothermally active; (2) rugged, mountainous landscapes affected recently (and currently) by volcanism and glacial activity; (3) located at relatively high latitude locations; (4) situated in an "empty" part of the world, that is, beyond major population clusters; and (5) viewed as "natural" landscapes or nature tourism destinations. In addition, both have resident populations that are currently changing from livelihoods based on agricultural land use to those based on using or "marketing" the land's natural qualities.

Both Yellowstone and Iceland have famous geysers and geyser basins that serve as important tourist attractions. In fact, the name of Iceland's most famous geyser, Geysir, became the word by which we refer to all geysers around the world. Unlike Yellowstone's geyser basins—especially the Upper Geyser Basin—the landscape around Geysir is stark and empty, a desolate moonscape. The basin is not crisscrossed with boardwalks. None of its thermal features have fences around them, and the view is not pock-marked with signs warning "dangerous area" or "stay on walk." As a result, it may be that walking through the thermal area at Geysir today allows us to experience the same eerie, spine-tingling, expect-the-unexpected experience that Yellowstone's first tourists described when they walked through the Upper Geyser Basin. To be fair, there are many thermal areas in Yellowstone's backcountry that really are wild and dangerous. But, again, Yellowstone is an exception to most protected areas in this country and abroad. Yellowstone is large enough to encompass both wild areas and large developed areas, but this may not always be the case.

The fact that many of Iceland's geyser basins, as well as its glacier-dotted interior high country, are still undeveloped and relatively undisturbed is at least partly the result of time and isolation. Despite being the world's oldest democracy, Iceland is a young country. In some ways, modern Icelanders have benefited from having been "out of the loop" when industrialization spread across Europe in the eighteenth and nineteenth centuries. Iceland's clean

air and water contribute to its citizens' being relatively free from the diseases that plague industrialized countries, and its people are among the longest-lived on the planet. Now, however, Iceland is very much aware that its location—geographically situated between wealthy western Europe and wealthier North America—and its unique landscapes are economic assets in the New World Order. Today, tourists from densely populated, highly urbanized countries who have disposable income and paid vacations are willing to pay to experience nature—the more "natural," the better. Hence, Iceland now markets itself as an international destination for adventurous travelers who want to engage in wilderness tourism.

Obviously, there are huge differences between the tourist experience provided in Yellowstone and that of individual geyser basins in Iceland. And it may be that within a decade, Geysir at Haukadalur will succumb to the same economic pressures pushing for tourist accommodations that helped develop so much of Yellowstone. Geysir may soon become the same sort of mini-city that the Old Faithful area has become. But one of the cultural differences between the two countries might set Iceland on a course different from Yellowstone's. Like most countries in western Europe, Iceland is a social welfare state, and everyone has state-sponsored medical coverage. If a person is injured as a result of a hot spring burn or a fall while hiking on a glacier, rescue and medical costs are covered just as they would be if someone were injured at home or on the job. Iceland does not, however, allow the injured person to sue for huge damages. People are expected to use common sense and accept personal responsibility for their actions, especially when in dangerous places such as geyser basins and backcountry hiking trails where caution is required.

It might be argued that the American legal system deters people from really experiencing nature in the national parks, because our culture discounts the role of personal responsibility even in supposedly wild places. We have all seen people walk off the boardwalk across a geyser field or saunter too close to bison or elk just to take a picture. It may be that people do this because they believe they are "safe;" they believe our government would not allow us to get hurt—not in a national playground such as Yellowstone. That same legal system forces U.S. park managers to dilute the nature experience by erecting warning signs, building boardwalks, closing trails, and further limiting people from really experiencing the danger of wild places. The perception of "nature red in tooth and claw" is very much a part of the nature experience in Iceland, but if the Yellowstone model is invoked for Iceland's future park development, Iceland's wildness may also be tamed with signs and other safeguards.

Lessons learned

As Yellowstone's managers collect data to help answer questions about bison migration, snowmobile use, invasive plant and animal species, borderland encroachment, and other issues facing them today, they might do well now and again to look and see how other protected places are coping with change. Yellowstone has been the deserved leader in nature protection efforts for so long, and the park evokes such a powerful sense of place, that it is hard for us to abandon our parochial, Yellowstone-centered views that have served us so well. However, some places, like Iceland, are growing in importance as nature tourist destinations and may eventually become Yellowstone's rivals for tourist dollars. It is difficult to imagine that Old Faithful will ever need to compete with Geysir for tourist dollars, because "Yellowstone" is a household word and will continue to attract national and international visitors. But Yellowstone's managers should be aware that Yellowstone is no longer the only show in town. There are changes afoot outside the park's borders that may play a role in Yellowstone's future. Hence, every now and then we need to reassess Yellowstone's situation relative to an international audience, global events, and global trends.

It is important to note that many of Iceland's thermal areas have already been converted to geothermal power plants, and hydroelectric dams have been built in Iceland's wild interior. But Icelanders are increasingly aware of how attractive their remaining, genuinely wild landscapes are to European tourists. Thus far, Iceland has been able to put the burden on its tourists to accept the dangers of a nature experience, rather than build fences and dot the landscape with warning signs. However, as tourist numbers and tourism-derived income increases, there will certainly be pressure to emphasize safety, comfort, and ease as Yellowstone's early developers did, while at the same time taming the dangers and uncertainties that make nature what it is. Land managers in Iceland and Yellowstone could learn from each other, and their combined efforts may help both places remain economically and ecologically viable.

Further, Yellowstone's managers have a responsibility to understand their role as global leaders in nature protection. That responsibility includes not only exporting the Yellowstone model abroad, but also steering the U.S. toward better land stewardship attitudes and policies. Perhaps Yellowstone should be the place where we truly do allow nature to run its course. Perhaps Yellowstone should be the place where Americans learn about the individual costs and responsibilities of preserving wild places and natural processes. If Yellowstone removed some of its warning signs, restricted the number of automobiles allowed on park roads each day, and reduced the number of services provided during the winter, what message would the park be sending the nation? It seems there should be room for nature even in crowded neighborhoods and cities if we are willing to sacrifice some comfort and control. Perhaps the U.S. needs to re-think its protectionist attitudes about the nature experience in light of ever-increasing numbers of tourists and higher expectations of access and services. Yellowstone National Park would be a great place to start moving the country toward a more realistic relationship with nature—danger, discomfort, and all.

Reference

Leakey, Richard. 2004. The A. Starker Leopold Lecture. Pages 168–178 *in* A. Wondrak Biel, ed., *Beyond the arch: community and conservation in Greater Yellowstone and East Africa*. Proceedings of the 7th Biennial Scientific Conference on the Greater Yellowstone Ecosystem, October 6–8, 2003, Mammoth Hot Springs Hotel, Yellowstone National Park. Yellowstone National Park, Wyo.: Yellowstone Center for Resources.

A Century of Fisheries Management in Grand Teton National Park

Susan E. O'Ney

Grand Teton National Park, P.O. Box 170, Moose, WY 83012 (307-739-3666, susan_o'ney@nps.gov)

Rob Gipson

Wyoming Game and Fish Department, P.O. Box 67, Jackson, WY 83001
(307-733-2383, ext. 226, rob_gipson@wgf.state.wy.us)

Abstract

Fisheries in Grand Teton National Park (GRTE) have historically been managed by the Wyoming Game and Fish Department (WYG&F). Management activities, including fish stocking, can be traced back to the early 1900s. Over the years, several non-native species of fish have been introduced. The management of fisheries in Grand Teton has also been affected by the Bureau of Reclamation's management of flow regimes from Jackson Lake Dam. In this paper, agency missions, management policies, and management actions of the National Park Service (NPS) and WYG&F as they relate to fisheries resources in GRTE are compared and contrasted over the course of the last century. At present, improved interagency cooperation and communication show a vast improvement over past practices, and should result in improved outcomes for fisheries management in Grand Teton National Park.

Introduction

A century of fisheries management in Grand Teton National Park (GRTE) has resulted in a mix of healthy native populations and isolated pockets of exotic species. The mission of the Fisheries Division of the Wyoming Game and Fish Department (WYG&F) and the purposes of the National Park Service (NPS)'s "Heritage of Fishing" overlap as guidance documents for managers. Both encourage science-based management and some level of public involvement, and both are committed to conservation of fisheries resource for future generations.

History of WYG&F and NPS philosophy

Until 1950, when GRTE's boundaries were enlarged to include the Snake River and its tributaries, its fisheries resource was managed solely by the state of Wyoming. From the time its first hatchery was established in 1894 until the late 1930s, the Wyoming State Fish Commission believed that Wyoming streams had been depleted of fish, and the public wanted re-stocking to maintain good angling (WYG&F 1993). Annual stocking was considered essential. By the mid-to-late 1930s, some state fisheries biologists had begun to show signs of concern about the ecological consequences of fish stocking. Simon (1940) "deplored promiscuous fish planting" and recommended: (1) no stocking in virgin waters without investigation and (2) priority for stocking only native trout. However, there seemed to be no follow-through from these recommendations to actual field activities. In fact, throughout this time period, when the park consisted of only the Teton mountains, lakes such as Phelps, Trapper, Bearpaw, Leigh, and Bradley were stocked with a variety of species, including non-native grayling and brook trout and native Yellowstone cutthroat and Snake River cutthroat trout.

In spite of its mandate to leave resources "unimpaired for the enjoyment of future generations," there was little understanding of ecology or ecosystem functional relationships evident in the National Park Service's resource management philosophies during the early 1900s. To enhance public enjoyment, aquaculture and fish-stocking to enhance recreational fishing was considered to be quite appropriate (Tilmant 1999). Managers conducting stocking activities within parks seldom considered the potential impacts to native species (Schullery 1979). The NPS issued its first written management policies in 1936, but they allowed park superintendents to stock waters previously barren of fish.

Throughout the 1940s, and even after GRTE's enlargement during the 1950s and 1960s, the

practice of stocking both native and exotic fish species was continued by WYG&F. There was a shift in emphasis from subsistence fishing toward recreational fishing. As staffing and facilities expanded, WYG&F personnel were able to spend less time at the fish hatchery and more time conducting investigations of fish habitat and biology. From the 1980s through the 1990s, there was increased emphasis on habitat restoration activities and collaboration with other agencies.

NPS policies did not recommend the phasing out of stocking programs until 1969. Management policies in 1988 allowed the stocking of reservoirs for recreational fishing. In 1992, the NPS adopted its recreational fisheries program, "A Heritage of Fishing." The *NPS Management Policies 2001,* in effect today, still permit the stocking of both native and exotics under special conditions, but under the caveat that stocking will not impair natural resources or processes.

Rivalry vs. partnership

Shortly after the enlargement of Grand Teton National Park in 1950, NPS and WYG&F officials met to discuss the development of a cooperative fisheries agreement. Fisheries in GRTE were unlike those in Yellowstone National Park, which was created before Wyoming was a state (thus, Wyoming "could not lay claim to any of the wildlife in Yellowstone") (Unknown 1950). Although both parties seemed amenable, no agreement was signed. Negotiations continued throughout both the 1950s and 1960s, with each agency posturing for control of the fisheries resource. Finally, in 1973, a memorandum of understanding was signed by both agencies. This umbrella agreement included GRTE. The document, however, had little substance directly related to fisheries management.

Early management activities in the Snake headwaters basin

Fisheries management activities in the Snake River headwaters date back to the late 1800s. Within GRTE, activities through the 1950s were mainly limited to WYG&F stocking activities. Which park waters were stocked? It would be easier to answer, "which park waters weren't stocked?" Almost every water in the park was stocked with anything from brook trout to steelhead, based mostly on what was available from hatcheries. Later, the type of species stocked was dependent upon elevation, with non-native golden trout being stocked at the highest elevations, non-native brook trout at the next with native cutthroats, and non-native rainbow and brown trout stocked at the lower elevations (WYG&F 1993).

Grand Teton National Park hired a fisheries biologist in the mid-1960s. While information was shared between agencies, there was little other cooperation. Special studies on the biology of the Snake River cutthroat trout were conducted by both agencies. Throughout the 1960s and 1970s, WYG&F's philosophy was one of "husbanding the natural supply of fish, keeping them healthy and productive to meet anglers' desires" (WYG&F 1993). GRTE's fisheries biologist attempted to pursue a variety of management strategies to improve the status of the native cutthroat trout, but for the most part, these strategies were not supported by the park's upper managers (P. Hayden, pers. comm.). These strategies included slot and creel limits, that is, limits on the fishing open season and on the numbers of fish that could be kept (recommended by GRTE in 1972, adopted by WYG&F in 1986) and catch-and-release fishing below Jackson Lake dam (never actually proposed due to park managers' opinion that the state would take a "dim view" of this recommendation). Fishing regulations for 2004 included a creel limit (six trout per day, only three of which could be Snake River cutthroat); and a slot limit (only one Snake River cutthroat over 12", only one trout of any kind over 20"). The winter fishery is catch-and-release for native cutthroat trout.

Fisheries management in GRTE has been further complicated by the Bureau of Reclamation's operation of Jackson Lake dam, which was originally constructed in 1906, rebuilt in 1911, and enlarged to its present size in 1916. Exotic lake trout colonized Jackson Lake after moving down the Snake River from Lewis and Shoshone lakes in Yellowstone National Park shortly after they were introduced there in 1890. NPS management strategies for this exotic species are confounded by the fact that prior to the dam's construction, Jackson Lake was an existing natural lake, which was artificially enhanced by the dam. NPS policies would apply different strategies to a natural lake than they would to a reservoir. Since 1937, Jackson Lake has been managed by WYG&F for trophy lake trout. It is still closed to fishing during October to protect lake trout spawning.

Recent management activities in the Snake headwaters basin

In the late 1980s, WYG&F recognized the need to establish minimum winter flows in the Snake River

below the dam to protect native cutthroat trout. National Park Service attempts at negotiating this need with the Bureau of Reclamation (BOR) were unsuccessful until October 1990, when a contract between the state of Wyoming and the BOR was signed that stipulated a 280-cfs minimum winter flow for the Snake—an action that protected critical habitat and provided much-needed connectivity for the native species.

Since 2001, GRTE and Jackson's WYG&F have developed and maintained an excellent working relationship. They conduct annual meetings to discuss fishing regulation updates and changes, field season activities, and potential collaborative research projects. During one of these meetings, park staff asked about the need for continued stocking of lake trout in Jackson Lake reservoir. WYG&F then undertook a review of past sampling data in Jackson Lake. The resulting report was completed in 2004. One management recommendation of that report was to phase out lake trout stocking due to low numbers of stocked lake trout in the creel (i.e., people were reporting catching low numbers of stocked lake trout) and no apparent correlation between trend netting catch per unit effort (i.e., numbers stocked and numbers captured in annual netting population surveys) (Stephens and Gipson 2004). The lake trout stocking program in Jackson Lake reservoir will be phased out by 2007. The report also revealed evidence that the absence of stocked lake trout might benefit other native species, including Snake River cutthroat trout, due to the increased availability of the zooplankton food source. WYG&F still stocks native cutthroats in Two Ocean Lake. This practice has been discontinued in Trapper and Bearpaw lakes, mostly due to increased communication and cooperation between GRTE and WYG&F.

The park and WYG&F have been involved in a variety of cooperative ventures, including the restoration of the upper Bar BC spring creek; a fish passage improvement project at Two Ocean Creek culvert; and an inventory of fish in high alpine lakes. They are also collaborating with neighboring agencies such as the U.S. Geological Survey (USGS) and U.S. Forest Service (USFS) on other studies that should yield valuable information for future fisheries management decisions. A bioenergetics modeling project being conducted by the USGS Jackson Field Station will help the park to determine whether lake trout are impairing natural resources or processes in Jackson Lake reservoir. These same researchers also conducted an evaluation of the native trout fishery using WYG&F records that confirmed an apparent trend between the total number of redds and the median daily discharge below the dam each year. This link between good water years and increases in juvenile habitat may have implications for negotiating spring flow releases from the dam with the Bureau of Reclamation.

A researcher from Utah State University, working for the USFS, recently completed an inventory of fish in the Snake River tributaries. The fieldwork was conducted with USFS crews in conjunction with WYG&F personnel. Approximately 251 km on 43 streams in GRTE were surveyed between 2002 and 2004 (Novak 2004). These surveys have provided invaluable information about the locations of exotic fish species (e.g., rainbow trout, brook trout, and rainbow–cutthroat hybrids) and the relative distributions of the native Yellowstone and the Snake River cutthroat trout. They have also identified areas for management concern, such as the location of anthropogenic barriers to fish passage and other habitat improvement opportunities.

The future

What is in the future of fisheries management for Grand Teton National Park? There will continue to be cooperative studies among WYG&F, GRTE, and neighboring agencies. The park is hoping to develop a fisheries management plan in the near future. Both GRTE and WYG&F will continue to work cooperatively to encourage the Bureau of Reclamation to schedule releases that are more representative of natural flows of the Snake River. Will there be catch-and-release-only regulations for the Snake River cutthroat? It is hard to say. But with improving interagency cooperation and communication, improved outcomes for fisheries management in Grand Teton National Park should be imminent.

References

Novak, M. 2004. Yellowstone and Snake River cutthroat trout subspecies distribution mapping. *2004 annual report and summary of accomplishments*. Moose, Wyo.: Grand Teton National Park Science and Resource Management Office.

Schullery, P. 1979. A reasonable illusion. *Rod and Reel* 1(5):44–54.

Simon, J. R. 1940. Report of Fish Division. Pages 38–52 *in* R. Grieve, Biennial report of the Wyoming Game and Fish Commission, 1939–1940. Cheyenne, Wyo.: Wyoming Game and Fish Department.

Stephens, T. J., and R. D. Gipson. 2004. Summary of Jackson Lake fishery investigations 1971–2003, with

management recommendations, *in* Wyoming Game and Fish Department, Fish Division, administrative report (January). Cheyenne, Wyo.: Wyoming Game and Fish Department. 50pp.

Tilmant, J. T. 1999. Management of non-indigenous fish in the U.S. National Park System. Paper presented at a symposium on ecological and genetic effects of aquaculture on the environment, 129th annual meeting of the American Fisheries Society, Charlotte, North Carolina, August 29–September 2.

Unknown. 1950. Teton Park fishing agreement discussed. *Wyoming Wildlife* XIV (December), 15–16.

Wyoming Game and Fish Department. 1993. Wyoming fish management, 1869–1993. Administrative report (July). Cheyenne, Wyo.: Wyoming Game and Fish Department.

Greater Yellowstone Bison Distribution and Abundance in the Early Historical Period

Paul Schullery

P.O. Box 168, Yellowstone National Park, WY 82190 (307-344-2220, paul_schullery@nps.gov)

Lee Whittlesey

P.O. Box 168, Yellowstone National Park, WY 82190 (307-344-2261, lee_whittlesey@nps.gov)

Abstract

Bison management in Yellowstone and Grand Teton national parks, as well as on other public and private lands in the Greater Yellowstone Ecosystem (GYE), has long been controversial. Both professional management and popular advocacy relating to bison are routinely based on presumptions about the historical distribution of the species in the region that have not yet been fully evaluated by ecological historians. In an exhaustive review of published and unpublished first-hand accounts of the GYE prior to the creation of Yellowstone National Park in 1872, we compiled all observations, accounts, and references to bison, including tracks, hide, meat, and other parts and evidence. Based on this substantial body of information, we describe the presence of bison in the first decades of Euro-American contact with Greater Yellowstone. We also provide and analyze anecdotal evidence of the decline of bison numbers and the contraction of bison distribution in the period before the famous industrial slaughter of the mid-1870s. Bison were spectacularly abundant in lower river valleys and prairie habitats, and were all but exterminated from those areas by the close of the study period. Contrary to still-popular belief, bison and other large herbivores were not "driven into higher country" by settlement, but inhabited those higher regions as environmental conditions permitted prior to the arrival of Euro-Americans. Key historiographical issues relating to this body of evidence and its use include: conflicting and incomplete previous interpretations of American Indian influences on bison population and distribution; the formidable weight of western and regional folklore regarding bison presence/absence; and previous misunderstandings of the meaning or relevance of early historical accounts to modern management dialogues. We discuss other avenues of investigation and evidence types awaiting attention.

Yellowstone's wildlife populations have been controversial for almost the entire history of the park. As Mary Ann Franke's new book on the bison of Yellowstone ably demonstrates, these controversies reach deeply into the political, economic, social, and even religious fabric of our society (Franke 2005). While today's scientists have produced a large and formidable body of bison research findings, and while agency professionals go to great lengths to dispense reliable information based on that research, the general public's awareness of Yellowstone wildlife history and ecology continues to be based in good part on folklore, hyperbolic rhetoric, and an appalling variety of misinformation. Even for those people with the time and inclination to search out what is actually known about the bison of Yellowstone, the task of understanding can be daunting. This is certainly true in unraveling the historical evidence of bison presence and abundance in Greater Yellowstone.

For our ongoing study of early Greater Yellowstone wildlife history, we have gathered observations, accounts, and references to bison (including tracks, hide, meat, and other parts and evidence) from several hundred accounts of the Greater Yellowstone Ecosystem (GYE) prior to 1882 (e.g., Schullery and Whittlesey 1992; 1995; 1999a). These accounts include formal government survey reports, published and unpublished journals of explorers, trappers, prospectors, military parties, and tourists, early published and unpublished maps, anthropological literature, popular journalism such as books and periodical articles about the GYE, and contemporary newspaper accounts. In this paper we summarize our findings in the following areas: First, we review what is known about the distribution and abundance of bison in Greater Yellowstone at the time of first Euro-American visits to the area. Second, we review the process of the decline of the bison population in the area. Third, we consider

several interesting aspects of the historiography of early historical evidence of wildlife, especially bison, in Greater Yellowstone.

Distribution of bison in the Greater Yellowstone Ecosystem

Prehistoric bison distribution in the GYE can perhaps best be summarized simply by saying that bison appear to have been living everywhere in Greater Yellowstone where habitats were suitable. The notion that bison are not native to the area now known as Yellowstone National Park, though still apparently a popular opinion, has no basis in historical record.

It is worth pointing out that we are not dependent solely upon the historical record for our knowledge of bison distribution in the park area. Archeological work, most of it within the past 20 years, has identified bison remains at park sites near Gardiner, Montana; in the Hellroaring drainage; near Tower Junction; in Lamar Valley; and on the Yellowstone Lake shore. These finds indicate bison presence in the park area for 8,000 years (Johnson 1997). Likewise, a recent survey of Greater Yellowstone archeological research has identified bison remains in 29 archeological and three paleontological sites (Cannon 2001).

Abundance of bison in the Greater Yellowstone Ecosystem

The historical record of Greater Yellowstone provides some vivid and fascinating evidence relating to the abundance of bison. In the first few decades of the nineteenth century, various writers reported vast herds of bison on the prairies along the edges of the Greater Yellowstone Ecosystem, including the Yellowstone, Wind, and Snake River drainages. Smaller numbers of animals were reported here and there throughout the ecosystem, most often in the internal valleys.

In almost no case prior to 1880, however, does the written historical record provide the means of calculating any herd size for any locale. Nor does such a spotty and intermittent set of records allow us to assume that a sighting of a certain herd in a certain valley or meadow in a certain year meant that bison occupied that site similarly year after year.

This is a central point, and of special importance in the case of animals with complicated migratory habits. We can only make so much of this evidence because it consisted almost entirely of brief verbal snapshots of a certain day and condition. Virtually all early journalists in the Rocky Mountains were transient. Most traveled through the region in the warmer months of the year. Some of their accounts specifically remarked on the mobility of the bison herds, and the amazing swiftness with which a horizon-crowding herd of bison could apparently vanish. Such behavior on the part of enormous herds of grazers may seem intuitively sensible to us today, but it complicated life for early travelers even if they did understand it. Not all early travelers found bison in the same places, and some could not find them at all when they most desperately needed them for food.

However, the absence of bison from entire large drainages was apparently not always just a matter of the bison being somewhere else on the day a party came through. Sometimes the animals may have been either driven off or eliminated from a given range by native people. On July 14, 1806, some miles west of present Bozeman, Montana, Sacagawea told William Clark that bison had recently been abundant in the upper Gallatin Valley, but that Shoshone Indians had wiped them out (Thwaites 1905, 260–261).

According to this account, because of the superior military might of their neighbors, the Shoshones were unwilling to venture east into other bison ranges, and had hunted the local animals in the upper Gallatin Valley to extinction. As Clark's party moved across the Gallatin Valley and east into the Yellowstone drainage, he repeatedly said that they followed an "old buffalow road" (Thwaites 1905, 261). Proceeding eastward, on across the north side of Greater Yellowstone, they saw more bison after reaching the Yellowstone River, encountering them in large numbers from the site of present Big Timber, Montana, on downstream (Thwaites 1905, 266–269). In this instance, Greater Yellowstone provided potential evidence of ways in which native humans' political distribution on the landscape had the kinds of pronounced effects on western wildlife distribution and abundance hypothesized by Martin and Szuter (1999), who suggested that wildlife flourished in the "war zones" of less densely populated land contested by warring tribes, and were reduced in number in "game sinks" where large numbers of native humans were in regular residence.

Perhaps the largest herds that actually occupied what we now think of as Greater Yellowstone were in the south. In June 1833, trapper Warren Ferris was camped on the Green River not far from present Daniel, Wyoming. This one extended quotation from several such descriptions will help capture the mood of what Greater Yellowstone has lost:

> Few persons, even in these romantic regions, have ever witnessed so interesting a scene as was presented to our view from an eminence or high mound, on which we were fortunately situated, overlooking the plains to a great distance. Immense herds of bison were seen in every direction galloping over the prairie, like vast squadrons of cavalry performing their accustomed evolutions. Platoons in one part filing off, and in another returning to the main bodies; scattering bands moving in various courses, enveloped in clouds of dust, now lost, and now reappearing to view, in their rapid movements; detachments passing and repassing, from one point to another, at full speed; and now and then a solitary patriarch of the mountain herds, halting for a moment behind the dashing cohorts, to ascertain, if possible, the cause and extent of the danger and alarm; but soon again with instinctive impulse, hurrying to join his less fearless files; and all rushing on, till form and numbers disappear in the dust and distance, and nothing remains visible of the long black lines but dark clouds slowly sweeping over the distant plains. . . . (Ferris 1940, 168).

We also can rely on Ferris for a similar if more succinct account of abundant bison along the western edge of Greater Yellowstone. When his party reached Pierre's Hole, the large plains west of the Teton Range, in August 1832, Ferris wrote, "The plains were covered with buffalo, in all directions, far as we could discern them" (Ferris 1940, 128). It is these western herds that we must consider next.

Decline of bison in the Greater Yellowstone Ecosystem

Our study of the decline of bison in Greater Yellowstone in the several decades before 1880 confirms recent portrayals of similar declines throughout the West. Though traditional accounts of the extermination of bison have tended to emphasize the great commercial slaughters of the 1870s and early 1880s, more recent scholarship has shown that the process was much more drawn out than that (Flores 1991; Benedict 1999; Isenberg 2000; Krech 2000). It certainly was in Greater Yellowstone.

The arrival of horses in the late 1700s, the arrival of whites with firearms soon after, and the arrival of increasing trade incentives through the early 1800s conspired to create a growing white and Indian hunting industry (Janetski 1987; Hoxie 1989; Fowler 1996). It was this complex set of changing conditions that led humans to make serious inroads on bison numbers in Greater Yellowstone at least three decades before Yellowstone National Park was created in 1872.

The most striking example is from the west side of the ecosystem, where bison had been abundant (though how abundant is still a matter of disagreement) at the time of the first white arrivals around 1800. By about 1840, increasingly effective human hunters, both white and Indian, had essentially eliminated bison from the Snake River Plain (Haines 1964; Daubenmire 1985; Janetski 1987; Van Vuren 1987; Urness 1989; Whittlesey 1994; Shaw 1995). Climatic factors, especially the severe winter of 1836, may have further reduced herds (Lupo 1996).

It was in good part because of this loss of bison on the west side of Greater Yellowstone that use of a network of Indian trails across northern Yellowstone, now collectively known as the Bannock Indian Trail, greatly increased (Haines 1964; Janetski 2002). By the early 1840s, mounted Indians began making annual pilgrimages across the Gallatin and Absaroka ranges to better hunting grounds to the east and north of the present park.

It seems most likely to us that as bison were eliminated from the Snake River Plain, hunters would necessarily have sought out whatever bison were available in the interior of the Greater Yellowstone Ecosystem, starting along the western edge of Greater Yellowstone and working east. Thus, bison in Jackson Hole and other smaller habitats, such as the Firehole–Madison area or Hayden and Pelican valleys, would also have been hunted, presumably with similar effects as on the Snake River Plain. And thus, any bison lingering along the route of the Bannock Indian Trail in Gardner's Hole, the Mammoth–Gardner Basin, Blacktail Plateau, Pleasant Valley, or Lamar Valley, would have been subjected to heavier hunting pressure as well.

It is extremely important to recognize probable effects that industrial-scale bison hunting on the outer fringes of Greater Yellowstone had on interior populations. The increased mobility and improved technology of native hunters between 1800 and 1880 meant, among other things, that the first whites to make any attempt to estimate bison population size in the present park area were too late to get a clear picture of what the population must have been like before Euro-American influences reached the region. No one attempted to provide an actual count of bison in Yellowstone National Park until about 1880, after three or four decades of increased Indian hunting pressure were concluded by several years of industrial-scale commercial hide-hunting by whites.

Historiographical notes

Throughout the many years that we've been looking at this historical record, we have been struck by the haste and confidence with which individual accounts of early Yellowstone have been used by modern writers to prove this or that. There is a huge amount of this early material, and only a small part of it, perhaps 10% of the volume of material we have examined, is handy in many libraries, usually in the form of reprints of early reminiscences by various travelers. It has been that small, handy part that has been repeatedly re-interpreted by all previous commentators on this topic. In our own studies, we have been impressed with how carefully some of those commentators handled such a small amount of evidence and extrapolated from it with reasonable accuracy. But the majority of such commentators weren't as successful (summarized by Schullery and Whittlesey 1992; 1995; 1999a; 1999b).

It is very easy to shop through these handiest historical sources for friendly evidence, whatever case you may wish to make. Highlight the right sentences and you can "prove," at least to your own satisfaction and the satisfaction of whichever constituencies favor your view, virtually any of the alternative scenarios that are most commonly discussed.

Likewise, it is easy, once the favored accounts have been extracted from their sources, to give them as much weight as seems necessary for rhetorical purposes. It is amazing how many trappers, prospectors, and other characters whose own companions might not have trusted them with a borrowed mule have been elevated by modern writers to the status of scientifically reliable ecological observers.

Even if the writer of an early account was the very soul of probity, as his party traveled through, let's say, Jackson Hole, they typically had neither the resources nor the inclination to scan every meadow, hollow, river bottom, and hilltop. Yet too many modern commentators have tended to treat the casually written fireside diaries of these early adventurers almost as if they were the equivalent of systematic modern aerial surveys.

On the other hand, many of these early accounts were written by savvy wilderness travelers, with great experience with western wildlife. They left us accounts and insights that are priceless to modern wildlife science. Our task should be to make the most of what they gave us, and our experience with this material has taught us important historiographical lessons.

First, the only acceptable way to employ this kind of evidence is in the largest amount possible. Using only a few accounts as somehow "representative" of a presumed greater body of material is never safe. This may be even more important for the study of bison history than for some other species, because bison were so mysteriously mobile, and could be seen by one traveler in nearly stupendous numbers while the next traveler missed seeing them.

Second, parties of different size, travel pace, observer skill, firearm habits, and other variables had remarkably dissimilar fortunes in finding wildlife.

Third, individual writers differed enormously in their interests, but there were also nearly uniform patterns of what animal species were regarded as worth writing about. Most obvious among the patterns was that animals below a certain size—from somewhere around the size of a coyote on down—were almost never mentioned. The largest animals, such as bison, were most likely to be regarded as notable. It is hard to overstate the effect this has had on analysis of the historical record of wildlife. Virtually no early writers except for a few zoologists said anything about the hundreds of species of songbirds, small mammals, reptiles, amphibians, and insects that they could not have avoided seeing. As well, there were extreme and not at all surprising observer biases toward visual evidence and away from auditory evidence. Except for reports of elk bugles, wolf howls, and a very few other animal noises, the historical record of first-hand accounts of wildlife would give the mistaken impression that the Greater Yellowstone Ecosystem was an almost silent wilderness. Bird songs and calls are especially absent from almost all accounts.

Fourth, in sharp contrast to modern natural-history writers, virtually no writers from our study period reported animal droppings of any kind. There were at least two reasons for this. The first reason is that, unlike us, all of these people came from a manure-rich world; the stuff was a routine sight at home, where it was a reality of both rural and urban landscapes. Bison droppings may have been even more uninteresting than some other types, because they so nearly resembled those of domestic cattle. The second reason is that animal droppings weren't the topic of polite writing.

An interesting sidelight of this topic is the general absence, from early historical photographs of Yellowstone National Park landscapes, of such obvious bison evidence as their droppings. If, as seems likely to us, bison numbers had been reduced especially in the most accessible portions of what would

become Yellowstone National Park well before 1871, when the first cameras arrived, then “buffalo chips,” even old ones, would probably have been scarce at that time. In addition, professional photographers of the day, who typically went to considerable effort to set up each image, would have most likely kicked the closest and most noticeable such unwelcome natural features out of view before taking their pictures. However, we consider such photographic evidence worth further consideration.

Fifth, large parties might have contained several writers, and all must be consulted. As we accumulated these early accounts from many sources, we discovered that even the third or fourth account from yet another member of the same party might reveal new insights.

Conclusion

Though the written historical record does establish the widespread distribution of bison throughout the GYE, that record was made too late to provide us with a full portrait of the relationships between native people and bison before those relationships were influenced by Euro-Americans. That written record was also made too late to portray anything necessarily resembling a so-called “pristine” state of ecological affairs in regional bison populations.

What the historical record does tell us is that bison were here, they were all over the place, they were abundant, and, if we may add a new and sadder meaning to Warren Ferris’s words, “nothing remains visible of the long black lines but dark clouds slowly sweeping over the distant plains.”

References

Benedict, J. B. 1999. Effects of changing climate on game-animal and human use of the Colorado high country (U.S.A.) since 1,000 B.C. *Arctic, Antarctic, and Alpine Research* 31(1):1–15.

Cannon, K. P. 2001. What the past can provide: contribution of prehistoric bison studies to modern management. *Great Plains Research* 11(1):145–174.

Daubenmire, R. 1985. The western limits of the range of the American bison. *Ecology* 66(2):622–624.

Ferris, W. A. 1940. *Life in the Rocky Mountains 1830–1835*. Salt Lake City: Rocky Mountain Bookshop.

Flores, D. 1991. Bison ecology and bison diplomacy: the southern plains from 1800 to 1850. *Journal of American History* 78(2):465–485.

Fowler, L. 1996. The Great Plains from the arrival of the horse to 1885. Pages 1–55 *in* B. G. Trigger and W. E. Washburn, eds., *The Cambridge history of the native peoples of North America*, vol. 1, North America, part 2. New York: Cambridge University Press.

Franke, M. A. 2005. *To save the wild bison: life on the edge in Yellowstone*. Norman: University of Oklahoma Press.

Haines, A. L. 1964. *The Bannock Indian Trail*. Yellowstone National Park: The Yellowstone Library and Museum Association.

Hoxie, F. 1989. *The Crow*. New York: Chelsea House Publishers.

Isenberg, A. 2000. *The destruction of the bison*. New York: Cambridge University Press.

Janetski, J. 1987. *The Indians of Yellowstone Park*. Salt Lake City: Bonneville Books, University of Utah Press.

Johnson, A. 1997. How long have bison been in the park? *The Buffalo Chip*, January–February–March, 5.

Krech, S., III. 2000. *The ecological Indian*. New York: W. W. Norton & Company.

Lewis, M., and W. Clark. 1905. *In* R. G. Thwaites, ed., *Original journals of the Lewis and Clark expedition*. New York: Dodd, Mead & Company.

Lupo, K. 1996. The historical occurrence and demise of bison in northeastern Utah. *Utah Historical Quarterly* 64(2):168–180.

Martin, P. S., and C. R. Szuter. 1999. War zones and game sinks in Lewis and Clark’s West. *Conservation Biology* 13(1):36–45.

Schullery, P., and L. H. Whittlesey. 1992. The documentary record of wolves and related wildlife species in the Yellowstone National Park area prior to 1882. Pages 1.3–1.173 *in* John D. Varley and Wayne G. Brewster, eds., *Wolves for Yellowstone? A report to the United States Congress*, volume 4, research and analysis. Yellowstone National Park, Wyo.: National Park Service.

______. 1995. A summary of the documentary record of wolves and other wildlife species in the Yellowstone National Park area prior to 1882. Pages 63–76 *in* L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. *Ecology and conservation of wolves in a changing world*. Canadian Circumpolar Institute, occasional publication No. 35.

______. 1999a. Early wildlife history of the Greater Yellowstone Ecosystem: an interim research report presented to National Research Council, National Academy of Sciences, committee on “Ungulate Management in Yellowstone National Park” (July). Copies available from the National Academy of Sciences, Washington, D.C., or from the Yellowstone Research Library or Yellowstone Center for Resources, Yellowstone National Park, Wyo.

______. 1999b. Greater Yellowstone carnivores: a history of changing attitudes. Pages 10–49 *in* T. P. Clark, P. C. Griffin, S. Minta, and P. Kareiva, eds., *Carnivores in ecosystems: the Yellowstone experience*. New Haven: Yale University Press.

Shaw, J. H. 1995. How many bison originally populated western rangelands? *Rangelands* 17(5):148–150.

Thwaites, R. G., ed. 1905. *Original journals of the Lewis and Clark expedition,* volume 5. New York: Dodd, Mead & Company.

Urness, P. J. 1989. Why did bison fail west of the Rockies? *Utah Science* 50(3):175–179.

Van Vuren, D. 1987. Bison west of the Rocky Mountains: an alternative explanation. *Northwest Science* 61(2):62–69.

Whittlesey, L. H. 1994. A pre-1905 history of large mammals in Pierre's Hole, Idaho; Jackson Hole, Wyoming; and the Bechler region of southwestern Yellowstone. In-house draft report, August 2, 1994. Yellowstone National Park, Wyo.: National Park Service.

Greater Yellowstone Pronghorn: A Nineteenth-Century Historical Context

Paul Schullery

P.O. Box 168, Yellowstone National Park, WY 82190 (307-344-2220, paul_schullery@nps.gov)

Lee Whittlesey

P.O. Box 168, Yellowstone National Park, WY 82190 (307-344-2261, lee_whittlesey@nps.gov)

Abstract

The pronghorn is a species of special concern for wildlife managers and advocates throughout the Greater Yellowstone Ecosystem (GYE). Issues relating to population isolation and migration corridors are currently significant in management dialogues. An important element in such dialogues should be the historical record of pronghorn in the GYE. In an exhaustive review of published and unpublished first-hand accounts of the GYE prior to the creation of Yellowstone National Park in 1872, we compiled all observations, accounts, and references to pronghorn, including tracks, hide, meat, and other parts and evidence. Early travelers of the lower river valleys and outlying grasslands of the GYE reported abundant pronghorn. The arrival, in the late 1700s and early 1800s, of Euro-American influences—in the form of horses, firearms, human and wildlife disease, and trade incentives—all had potential and perhaps significant effects on abundance of pronghorn as the nineteenth century passed, but the arrival of growing numbers of settlers and hide-hunters beginning in the 1860s seems to have had more far-reaching effects, such as wholesale declines in pronghorn numbers through much of the GYE. However, even in the 1860s and early 1870s, pronghorn were still reported as abundant in at least some appropriate habitats in the GYE, and especially on and near Yellowstone National Park's northern range. Because of its intolerance for winter conditions, the pronghorn was probably least able to take advantage of the year-round sanctuary eventually provided the other ungulates following the creation of Yellowstone National Park in 1872. Historiographical issues abound in studying large numbers of anecdotal, "snapshot-type" observations in a large, dynamic wildland.

The northern Yellowstone pronghorn population has been of special interest to managers for more than a century (Skinner 1924). Concerns, especially with genetic issues, have heightened in recent decades (White and Treanor 2002). Long-term viability of historic migration routes of pronghorn are likewise of public and scientific concern elsewhere in the Greater Yellowstone Ecosystem (Sawyer and Lindzey 2000; Berger 2004). Conservation of far-ranging migratory wildlife populations provides national parks and similar reserves with a stern test of their ideals and mandates, and pronghorn management in Greater Yellowstone is recognized as an important exemplar of such tests (Berger 2003).

Wildlife managers are routinely confronted with the task of maintaining robust populations of favored species with relatively imprecise information on the actual historic or prehistoric abundance of the species (Schullery 1997). The Greater Yellowstone Ecosystem (GYE), often characterized as one of the last intact natural ecosystems in the temperate zone of Earth, is widely recognized as a place where wildlife thrive in numbers and distribution at least vaguely resembling pre-Columbian conditions. Prior to our study, no exhaustive review of those conditions, as reflected in the earliest historical record (for the period roughly 1790–1880), has been conducted.

Estimates of the pre-Columbian population of pronghorn in the Mexican and North American West have ranged from about 10 million to 40 million (McCabe et al. 2004). It is an especially interesting feature of the study of pronghorn history that the size and other characteristics of pronghorn populations in the American West in the early national period must be extricated from the shadows cast by larger animals. Every American schoolchild who is exposed to any information about the native western landscape is certain to learn of the fabulous abundance of bison, but will probably not become aware that there is such an animal as the pronghorn until they make a vacation trip to the West and see one.

In many early eyewitness accounts of the American West generally and Greater Yellowstone specifically, pronghorn are most typically listed as also-rans

or bit players in narratives dominated by breathless accounts of the stupendous numbers of bison seen on the Great Plains. The irony of this masking of pronghorn narratives under bison narratives is that had none of the other large mammals been present in the American West, and had pronghorn numbers merely stayed what they were in the presence of bison, our textbooks and popular writers would today speak in awe of the genuinely African spectacle provided by those pronghorn 200 years ago.

For our ongoing study of early Greater Yellowstone wildlife history, we gathered observations, accounts, and references to pronghorn (including tracks, hide, meat, and other parts and evidence) from several hundred accounts of the GYE prior to 1882 (e.g., Schullery and Whittlesey 1992; 1995; 1999a; Whittlesey 1992; 1994). These accounts include formal government survey reports, published and unpublished journals of explorers, trappers, prospectors, military parties, and tourists, early published and unpublished maps, anthropological literature, popular journalism such as books and periodical articles, and contemporary newspaper accounts. In this paper we summarize our findings relating to pronghorn in the following areas: First, we summarize what the historical record tells us about distribution and abundance of pronghorn in Greater Yellowstone at the time of first Euro-American visits to the area. Second, we describe the decline of the pronghorn population in the area. Third, we consider what the study of the historic record of pronghorn in the Greater Yellowstone Ecosystem might tell us about the historiography of early historical evidence of pronghorn.

Original distribution and abundance of pronghorn in the Greater Yellowstone Ecosystem

We hesitate to use the term "original" in describing the distribution and abundance of pronghorn in Greater Yellowstone without qualifying the term. For many people, the term "original" implies both some stable number and some ultimately "correct" number, when in fact changing environmental conditions are known to have been the rule in Greater Yellowstone throughout the Holocene (Romme and Despain 1989; Whitlock et al. 1991; Engstrom et al. 1991; Barnosky 1994; Whitlock and Bartlein 1993; Millspaugh and Whitlock 1995). Environmental conditions, especially climate, changed on scales of years, decades, centuries, and millennia, thus making portions of Greater Yellowstone less or more hospitable to various life forms, including native humans whose effects on the setting likewise would have varied over time. History can provide us with many answers to questions about wildlife, but because of these changing environmental conditions, the study of history can not provide us with a prescription for some imagined optimum scenario for wildlife on the modern landscape.

We also must emphasize that the written historical record of animals in the GYE, which dates to the 1790s, documents a region already feeling the first effects, both cultural and ecological, of Euro-American presence. The arrival of horses in the region in the late 1700s; the arrival of both human and wildlife diseases at roughly the same time or soon after; the arrival of Euro-American technology including firearms, edged weapons, traps, and other tools in the early 1800s; and the arrival of new and often forceful trade incentives all had enormous potential for affecting native wildlife (Janetski 1987; Hoxie 1989; Fowler 1996; Schullery 1997).

It is thus essential to recognize that the documentary record of Greater Yellowstone wildlife for the 70 or so years prior to the creation of Yellowstone National Park in 1872, as helpful and interesting as that record is, should not be perceived as a window onto some "pristine," or Edenic, or pre-Columbian state of ecological affairs in the regional landscape (see also Schullery and Whittlesey, "Greater Yellowstone Bison Distribution and Abundance in the Early Historical Period," in this volume).

Perhaps the most interesting element of public understanding of Greater Yellowstone wildlife concerns the history of large mammals. There exists in regional folklore and received wisdom the persistent view that 150 years ago, large portions of Greater Yellowstone were nearly or completely bereft of large mammals (Skinner 1928; Chase 1986; Kay 1990; Richard and Bagne 2002). This view was most aggressively proclaimed in recent times by opponents of wolf recovery, who maintained that the very idea of wolf recovery was fundamentally flawed because neither wolves nor, by implication, their prey inhabited the present Yellowstone National Park area prior to the late 1800s (Mader 1989).

This apparently quite attractive notion—that large portions of the intermountain West were biological vacuums until settlement forced plains animals such as bison, elk, and pronghorn into higher country, apparently arose more than 100 years ago, and has survived repeated and competent demolition by generations of scholars (Murie 1940; Koch

1941; Houston 1982). As admired a historian as Stephen Ambrose, in his deservedly popular book on Lewis and Clark, endorsed this erroneous notion, presumably having read some of the countless earlier publications that have kept it alive against all reason (Ambrose 1996).

In previous publications we have established that the belief that any portion of Greater Yellowstone was occupied only recently by large mammals because of growing white human population pressures is without any basis in the historical record (Schullery and Whittlesey 1992; 1995; 1999a; 1999b). Specifically, reports of large numbers of pronghorn throughout Greater Yellowstone, including within the present boundaries of Yellowstone National Park, appear in the historical record early enough that the nearest contemporaneous Euro-American population pressures were being exerted by the suburbs of frontier St. Louis, and perhaps by a few white traders hanging out in the Mandan Villages of western North Dakota. In other words, the animals were present in large numbers many years before the supposed Euro-American settlement pressures could have been exerted.

The historical record further indicates that pronghorn were abundant in appropriate habitats throughout Greater Yellowstone, and were especially numerous in the lower river valleys and along the various prairie edges of the region. A few representative early observations will serve. In 1806, William Clark and his party were among the first known, and probably the first, whites to enter Greater Yellowstone. Specifically, in the Yellowstone Valley, as he traveled east from the site of present Livingston, Montana, Clark reported "great numbers of Antelopes" (Thwaites 1905, 5:265). More typical of early reports of pronghorn abundance is trapper Joe Meek's nostalgic reminiscence that in the 1830s, "The whole country lying upon the Yellowstone and its tributaries, and about the head-waters of the Missouri, at the time of which we are writing, abounded not only in beaver, but in buffalo, bear, elk, antelope, and many smaller kinds of game" (Victor 1870, 90).

A similar pattern emerges among the many accounts of wildlife on the southern edge of Greater Yellowstone. In 1832, Captain Nathaniel Wyeth, traveling with trappers along the Green River, reported that pronghorn were "plenty." On July 25, near present Pinedale, Wyoming, following the pronghorn-as-afterthought pattern, Wyeth reported "Buffaloe throwing dust in the air in every direction and Antelope always in sight" (Wyeth 1899, 206).

Even earlier, in October of 1812, Robert Stuart's party crossed the southern end of the ecosystem. Along the base of the Wind River Range, near present East River, they saw "many Antelopes" (Stuart 1935, 160). In the Teton Basin, west of the Teton Range, he said, "numerous bands of antelope were seen" (Stuart 1935, 289).

As is the case with most other large animal species in Greater Yellowstone, with only a few important exceptions early narratives tend to say little or nothing about pronghorn seasonal movements. Almost all narratives prior to the creation of Yellowstone National Park in 1872 were written by transients, most of whom did their traveling and observing in the warmer months of the year. Parties might or might not see concentrations of wildlife, depending upon the serendipitous nature of such sightings given the realities of the migration habits of the animals. Until a few literate people spent a large portion of a year in one spot, as began to happen in the 1860s, no one could leave written observations of wildlife conditions through more than one season in one location. Other disciplines, especially archeology, have been helpful in resolving some details of seasonal wildlife movements (e.g., Meredith Taylor, "Ancient Corridors: The Trapper's Point Story of the Prehistoric Path of the Pronghorn," this volume).

Decline in abundance of pronghorn in Greater Yellowstone

For reasons including their lower value for food and hides, pronghorn may have persisted in what we would now regard as abundance in some parts of Greater Yellowstone far longer than did more commercially desirable game such as elk and bison. The primary destroyer of large mammals in Greater Yellowstone even as late as the 1870s was not settlement or other habitat destruction. It was continued commercial hunting, and it seemed to focus either more intensively or more successfully on bison and elk than on pronghorn. A few representative accounts will help portray the changes during this period.

Though bison had been eliminated from much of western Greater Yellowstone by 1860, in late June of that year, Captain William Raynolds and his exploring party were traveling the lower Madison Valley, west of present Yellowstone National Park, and reported that "Antelopes have been visible in large numbers upon all sides" (Raynolds 1868, 100). In September 1864, prospector Edward B. Nealley described the area we now call Paradise Valley, on the Yellowstone River south of present Livingston,

Montana, as a "paradise" that was "full of wild game." He said more about pronghorn than did most other early observers:

> The most interesting of all the wild animals is the antelope. Every hour we passed flocks of these little fellows. They are timid as school-girls, but as inquisitive as village gossips; and while frightened and trembling at our presence, they could not resist keeping long in our view, and stopping every few moments to watch us, with most childish curiosity. Though fleet as the wind, I have seen many of the meek-eyed little fellows watch too long, and pay for their curiosity with their lives (Nealley 1866, 245).

We have a number of accounts of wildlife in Paradise Valley in the mid-1860s, written by early prospectors in the Emigrant area. These observations were made well before the park was created in 1872, and they corroborate Nealley's report of wildlife abundance. Most important, because some of the observers spent the winter in that area, they left us our first accounts of migrations by these animals.

It appears that pronghorn persisted in good numbers in the upper Madison Valley at least until the late 1870s. In 1879, near present West Yellowstone, Montana, Richard B. Hassell "discovered an open part of the valley that was alive with antelope." Hassell wrote, "We took our horses and had great sport chasing the graceful creatures. They would run up one canyon, cross over a hog-back and come down another canyon on to the same plain. We were often close upon their heels but had no camera. There must have been a thousand antelope in this herd" (Hassell 1929, 6).

In the winter of 1866–1867, pioneer Joe Brown wintered on Bear Gulch, near present Gardiner, Montana, and later remembered a great abundance of wild game. He said, "There was lots of antelope in the summer, but they all left in the fall. The elk also came down farther in the valley and the deer didn't like the climate up there. But the sheep stayed with us all winter" (*Livingston Enterprise* 1909).

Though they enjoyed a fair abundance after the bison were mostly gone, pronghorn were by no means immune from the general wildlife slaughter. We have numerous reports of such killing in Greater Yellowstone. In 1873, the new Bozeman newspaper reported that people were killing Yellowstone Valley antelope and other species "for the pleasure of seeing them fall while others were killing them for their hides" (*Avant Courier* 1873). In 1880, Yellowstone National Park Superintendent Philetus Norris said of the pronghorn that "No other animal has suffered such severe slaughter, not alone within the Park, but upon the great plains, below the Gate of the Mountains [near present Livingston, Montana], and upon the Yellowstone, where in their migrations they were wont to winter" (Norris 1881, 40).

Norris's claim appears to us, judging from the many other accounts we have examined, to have been an overstatement. The historical record suggests that, at the time he was writing, bison and elk were more dramatically affected than pronghorn by the commercial slaughter to which Norris referred. But Norris's emphasis on pronghorn does accurately indicate that in many areas the severity of their slaughter was extreme.

At the end of our study period in the early 1880s, though pronghorn were substantially reduced in number, they were still routinely seen throughout the region. Historical studies of the three-state region around Greater Yellowstone suggest that pronghorn remained widely if thinly distributed in many parts of the three states for some decades after the bison were reduced to a last wild herd in Yellowstone National Park (Nelson 1925). Though remaining numbers of pronghorn grew perilously small, the species did not reach its lowest population levels in Montana until around 1930 (Mussehl and Howell 1971).

Pronghorn and the historiography of early wildlife study

Pronghorn were a species so unknown to early western travelers that they were often completely misnamed. In the cases of some other species in the American West (such as wolves and coyotes), nomenclature confusion in early narratives has caused genuine uncertainty over which animal was being reported. But the most common alternative early name of the pronghorn was "goat," which has led to very little confusion. Because of the extreme geographical and topographical isolation of most bighorn sheep and mountain goat populations from pronghorn habitat, we could almost always be certain that early travelers who mentioned "goats" in fact meant the animal we now know as the pronghorn or antelope.

There are more subtle questions raised by early accounts of pronghorn, questions that are not readily resolved. These have to do with the partiality of observers for some species, and the overwhelming abundance of certain species that may have tended to mask observations of other species—a potential problem with pronghorn observations that we mentioned earlier.

We assume that in their written accounts of the region, early observers did tend to preferentially mention animals and other landscape features that for whatever reason or reasons mattered most to them. Trappers focused most heavily on furbearers, and big game hunters on their preferred quarry. Early tourists, like many modern tourists, would much prefer to have seen a grizzly bear than a black bear; this may have meant they were more likely to mention a grizzly bear sighting, but it may also have meant they were more likely to "see" a grizzly bear even if the observed animal was in fact a black bear. Besides, most observers were more impressed by the largest animals. It is to be expected that most early travelers would find a grizzly bear sighting more noteworthy than a ground squirrel sighting, just as a trapper would be more inclined to discuss beaver sign rather than sandhill crane songs.

Exactly how such biases may have played out in the accumulated body of pronghorn observations is an intriguing and difficult question. On the one hand, pronghorn were of considerably less practical interest (for example, as food) to many early travelers than were several other species, and thus might be underrepresented in the record. But on the other hand, the pronghorn was the most exotic and unfamiliar large mammal these travelers would encounter on the prairies. Besides, the pronghorn's habitats, habits, and markings often make them extraordinarily visible on their summer ranges.

It is our general conclusion that, just as overemphasis on selected early reports of complete animal absence is injudicious, so is placing too much emphasis on the reports of exceptional animal abundance. This is not to question the accuracy of the reports of the largest concentrations of animals; no doubt such concentrations did occur. But, in light of the rarity of the most extreme statements of pronghorn abundance, we should at least wonder if those statements represent unusual circumstances (such as, for example, animals concentrated for brief periods of time during migrations) rather than typical conditions. In their splendid recent review of early pronghorn history, Richard McCabe, Bart O'Gara, and Henry M. Reeves counsel caution in extrapolating too freely from the occasional report of the slaughter of large numbers of pronghorn, to some imagined and far greater prehistoric pronghorn population (McCabe et al. 2004). We think that advice is wise, and likewise apply it to the occasional report of this or that exceptional concentration of pronghorn somewhere in Greater Yellowstone in the nineteenth century. No doubt by today's standards, nineteenth-century Greater Yellowstone pronghorn populations constituted a thrilling spectacle, but the historical record is not refined or extensive enough to tell us much more than that.

Conclusion

The early historical record of pronghorn distribution and abundance in Greater Yellowstone, though intriguing in many particulars, is not sufficient to allow more than general estimations of conditions. Pronghorn were routinely observed to be generously common in suitable habitats throughout the region, including in both present Yellowstone and Grand Teton national parks. Unlike some of the larger mammals, pronghorn were heavily hunted but still weathered the great commerce-related wildlife purges of the nineteenth century without being entirely eliminated from major portions of Greater Yellowstone.

References

Ambrose, S. E. 1996. *Undaunted courage: Meriwether Lewis, Thomas Jefferson, and the opening of the American West.* New York: Simon & Schuster.

Avant Courier (Bozeman, Mont.), February 21, 1873.

Barnoksy, E. 1994. Ecosystem dynamics through the past 2000 years as revealed by fossil mammals from Lamar Cave in Yellowstone National Park, U.S.A. *Historical Biology* 8:71–90.

Berger, J. 2003. Is it acceptable to let a species go extinct in a national park? *Conservation Biology* 17:1451–1454.

______. 2004. Long distance migrations: Yellowstone in a global context. Pages 18–23 *in* A. Wondrak Biel, ed., *Beyond the arch: community and conservation in Greater Yellowstone and East Africa*. Proceedings of the 7th Biennial Scientific Conference on the Greater Yellowstone Ecosystem. October 6–8, 2003, Mammoth Hot Springs Hotel, Yellowstone National Park. Yellowstone National Park, Wyo.: Yellowstone Center for Resources.

Chase, A. 1986. *Playing God in Yellowstone*. Boston: Atlantic Monthly Press.

Engstrom, D. R., C. Whitlock, S. C. Fritz, and H. E. Wright, Jr. 1991. Recent environmental changes inferred from the sediments of small lakes in Yellowstone's northern range. *Journal of Paleolimnology* 5:139–174.

Fowler, L. 1996. The Great Plains from the arrival of the horse to 1885. Pages 1–55 *in* B. G. Trigger and W. E. Washburn, eds., *The Cambridge history of the native peoples of North America*, vol. 1, North America, part 2. New York: Cambridge University Press.

Hassell, R. B. 1928. A trip to the Yellowstone 49 years ago. Ms., Yellowstone National Park Research Library, Yellowstone National Park, Wyo.

Houston, D. B. 1982. *The northern Yellowstone elk, ecology and management*. New York: Macmillan.

Hoxie, F. E. 1989. *Indians of North America, the Crow.* New York: Chelsea House Publishers.

Janetski, J. C. 2002. *The Indians of Yellowstone Park*. Salt Lake City: Bonneville Books, University of Utah Press.

Kay, C. 1991. *Yellowstone's northern elk herd: a critical evaluation of the "natural regulation" paradigm*. Ph.D. dissertation, Utah State University, Logan, Utah.

Koch, E. 1941. Big game in Montana from early historical records. *Journal of Wildlife Management* 5(4):357–370.

Livingston Enterprise (Montana), December 18, 1909.

Mader, T. 1989. *Unnatural wolf transplant in Yellowstone National Park*. Gillette, Wyo.: Common Man Institute.

McCabe, R. E., B. W. O'Gara, and H. M. Reeves. 2004. *Prairie ghost: pronghorn and human interaction in early America*. Boulder, Colo.: University Press of Colorado and the Wildlife Management Institute.

Millspaugh, S. H., and C. Whitlock. 1995. A 750-year fire history based on lake sediment records in central Yellowstone National Park, USA. *The Holocene* 5(3):283–292.

Murie, A. 1940. *Ecology of the coyote in the Yellowstone*. Fauna of the National Parks No. 4. Washington, D.C.: U.S. Government Printing Office.

Mussehl, T. W., and F. W. Howell, eds. 1971. *Game management in Montana*. Helena: Montana Fish and Game Department.

Nealley, E. B. 1872. A gold-hunt on the Yellowstone. *Lippincott's Magazine* 9:204–212.

Nelson, E. W. 1925. Status of the pronghorned antelope, 1922–1924. United States Department of Agriculture Department Bulletin No. 1346. Washington, D.C.: U.S. Department of Agriculture.

Norris, P. 1881. Annual report of the Superintendent of the Yellowstone National Park to the Secretary of the Interior for the year 1880. Washington, D.C.: U.S. Government Printing Office.

Raynolds, W. F. 1868. The report of Brevet Brigadier General W. F. Raynolds on the exploration of the Yellowstone and the country drained by that river. 40th Cong., 1st Sess., Sen. Ex. Doc. 77. Washington, D.C.: U.S. Government Printing Office.

Richard, B., and M. Bagne. 2002. *Yellowstone country: the photographs of Jack Richard*. Boulder, Colo.: Roberts Rinehart.

Romme, W. H., and D. G. Despain. 1989. The Yellowstone fires. *Scientific American* 261(5):37–46.

Sawyer, H., and F. Lindzey. 2000. Jackson Hole pronghorn study. Laramie, Wyo.: Cooperative Fish and Wildlife Research Unit.

Schullery, P. 1997. *Searching for Yellowstone*. Boston: Houghton Mifflin Company.

Schullery, P., and L. H. Whittlesey. 1992. The documentary record of wolves and related wildlife species in the Yellowstone National Park area prior to 1882. Pages 1.3–1.173 *in* John D. Varley and Wayne G. Brewster, eds., *Wolves for Yellowstone? A report to the United States Congress,* volume 4, research and analysis. Yellowstone National Park, Wyo.: National Park Service.

______. 1995. A summary of the documentary record of wolves and other wildlife species in the Yellowstone National Park area prior to 1882. Pages 63–76 *in* L. N. Carbyn, S. H. Fritts, and D. R. Seip, eds. *Ecology and conservation of wolves in a changing world*. Canadian Circumpolar Institute, occasional publication No. 35.

______. 1999a. Early wildlife history of the Greater Yellowstone Ecosystem: an interim research report presented to National Research Council, National Academy of Sciences, committee on "Ungulate Management in Yellowstone National Park" (July). Copies available from the National Academy of Sciences, Washington, D.C., or from the Yellowstone Research Library or Yellowstone Center for Resources, Yellowstone National Park, Wyo.

______. 1999b. Greater Yellowstone carnivores: a history of changing attitudes. Pages 10–49 *in* T. P. Clark, P. C. Griffin, S. Minta, and P. Kareiva, eds., *Carnivores in ecosystems: the Yellowstone experience*. New Haven: Yale University Press.

Skinner, M. P. 1924. The American antelope in Yellowstone National Park. *Journal of Mammalogy* 3(2):82–105.

______. 1928. The elk situation. *Journal of Mammalogy* 9(4):309–317.

Stuart, R. 1935. Robert Stuart's narratives of his overland trip eastward from Astoria in 1812–13. Pages 1–186 *in* P. A. Rollins, ed., *The discovery of the Oregon Trail.* New York: Charles Scribner's Sons.

Thwaites, R. G., ed. 1905. *Original journals of the Lewis and Clark expedition,* volume 5. New York: Dodd, Mead & Company.

Victor, F. F. 1870. *River of the West*. Hartford, Conn: R. W. Bliss and Company.

White, P. J., and J. Treanor. 2002. Yellowstone pronghorn conservation assessment workshop, Mammoth Hot Springs, Yellowstone National Park, January 28–31, 2002. Yellowstone National Park, Wyo.: Yellowstone Center for Resources, National Park Service, report available in Yellowstone Park Research Library.

Whitlock, C., and P. J. Bartlein. 1993. Spatial variations of holocene climatic change in the Yellowstone region. *Quaternary Research* 39:231–238.

Whitlock, C., S. C. Fritz, and D. R. Engstrom. 1991. A prehistoric perspective on the northern range. Pages 289–305 *in* R. B. Keiter and M. S. Boyce, eds., *The Greater Yellowstone Ecosystem: redefining America's wilderness heritage*. New Haven: Yale University Press.

Whittlesey, L. H. 1992. A history of large animals in Yellowstone National Park before 1882. In-house research report available in Yellowstone National Park Research Library, Yellowstone National Park, Wyo.

______. 1994. A pre-1905 history of large mammals in Pierre's Hole, Idaho; Jackson Hole, Wyoming; and the Bechler region of southwestern Yellowstone. In-house draft report, August 2, 1994. Yellowstone National Park, Wyo.: National Park Service.

Wyeth, N. J. 1899. *The correspondence and journals of Captain Nathaniel J. Wyeth 1831–6*. Eugene, Ore.: Oregon Historical Society.

Through the Historical Lens: An Examination of Compositional Change in Yellowstone's Bunchgrass Communities, 1958–2002

Pamela G. Sikkink

College of Forestry and Conservation, University of Montana, Missoula, MT 59812

Paul B. Alaback

College of Forestry and Conservation, University of Montana, Missoula, MT 59812

Abstract

During the past 50 years, bunchgrass communities in and around Yellowstone National Park (YNP) have been affected by fluctuating climate, grazing pressure, and increased interactions with non-native species. The response of the communities to this environmental change has been recorded by a natural experiment that was initiated in 1958, when permanent plots were established inside and outside of big game exclosures in YNP. The monitoring records from these permanent plots show that the bunchgrass cover has been highly variable over five decades, and associated with changing environmental conditions. Compositionally, species within the bunchgrass communities changed frequently between 1958 and 2002, and species turnover was quite high. Even when individual species were present, their dominance varied significantly in the community. Between 1958 and 2002, the mean frequency of grass species decreased in both grazed (–11%) and ungrazed (–28%) areas. Drought-tolerant genera, such as opuntia, phlox, and sedum, increased in both areas. Shrub dominance increased significantly in the absence of grazing, but diversity was not significantly different between ungrazed and grazed areas. Diversity and overall frequency of each lifeform was highest in the mid-1970s to early 1980s, but both decreased significantly at most sites by 2002. Using path analysis, the correlation of multiple environmental variables with community compositional change between sample periods was tested. Fluctuations in climatic factors correlated more significantly with species change than did variations in non-native species or wildlife populations. The most significant environmental factors were spring and summer precipitation and spring and winter temperatures.

Introduction

"To look backward in time is to refresh the eye, to restore it, and to render it more fit for its prime function of looking forward."

—Margaret Fairless Barber, 1869–1901
(Andrews et al. 1996)

To the casual observer, the grassland landscape of Yellowstone National Park (YNP)'s northern big-game range looks almost unchanged after half a century of tourist visits and wildlife use in the park. The landscape gives the impression that its grassland communities are quite stable and resistant to environmental change (Figure 1). To determine whether these grasslands really are resistant to change, and for how long, however, requires an historical lens that focuses on individual community members and tracks their dynamics over time. Five decades of monitoring data from the Yellowstone winter range provides the historical lens needed to "look backward" at compositional changes in vegetation within this area and see whether the communities are truly resistant to environmental change.

The historical perspective for this paper begins in the late 1950s, when several exclosures were constructed on YNP's northern range. The exclosures were created to allow for in-depth scientific studies and to provide demonstration areas for park personnel and visitors showing how grazing affects grass and shrub trends in the park (Edwards 1957). Transects established at the same time as these exclosures have constituted the main vegetation monitoring program in the park. Long-term monitoring data from the transects have been crucial to many scientific studies, especially those on the effects of elk grazing on vegetation (Houston 1982; Coughenour 1991; Barmore Jr. 2003) and the response of vegetation to fluctuations in temperature and precipitation (Coughenour et al. 1991). This study examines plant composition and species dynamics along these transects between 1958 and 2002.

The aim of this paper is to examine the development of bunchgrass communities on the northern

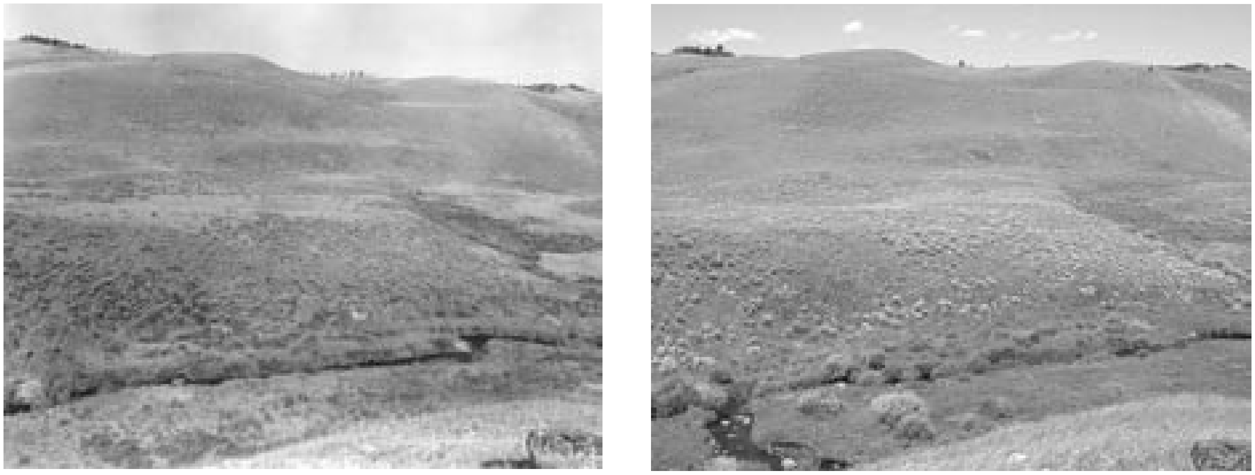


Figure 1. Landscape showing Blacktail Ponds exclosures in 1962 (left) and 2005 (right).

range of YNP over the past 50 years, as well as the correlation of environmental factors with community change. By examining the compositional and structural changes that the communities have experienced in the past, we can get an indication of how future changes in climate and disturbance regimes may affect vegetation on the northern range of YNP, and what management strategies may be feasible for these particular grass and shrub communities.

Methods

In 1957, YNP personnel constructed eight exclosures in the park's northern big-game winter range that eliminated all big-game grazing within their fenced, two-ha (five-acre) boundaries (Edwards 1957). Inside each exclosure, they established between two and five permanent transects. Transects measured 33.3 m (100 ft) long and were marked at the beginning, middle, and end with metal stakes. Just outside the exclosures, complementary transects were established that remained open to big-game grazing year-round. In 1962, a second exclosure was constructed in close proximity to the 1957 exclosures. Each also had new transects established within its boundaries and transects with matching slopes and aspects on the outside.

With the establishment of the exclosures and permanent transects, YNP began a long-term, natural experiment to demonstrate how grass and shrub communities were affected by grazing of fluctuating populations of wildlife in the park. The first descriptions of vegetation along the transects were done in 1958, by W. H. Kittams, NPS Regional Biologist from Omaha, and G. B. Denton of Montana State College, using a procedure established by K. W. Parker (Parker 1954). The procedure, known as the Parker Three-Step method, was designed for long-term repeatability in vegetation sampling. It was also a fast, simple technique for sampling all transects established inside and outside the exclosures within a reasonable time frame. Along each line, vegetation or substrate encountered at each 0.33-m (1-ft) mark was recorded. Vegetation "hits" were identified to species and recorded as either overstory or understory in the canopy. Substrate hits were recorded as bare ground, rock, pavement, litter, or moss/lichen. All species and substrate hits were tallied separately. Each line had a total of 100 hits, so all species and substrate variables were given as a frequency of occurrence in each sample year. For almost five decades, transects were re-sampled at irregular intervals by different personnel using the same sampling protocol. The timing for each re-sampling was matched as closely as possible to the timing of historic samplings so that changes in species frequency over the monitoring period were not confused with seasonal physiologic changes. Photographs were taken of each line, as required by the sampling protocol, to visually capture vegetation structure and plant distribution that was not evident from the small-scale sampling. The most recent sampling analyzed for this study was completed in 2002 (Sikkink 2005).

The monitoring data were analyzed diagrammatically and statistically. The changes in species frequency from 1958 to 2002 were diagrammed using facies diagrams. Facies diagrams (with each species considered a facie) summarized overall changes in the community composition through time. They also visually depicted the changes in frequency of each grass, forb, and shrub species to scale and indicated the constancy of each species through time. Two transects from the Blacktail Ponds area were

selected to be diagrammed as case studies for this paper. They were chosen because they portrayed the common patterns of vegetation change inside and outside of exclosures, were re-sampled at the same times in history, and had complete photographic coverage for five decades.

Changes in community composition, diversity, and structure were analyzed using non-metric multidimensional scaling (NMS). NMS integrated all species at each sampling into a numeric value that represented the "community." Community similarities over time, both within a single transect and between different transects, were compared using their relative positions within the NMS diagram. Similar compositions plotted close to each other in the NMS diagram; very different compositions plotted far apart. Ten transects, which were all that were sampled in 2002 using the Parker Three-Step method, were compared in the NMS ordinations. Both grazed and ungrazed transects were tested together in the ordination but diagrammed separately to contrast their change patterns. NMS was calculated within PCOrd V4.27 statistical software (McCune and Mefford 1999) using a Bray–Curtis distance measure and the autopilot function (step-down dimensionality starting in 6-D space, stability criterion=0.005, random number start). Each NMS analysis was run several times with random start numbers to ensure that the best configuration was achieved (i.e., to locate the solution with the least stress). Path analysis was used to test the strength of correlations between the changes in community composition and the environmental variables. Difference matrices were created that held differences in climatic, substrate, and origin variables between samples on the transect lines. These differences were tested for their correlations with the differences in positions of the plant "communities" (i.e., points) in species space of the NMS at each sample interval. In each path model, the changes in community composition were represented by changes in the NMS axes (designated y-variables). The covariance of each y-variable was tested against the absolute changes in environmental variables (x-variables). The x-variables included the frequency of bare soil, rock, and litter; average air temperature by season (FallTave, WinTave, SprTave, SumTave); precipitation by season (FallPrec, WinPrec, SprPrec, SumPrec); and species origin (native or non-native). Tests were run within LISREL 8.54 statistical software (Jöreskog and Sörbom 2003) using maximum likelihood estimations, 250 iterations, and a 0.000001 convergence criterion. The climate values were assigned to transect locations using a technique developed by Jolly et al. (2004), which interpolated values from nearby climate stations to specific sites on the landscape by adjusting for climatic variations caused by a site's unique elevation, slope, and aspect.

Results

Over five decades, 69 species from 22 families were recorded along the 10 transects examined for this study. Seventy-three samplings were done. For all samplings inside and outside the exclosures, grass and sedge were encountered an average of 70% of the time along a line, shrubs 13%, and forbs 27%. Drought-tolerant species, such as cactus (*Opuntia polyacantha*), phlox (*Phlox hoodii*), and sedum (*Sedum lanceolatum* and *Sedum stenopetalum*) all increased in frequency between 1958 or 1962 and 2002. Cactus increased from 0.0 to 2.95 mean hits; members of the phlox family increased from a mean of 4.5 to 6.2; and mean hits of *Crassulaceae* increased from 1.06 to 1.33. None of the increases between 1958 and 2002 were significant, however, with a two-sample t-test ($p>0.05$). The average richness for all samples was 9.75 species.

Case study: Blacktail 58 C2T2 (ungrazed area)

When YNP's natural experiment began in 1958, grass was encountered more frequently (23%) than shrubs (15%) along the case-study line in the Blacktail exclosure. Four grass species, three types of shrubs, and one forb (*Lupinus sericeus*) were identified. By 2002, the frequency of shrubs had increased significantly (Figure 2). Shrub and grass species were almost equally present along the line, and two added species of grass were more dominant than the four original grasses and sedge species. Between 1958 and 2002, both total vegetation and community richness fluctuated significantly along the line (Figure 3). Total vegetation hits fluctuated from about 20% to 85% (Figure 3). Richness varied from four species in 1986 to 11 species in 1974. On almost all transects, richness was highest between the mid-1970s and early 1980. The frequency of individual species varied within all of the lifeforms. Focal perennial bunchgrasses were not present along the line in some years (i.e., *P. spicata* in 1986; *F. idahoensis* in 1994), but were abundant in others (see 1981 in Figure 3). On the case study line, the bunchgrasses varied as much in time and space as annual and biennial forbs and grasses (Figure 3). Only *L. sericeus* was encountered in every sampling on the case-study transect, and its frequency varied from 1 to 10%.

Figure 2. Transect B58-C2T2 within the Blacktail exclosure in 1958 (left) and 2002 (right).

Case study: Blacktail MC1T1 (grazed area)

In the area open to grazing, the case-study line looked very similar in 1958 and 2002 (Figure 4). Both samplings had the same number of species, little or no shrub cover, and significant bare ground. Differences in composition were subtle, especially in the dominant grasses. *Koeleria macrantha* was the dominant grass in 1958; *Poa* spp. and *P. spicata* were co-dominant in 2002 (Figure 5).

In the intervening years between 1958 and 2002, however, the long-term monitoring records showed major differences in diversity, composition, and structure (Figure 5). Richness ranged from six species in 1967 to 13 in 1981. Grazed areas generally had higher richness than ungrazed areas, although the mean differences in richness between the grazed and ungrazed sites were not significant (9.7 and 9.8, respectively; $p>0.1$). As in the exclosures, richness was greatest between 1974 and 1981. Grazed areas had fewer vegetation hits and more bare ground during each sampling than the exclosures did. Total vegetation hits were less than 50%. The amount of bare ground and lack of vegetation did not correlate with years of high bison or elk counts in the park (R. Wallen, pers. comm.; P. White, pers. comm.). Individual species varied in their frequency between years, but the differences were not as extreme as in the exclosures (Figure 5). More species spanned the entire monitoring interval, which resulted in the appearance of a more stable community. Forbs, in particular, appeared more constant. Shrubs, especially *A. tridentata*, were infrequent in all years. However, comparison of 1958 and 2002 photographs showed that shrubs did increase in local patches adjacent to the line (Figure 4).

Community comparisons

Ungrazed and grazed communities had different change patterns. The ungrazed communities followed pathways from the grass-dominant portion of the ordination to the shrub-dominated portion through time (Figure 6). All samplings moved from the upper portion of Figure 6 to the lower left corner, where *A. tridentata* composed a high percentage of the community. The direction and amount of movement of the samples in species space between 1958 and 2002 indicated major changes in composition over the 50 years (Figure 6). The 1958 and 2002 samples were widely separated in species space for most transects and, therefore, not very similar in composition. Alternately, the grazed transects showed no clear change patterns in the NMS. As a group,

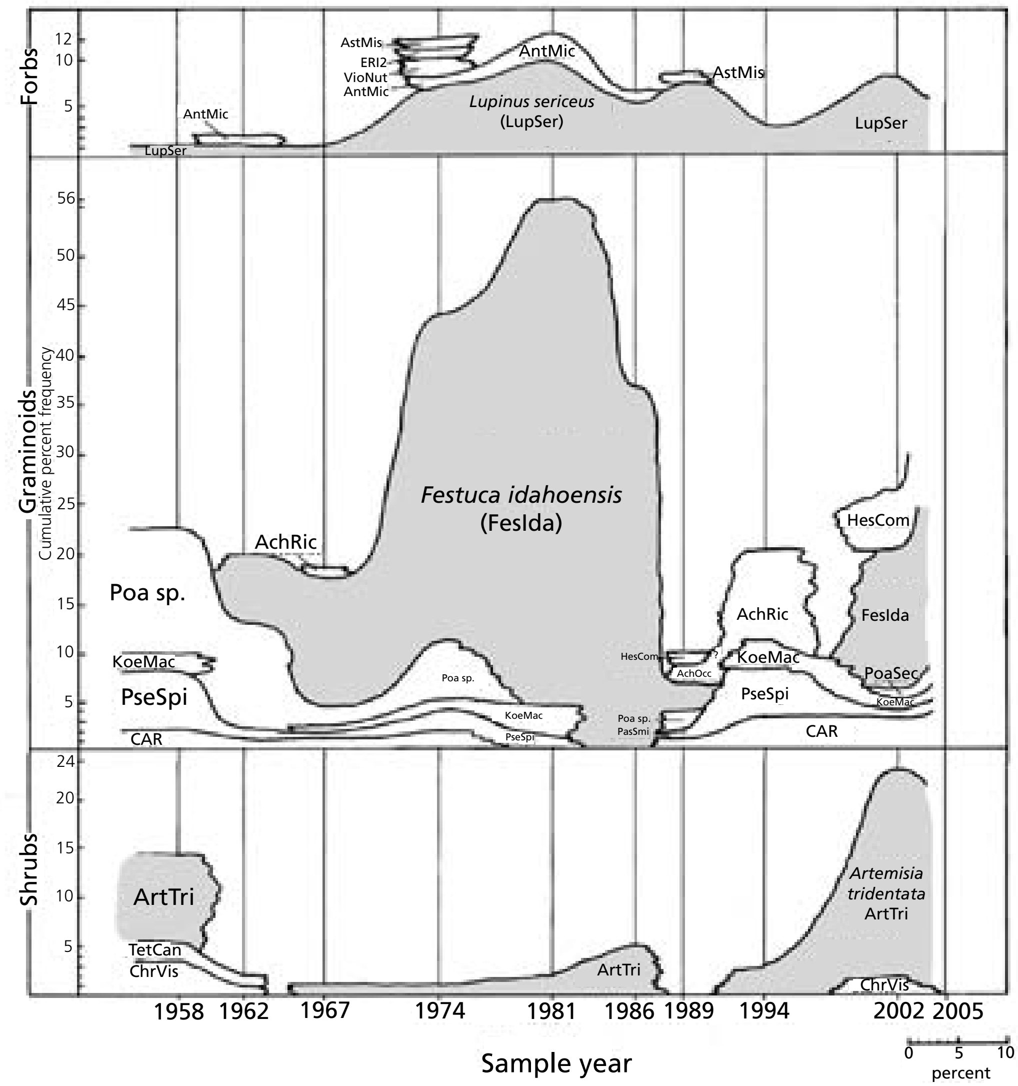


Figure 3. Facies diagram for B58-C2T2, inside the Blacktail (1958) exclosure (ungrazed area), Yellowstone National Park. Sample years are at vertical lines. Intervals between samples were manually interpolated. Percent cumulative frequency is diagrammed to scale by lifeform. Species abbreviations are listed in Appendix A.

they did not have strong directional trends toward any single part of the ordination diagram, nor were shrubs any more dominant in 2002 than in 1958. Two of the sample areas oscillated around a point in species space where *F. idahoensis* was the dominant grass (I and L, Figure 7). Two changed significantly over time from *P. spicata* and/or *K. macrantha* communities to *Poa* spp. or *Hesperostipa comata* communities, and each followed opposite change pathways through time (C and F, Figure 7).

Correlations of community change with environmental variables

The fluctuations of "community" positions within the NMS over time correlated significantly with changes in several substrate and climatic variables between samplings. The most significant variables were frequency of bare soil and litter, spring and summer precipitation, and spring and winter temperatures; all had t-values greater than +/− 0.35 and were significant at $p<0.05$. Of these variables, only spring precipitation and winter temperature were positively correlated with point movements in species space (Figure 8). Bare soil and litter were negatively correlated with plant composition changes, and were probably not independent of the climate variables in the analysis. Non-native species were insignificant to community change in this analysis.

Figure 4. Transect MC1T1 outside the Blacktail exclosure in 1958 (left) and 2002 (right).

Discussion

Insights into the development of temperate grassland communities and the environmental stresses that affect each of them over time can only be obtained through an historical lens. An historical lens focused on the temperate grasslands of YNP reveals that its plant communities change continually within a grassland landscape that at a larger scale appears relatively unchanged with the passage of time.

The most obvious general change in the bunchgrass communities occurred within the exclosures. Between 1958 and 2002, shrub coverage increased dramatically. Most of the expansion occurred after the early 1990s, when a combination of factors, including exclusion of grazing, exclusion of fire, and drought prevailed in YNP. The YNP exclosures are not unique in their response to these environmental stresses. Similar increases in shrub cover were found in areas excluded from grazing or fire in southeastern Idaho by Anderson and Holte (1981), regionally by Briggs et al. (2005), and worldwide by Archer et al. (1995). In YNP, elimination of grazing and fire is not associated with changes in diversity in these communities. In other grassland communities, the effects of shrub encroachment and elimination of grazing on diversity have been mixed (Floyd et al. 2003; Landsberg et al. 2003; Metzger et al. 2005), but in this study, diversity (richness) was the same in 1958 and 2002 in both the grazed and ungrazed areas. This supports previous work on diversity indices in YNP by Stohlgren et al. (1999), who found no significant differences among several measures of species diversity between grazed and ungrazed sites at a 1,000-m^2 plot scale. Interestingly, if 1958 and 2002 were the only monitoring points, then the communities would appear static. However, like shrub cover, diversity varied significantly in the intervening years. Both areas had their highest richness values in the mid-1970s to early 1980s, when annual precipitation was greater in the area. The differences in diversity between the grazed and ungrazed areas were not statistically significant.

From 1958 to 2002, the dynamic bunchgrass communities were affected by climatic fluctuation, changes in natural disturbance regimes, and invasion of native plants. These environmental stresses are also not unique to YNP. The composition and community dynamics of many temperate grasslands worldwide have been influenced by the timing and amount of precipitation (Fay et al. 2002), temperature fluctuations (Alward et al. 1999), the timing and intensity of disturbance (Fuhlendorf et al. 2001; Jacobs and Schloeder 2002), fire exclusion (Leach and Givnish 1996), and invasion of non-native

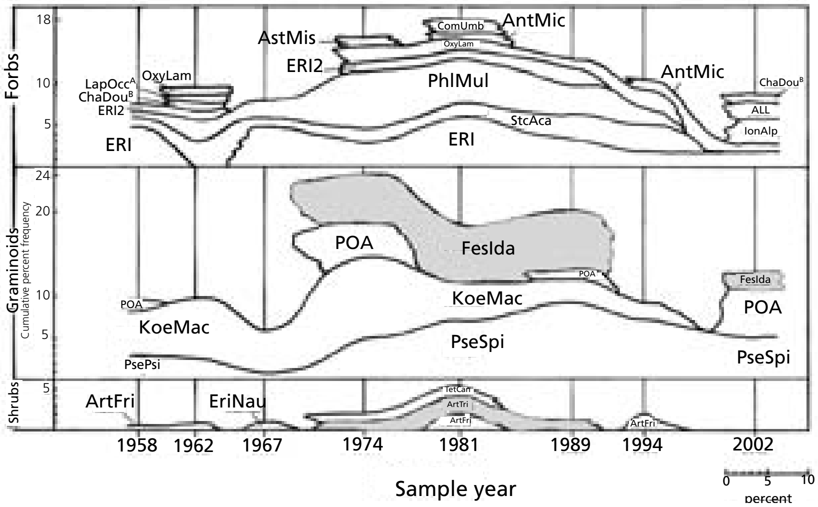


Figure 5 (top). Facies diagram for MC1T1, outside Blacktail exclosure (grazed area), Yellowstone National Park. Sample years are at vertical lines. Intervals between samples were manually interpolated. Percent cumulative frequency is diagrammed to scale by lifeform. A= annual; B= biennial. Species abbreviations are listed in Appendix A.

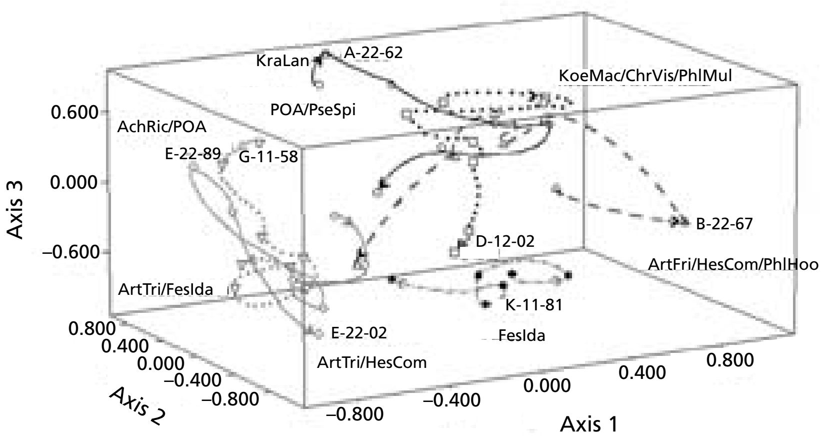


Figure 6 (middle). Plot movements in NMS ordination space for ungrazed plots of YNP using all species in community. The vectors connect consecutive sampling units and show directions (first and last arrows only), magnitudes, and compositional trends at each site over the monitoring period of each plot. A-22-YR = Gardiner 58 exclosure line C2T2; B-22-YR = Gardiner 62 exclosure line C2T2; D-12-YR = Blacktail 58 line C1T2; E-22-YR= Blacktail 62 line C2T2; G-11-YR = Lamar 58 line C1T1; K-11-YR = Junction Butte 62 line C1T1. (YR = year sampled.) Species abbreviations are listed in Appendix A. (Note: Grazed and ungrazed plots are processed together in NMS but plotted in separate diagrams to highlight differences.)

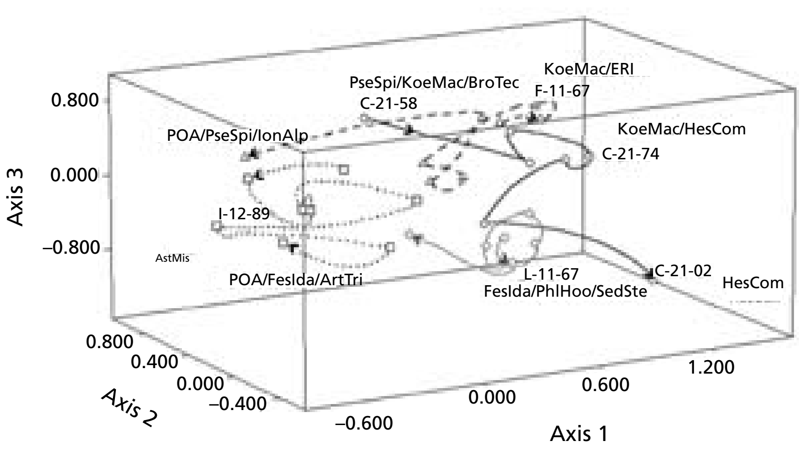


Figure 7 (bottom). Plot movements in NMS ordination space for grazed plots of YNP using all species in community. Vectors connect consecutive sampling units and show directions (first and last arrows only), magnitudes, and compositional trends at each site over the monitoring period of each plot. C-21-YR = line C2T1 outside Gardiner exclosure; F-11-YR = line C1T1 outside Blacktail exclosure; I-12-YR = outside Lamar exclosure; L-11-YR = outside Junction Butte exclosure. (YR = year sampled.) Species abbreviations are given in Appendix A. (Note: Grazed and ungrazed plots are processed together in NMS but plotted in separate diagrams to highlight differences.)

species (Abbott et al. 2000). The most important influence on the presence of individual species and species dominance at any point in time in YNP, however, appears to be climatic fluctuation. Inside and outside the exclosures, diversity as well as grass and forb species have responded in similar ways through time, indicating that climatic controls on specific species override grazing effects in determining species dominance within these particular communities. Both areas had years when certain species were abundant (i.e., *F. idahoensis* in 1974 and 1981, Figures 3 and 5) and other years when the same species were absent (i.e., *F. idahoensis* in 1958 and 1994). Shrub encroachment, although influential to community change within these grasslands, has also been related to climatic factors (Archer, Schimel, and Holland 1995). Even though the data do not show that shrubs have increased in grazed areas as much as in ungrazed ones, photographs of the transect lines do show shrub increases in both areas, which supports a climatic influence for encroachment. Path analysis indicates that the most important climatic factors for this time interval were mild spring and winter temperatures and increased moisture early in the growing season. Coughenour et al. (1991) found similar overriding climate controls on composition on the transect lines in YNP. Surprisingly, non-native species are not a significant influence on compositional change in the exclosures or their surrounding areas, although they have dramatically changed other grassland ecosystems (Hobbs 2001) and are a source of concern in other areas of the park (Yellowstone National Park 2005).

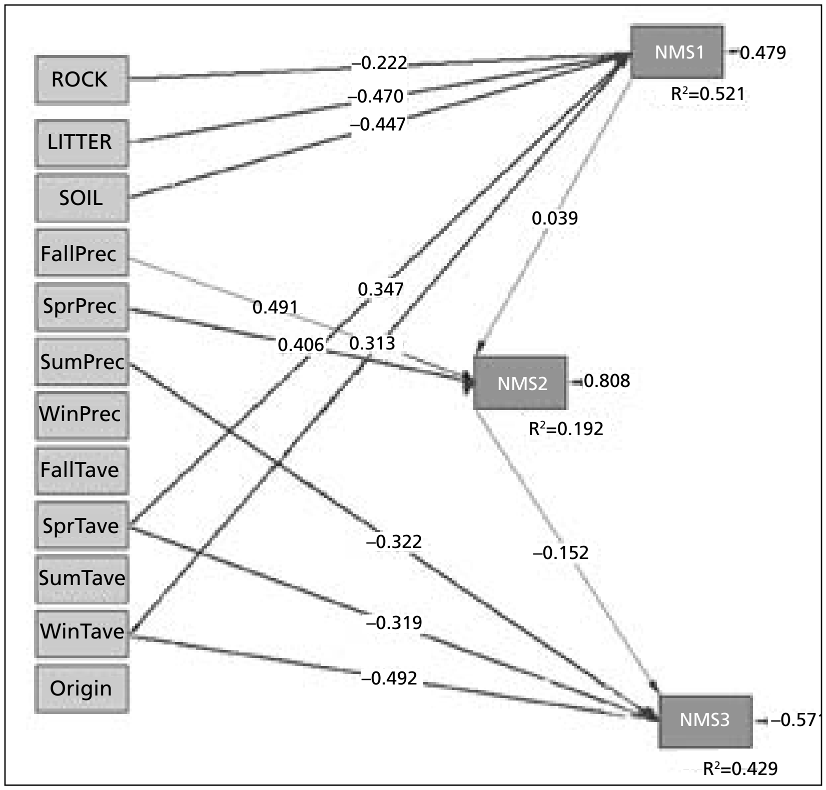


Figure 8. Path coefficients for transects in Yellowstone National Park. Only paths with significant t-values are shown. NMS = Non-metric multidimensional scaling position on axis 1, 2 or 3. FallPrec = Fall precipitation. FallTave = Fall average temperature. Origin = native or non-native species. Chi-square = 5.60, df = 11, p value = 0.89894, RMSEA = 0.000, n = 63.

In communities that are very responsive to climatic fluctuations, long-term management or restoration must plan for community change. These data suggest that global climate change, which for this region is predicted to result in increasingly prolonged droughts, will create profound challenges for conservation of grassland systems in Yellowstone. Continued monitoring of these exclosures will be critical to determine the resiliency of these systems to increased climate-induced stress and further exotic species invasions, as well as their ability to sustain large populations of ungulates.

Acknowledgements

Research was conducted in Yellowstone National Park under research permit #YELL-2002-SCI-5252. Roy Renkin and the Yellowstone archives staff helped access historical transect data and historical photographs. Precipitation and temperature interpolations from climate stations to individual transect lines were done by Matt Jolly, Numerical Terradynamic Simulation Group, University of Montana.

Appendix A. Species codes and characteristics.

Code	Genus/species	Common name	Lifecycle	Origin	Family
AchOcc	*Achnatherum occidentale (Stipa occidentalis Thurb. ex S. Wats)*	Western needlegrass	Perennial	Native	*Poaceae*
AchRic	*Achnatherum richardsonii (Stipa richardsonii Link)*	Spreading needlegrass	Perennial	Native	*Poaceae*
ALL	*Allium spp.*	Wild onion	Perennial	Native	*Liliaceae*
AntMic	*Antennaria microphylla*	Rosy pussytoes	Perennial	Native	*Asteraceae*
ArtFri	*Artemisia frigida*	Fringed sagewort	Perennial	Native	*Asteraceae*
ArtTri	*Artemisia tridentata*	Big sagebrush	Perennial	Native	*Asteraceae*
AstMis	*Astragalus miser Dougl.*	Weedy milkvetch	Perennial	Native	*Fabaceae*
BroTec	*Bromus tectorum*	Cheatgrass or downy brome	Annual	Introduced	*Poaceae*
CAR	*Carex spp.*	Sedge	Perennial	Native	*Cyperaceae*
ChaDou	*Chaenactis douglasii*	Dusty maiden	Biennial/ Perennial	Native	*Asteraceae*
ChrVis	*Chrysothamnus viscidiflorus*	Rabbitbrush	Perennial	Native	*Asteraceae*
ComUmb	*Comandra umbellata*	Pale bastard toadflax	Perennial	Native	*Santalaceae*
ERI	*Erigeron spp.*	Fleabane	Unknown	Undeter-mined	*Asteraceae*
ERI2	*Eriogonum spp.*	Wild buckwheat	Annual/ Perennial	Undeter-mined	*Polygona-ceae*
EriNau	*Ericameria nauseosus (Chrysothamnus nauseosus (Pallas) Britton)*	Gray rabbitbrush	Perennial	Native	*Asteraceae*
FesAlt	*Festuca altaica (F. scabrella Torr. ex Hook.)*	Rough fescue	Perennial	Native	*Poaceae*
FesIda	*Festuca idahoensis*	Idaho fescue	Perennial	Native	*Poaceae*
HesCom	*Hesperostipa comata (Stipa comata Trin. & Rupr.)*	Needle and thread	Perennial	Native	*Poaceae*
IonAlp	*Ionactis alpina (Aster scopulorum Gray)*	Crag aster/lava aster	Perennial	Native	*Asteraceae*
KoeMac	*Koeleria macrantha (K. cris-tata auct. P.p. non Pers.)*	Prairie Koeler's grass/junegrass	Perennial	Native	*Poaceae*
KraLan	*Krascheninnikovia lanata (Ceratoides lanata)*	Winterfat/white sage	Perennial	Native	*Chenopodia-ceae*
LapOcc	*Lappula occidentalis (Lap-pula redowskii (Hornem.) E.*	Flat-spine sheepburr	Annual	Native	*Boragina-ceae*
LupSer	*Lupinus sericeus*	Blue-bonnet lu-pine, silky lupine	Perennial	Native	*Fabaceae*
OxyLam	*Oxytropis lambertii*	Colorado loco purple	Perennial	Native	*Fabaceae*
PHL2	*Phlox spp.*	Phlox	Perennial	Undeter-mined	*Polemoniace*

Code	Genus/species	Common name	Lifecycle	Origin	Family
PhlHoo	*Phlox hoodii*	Hood's phlox	Perennial	Native	*Polemonia-ceae*
PhlMul	*Phlox multiflora*	Rocky mountain phlox	Perennial	Native	*Polemoniace*
POA	*Poa spp.*	Bluegrass	Annual/ Perennial	Undeter-mined	*Poaceae*
PoaSec	*Poa secunda (Poa sandbergii Vasey)*	Curly bluegrass	Perennial	Native	*Poaceae*
PasSmi	*Pascopyrum smithii (Agropyron smithii Rydb.)*	Western wheatgrass	Perennial	Native	*Poaceae*
PseSpi	*Pseudoroegneria spicata (Agropyron spicatum Pursh)*	Bluebunch wheatgrass	Perennial	Native	*Poaceae*
SteAca	*Stenotus acaulis (Haplopap-pus acaulis (Nutt.) Gray)*	Stemless mock goldenweed	Perennial	Native	*Asteraceae*
SedSte	*Sedum stenopetalum*	Worm-leaf stonecrop	Perennial	Native	*Crassulaceae*
TetCan	*Tetradymia canescens*	Gray horse-brush	Perennial	Native	*Asteraceae*
VioNut	*Viola nuttallii*	Nuttall's violet	Perennial	Native	*Violaceae*

References

Abbott, I., N. Marchant, and R. Cranfield. 2000. Long-term change in the floristic composition and vegetation structure of Carnac Island, Western Australia. *Journal of Biogeography* 27(2):333–346.

Alward, R. D., J. K. Detling, and D. G. Milchunas. 1999. Grassland vegetation changes and nocturnal global warming. *Science* 283:229–231.

Anderson, J. E., and K. E. Holte. 1981. Vegetation development over 25 years without grazing on sagebrush-dominated rangeland in southeastern Idaho. *Journal of Range Management* 34(1):25–29.

Andrews, R., M. Biggs, M. Seidel, and others, eds. 1996. *The Columbia world of quotations*, quotation #5566 from 1900 version of Roadmender, 3(3). CD-Rom edition. New York: Columbia University Press.

Archer, S. R., D. S. Schimel, and E. H. Holland. 1995. Mechanisms of shrubland expansion: land use, climate or CO_2? *Climatic Change* 29:91–99.

Barmore, W. J., Jr. 2003. *Ecology of ungulates and their winter range in northern Yellowstone National Park: research and synthesis 1962–1970*. Mammoth Hot Springs, Wyo.: National Park Service.

Briggs, J. M., A. K. Knapp, J. M. Blair, J. L. Heisler, G. A. Hoch, M. S. Lett, and J. K. McCarron. 2005. An ecosystem in transition: causes and consequences of the conversion of mesic grassland to shrubland. *BioScience* 55(3):243–254.

Coughenour, M. B. 1991. Biomass and nitrogen responses to grazing of upland steppe on Yellowstone's northern winter range. *Journal of Applied Ecology* 28:71–82.

Coughenour, M. B., F. J. Singer, and J. Reardon. 1991. The Parker transects revisited: long-term herbaceous vegetation trends on Yellowstone's northern winter range. Conference paper presentation at *Plants and their environments*, 1st Biennial Scientific Conference on the Greater Yellowstone Ecosystem, September 16–17, 1991, Yellowstone National Park, Wyoming.

Edwards, H. O. 1959. Letter to Yellowstone National Park personnel on exclosure construction and rationale, National Park Service, January 19. Located in Yellowstone National Park Archives.

Fay, P. A., J. D. Carlisle, B. T. Danner, M. S. Lett, J. K. McCarron, C. Stewart, A. K. Knapp, J. M. Blair, and S. L. Collins. 2002. Altered rainfall patterns, gas exchange, and growth in grasses and forbs. *International Journal of Plant Sciences* 163(4):549–557.

Floyd, M. L., T. L. Fleischner, D. Hanna, and P. Whitefield. 2003. Effects of historic livestock grazing on vegetation at Chaco Culture National Historic Park, New Mexico. *Conservation Biology* 17(6):1703–1711.

Fuhlendorf, S. D., D. D. Briske, and F. E. Smeins. 2001. Herbaceous vegetation change in variable rangeland environments: the relative contribution of grazing and climatic variability. *Applied Vegetation Science* 4(2):177–188.

Hobbs, R. J. 2001. Synergisms among habitat fragmentation, livestock grazing, and biotic invasions in Southwestern Australia. *Conservation Biology* 15(6):1522–1528.

Houston, D. B. 1982. *The northern Yellowstone elk: ecology and management*. New York: Macmillan.

Jacobs, M. J., and C. A. Schloeder. 2002. Fire frequency and species associations in perennial grasslands of south-west Ethiopia. *African Journal of Ecology* 40(1):1–9.

Jolly, W. M., J. M. Graham, A. Michaelis, R. Nemani, and S. W. Running. 2004. A flexible, integrated system for generating meteorological surfaces derived from point sources across multiple geographic scales. *Environmental Modeling and Software* 20(7):873–882.

Interactive LISREL 8.54 (statistical software). Scientific Software International, Inc.

Landsberg, J., C. D. James, S. R. Morton, W. J. Muller, and J. Stol. 2003. Abundance and composition of plant species along grazing gradients in Australian rangelands. *Journal of Applied Ecology* 40(6):1008–1024.

Leach, M. K., and T. J. Givnish. 1996. Ecological determinants of species loss in remnant prairies. *Science* 273 (September 13):1555–1558.

PC-Ord Version 4.33. MjM Software Design, Gleneden Beach, Oregon.

Metzger, K. L., M. B. Coughenour, R. M. Reich, and R. B. Boone. 2005. Effects of seasonal grazing on plant species diversity and vegetation structure in a semi-arid ecosystem. *Journal of Arid Environments* 61:147–160.

Parker, K. W. 1954. A method for measuring trend in range condition on national forest ranges with supplemental instructions for measurement of vigor, composition and browse. Washington, D.C.: U.S. Department of Agriculture Forest Service.

Sikkink, P. G. 2005. The nature of change in Montana's bunchgrass communities. Ph.D. dissertation, College of Forestry and Conservation, University of Montana, Missoula, Montana.

Stohlgren, T. J., L. D. Schell, and B. Vanden Heuvel. 1999. How grazing and soil quality affect native and exotic plant diversity in Rocky Mountain grasslands. *Ecological Applications* 9(1):45–64.

Yellowstone National Park. 2005. *Yellowstone resources and issues 2005: a compendium of information about Yellowstone National Park*. <http://www.nps.gov/yell/publications/pdfs/handbook/index.htm publication>.

Greater Yellowstone Area Air Quality Assessment Update

Mark T. Story

Gallatin National Forest, P.O. Box 130, Bozeman, MT 59771 (406-522-8573, mstory@fs.fed.us)

Julie Shea

Gallatin National Forest, P.O. Box 130, Bozeman, MT 59771 (406-587-6706, jshea@fs.fed.us)

Terry Svalberg

Bridger-Teton National Forest, 29 E. Fremont Lake Rd., Pinedale, WY 82941 (307-367-5797, tsvalberg@fs.fed.us)

Mary Hektner

Yellowstone National Park, P.O. Box 168, Mammoth, WY 82190 (307-344-2151, mary_hektner@nps.gov)

George Ingersoll

U.S. Geological Survey, Water Resource Division–Colorado District, MS 415, Federal Center, Denver, CO 80225 (303-236-4882 ex. 292, gpingers@usgs.gov)

Abstract

The Greater Yellowstone Area Clean Air Partnership (GYACAP) has recently completed an assessment update of air quality in the Greater Yellowstone Area (GYA). GYACAP consists of air resource program managers and specialists for the National Park Service; U.S. Forest Service; Bureau of Land Management; U.S. Fish and Wildlife Service; the Departments of Environmental Quality in Wyoming, Montana, and Idaho; and the Idaho National Engineering and Environmental Laboratory. The primary purposes of GYACAP are to serve as a technical advisory group on air quality issues to the Greater Yellowstone Coordinating Committee (GYCC), provide a forum for communicating air quality information and regulatory issues, and coordinate monitoring between states and federal agencies in the GYA. In 1999, GYACAP prepared an air quality assessment document for the GYCC for purposes of identifying air quality issues, conditions, pollution sources, and monitoring sites; summarizing known information; and advising the GYCC on air quality issues at the time. Five years later, GYACAP identified the need to update the assessment with a focus on new information on the four primary air quality issues within the GYA: urban and industrial emissions, oil and gas development in southwest Wyoming, prescribed and wildfire smoke, and snowmobile emissions. This presentation will include a summary of the assessment update on the four main air quality issues in the GYA.

Purpose of the GYA air quality assessment update

The Greater Yellowstone Area Clean Air Partnership (GYACAP) consists of air resource program managers and specialists for the National Park Service (NPS); U.S. Forest Service (USFS); Bureau of Land Management (BLM); U.S. Fish and Wildlife Service; the Departments of Environmental Quality (DEQ) in Wyoming, Montana, and Idaho; and the Idaho National Energy and Environmental Laboratory. The primary purposes of GYACAP are to serve as a technical advisory group on air quality issues to the Greater Yellowstone Coordinating Committee (GYCC), provide a forum for communicating air quality information and regulatory issues, and coordinate monitoring between states and federal agencies in the Greater Yellowstone Area (GYA). The GYCC consists of park superintendents, forest supervisors, and wildlife refuge managers; it was created to allow better communication and more integrated management between the GYA land and resource management agencies.

The purpose of the assessment is to help GYA land managers maintain a basic understanding of air quality issues and help them address resources issues, foster partnerships, and secure funding. The assessment is not a decision document. It does not make resource management decisions, and does not replace analysis needed at the project level to fulfill the requirements of the National Environmental Policy Act (NEPA). The goal of the assessment is to update the GYACAP (1999) air quality assessment document with a focus on new information on the four primary air quality issues within the GYA. These include urban and industrial emissions; oil and gas development in southwest Wyoming; prescribed and wildfire smoke; and snowmobile emissions.

The GYACAP (1999) Air Quality Assessment Document was prepared to provide the GYCC with comprehensive GYA air quality information, including an air quality legal framework; GYA air quality issues; current and potential impacts on GYA air quality; GYA air quality monitoring and summary of known information; and needs and recommendations. This assessment is intended to be useful in agency planning documents, national forest plan revisions, and NEPA documents; in facilitating air quality information exchange; and in providing air quality information to the public and other agencies.

Urban and industrial emissions

Urban and industrial emissions consist of a variety of industrial, petroleum refining, gas transmission, agricultural processing, wood processing, mining, power generation, sand and gravel, and mining sources. Most of these sources produce emissions continuously, which can concentrate pollution in surrounding communities during inversions. The U.S. Environmental Protection Agency (EPA)'s AIRData base (EPA 2004a) was queried for the total permitted major stationary sources of industrial emissions, in 1999, for the Montana, Wyoming, and Idaho counties in and surrounding the GYA. Many of these emissions, particularly the Wyoming, Idaho, and Gallatin County, Montana, sources, can be transported to GYA lands. Montana has the largest number of permitted stationary sources and the highest total emissions of nitrogen oxides (NOx), particulates (PM_{10}), and volatile organic compounds (VOCs). Idaho has the largest amount of permitted sulfur dioxide (SO_2) and carbon monoxide (CO) emissions (see Table 1).

The Montana sources are concentrated in the Billings/Laurel area, where the largest concentration of petroleum refining and other industrial sources in the Montana/Wyoming/Idaho area occurs. Prevailing western winds disperse these emissions predominantly to the east and away from the GYA. Periodically, east winds can cause "upslope" conditions that carry these emissions toward the Beartooth and Absaroka Mountains on the Custer and Gallatin national forests. These east winds, however, are usually associated with tight pressure gradients, and are highly turbulent, with robust mixing heights and dispersion energy. The Wyoming stationary sources are energy generation, mining/minerals, and natural gas processing and transmission in the southwestern part of the state; these will be discussed in detail later in this update. These industrial emissions, in combination with minor sources and the extensive drill-rig emissions in southwest Wyoming, are the major air quality concern in the GYA. The Idaho sources are dominated by chemical and fertilizer manufacturing facilities in the Soda Springs and Pocatello areas, which can cumulatively combine with the energy-related sources in southwest Wyoming.

The EPA AIRData base (EPA 2004b) was also queried for currently listed non-attainment areas. These are geographic areas that have periodic violations of National Ambient Air Quality Standards (NAAQS). The non-attainment areas in proximity to the GYA include Billings, Montana, for SO_2, and Pocatello, Idaho, for PM_{10}. No non-attainment areas around the GYA occur in Wyoming, as the only listed Wyoming non-attainment area is Sheridan (for PM_{10}).

Table 1. Stationary-source industrial emissions near the GYA (tons/year).

	CO	NOx	PM_{10}	SO_2	VOCs
Montana	2,066	5,501	1,330	13,541	2,591
Wyoming	1,488	3,436	78	5,127	689
Idaho	11,438	1,733	1,465	14,880	51

Greater Yellowstone/Teton Clean Cities Coalition

The U.S. Department of Energy's formal "Clean Cities" designation for the Greater Yellowstone/Teton Clean Cities Coalition (GYTCCC) occurred on September 18, 2002. This event marked an important milestone in the energy and transportation direction of the Greater Yellowstone region. After nearly five years of collaborative effort, the achievements of regional public and private organizations were formally recognized when the GYTCCC became the only designated "Clean City" in Idaho, Montana, or Wyoming.

This coalition is distinguished by the scope and diversity of its stakeholders, including three states, five national forests, two national parks, seven communities, and six counties, as well as dozens of private organizations. The majority of the existing U.S. Clean Cities are based in urban regions, where air quality serves as a primary driver for the initiative. The Greater Yellowstone/Teton region does not represent a city, but rather a focus on environmental protection and reduced energy consumption. The coalition has coordinated a number of projects that ordinarily would be beyond the scope of a single community or organization.

The primary thrust of the coalition is to reduce stationary and mobile air pollution sources. In 1999, Yellowstone National Park (YNP) and some surrounding communities began the switch to cleaner-burning, renewable fuels. All public and administrative refueling stations began dispensing only ethanol-blended fuel (unleaded). The Montana DEQ estimates that since the switch, YNP has reduced CO emissions by more than 50 tons. In 2001, YNP switched its entire diesel fleet (more than 300 vehicles) to biodiesel-blend oil (canola). Additionally, all standby generators and boilers within the park were switched to biodiesel-blend oil. A public biodiesel pump has opened in West Yellowstone, Montana, and another is slated to open in Belgrade, Montana, later this year (2005).

In 2004, YNP was the recipient of four donated, hybrid vehicles from Toyota. These Toyota Prius vehicles are used for outreach and education purposes to help visitors understand the latest in hybrid technology. Several of the GYA national forests are also beginning to use alternate fuel vehicles such as propane and hybrids.

Yellowstone National Park continues to seek funding to purchase more vehicles known as the new "yellow buses." The first (current) generation of yellow buses runs on biodiesel and meets forthcoming EPA diesel emission requirements. Propane and natural gas versions are being developed and will be used in the future. The buses will be introduced in the GYA for mass transportation and a shuttling service. They will also play a pivotal role in the creation of a rural tour district. Eventually, the tour district will not only be capable of moving visitors throughout the region, but also could be utilized to transport local residents. The first "leg" of the tour district will be a shuttle service from Driggs, Idaho, to Jackson, Wyoming, over Teton Pass. This will eliminate thousands of private commuter vehicles (and associated emissions) from that stretch of highway each day. More information on the Greater Yellowstone/Teton Clean Cities Coalition is available at <www.eere.energy.gov/cleancities/>.

Oil and gas drilling and production: southwest Wyoming

Oil and gas development is rapidly expanding in south-central and southwest Wyoming. High demand and high market prices have stimulated considerable interest in additional natural gas development within the Upper Green River Basin. Development of new gas resources is consistent with the Comprehensive National Energy Strategy announced by the U.S. Department of Energy in April 1998, and meets the purpose and need of the Energy Policy and Conservation Act. Increasing energy development results in increased emissions. Management of these energy development emission increases is currently the most pressing air quality issue in the GYA.

The Upper Green River Basin has about 2,900 existing wells listed with the Pinedale District Field Office, which is the most active BLM field office in the U.S. for gas development activity. Recently, the Pinedale office has processed 200–300 wells per year. About 425 new wells will be processed in 2005, and 475 in 2006 and 2007. The BLM Pinedale Resource Management Field Office is preparing a revision of its Resource Management Plan. Up to 8,700 new wells may be proposed within the Pinedale area.

As long as natural gas and condensate prices remain high and technology advances to improve recovery, it is expected that development of current fields will continue, as will the exploration for other gas deposits in the Upper Green River Basin. Compliance with NAAQS and prevention-of-significant-deterioration (PSD) increments, and protection of air-quality-related values (AQRVs)—particularly visibility—will require continued cooperation of the

USFS, NPS, BLM, Wyoming DEQ, and energy development companies.

Natural gas development is active in the Jonah II and Pinedale Anticline natural gas fields. Proposed new developments include the Jonah Infill, Pinedale Anticline Infill, South Piney coalbed methane, Riverton Dome gas, and Atlantic Rim gas. Additional development is likely north of the Pinedale Anticline in the Daniel area.

Wyoming DEQ air resource management

In response to the rapidly changing oil and gas development in the Upper Green River Basin, the Wyoming DEQ is implementing multiple air resource management strategies:

Permitting and compliance

The Wyoming DEQ has a program to ensure that all oil and gas production units are permitted and that Best Available Control Technology (BACT) is utilized to control or eliminate emissions. To guide oil and gas producers through the New Source Review (NSR) permitting process, the Wyoming DEQ developed the *Oil & Gas Production Facilities Chapter 6, Section 2: Permitting Guidance*. To address the increased activity and emission levels within the Jonah and Pinedale Anticline gas fields, the emission control requirements and permitting process were revised, effective July 28, 2004, with the result that more emissions are being controlled earlier in the life of the well for single-well facilities, and controlled on startup of all wells at multiple-well or drill pad facilities (WYDEQ 2004). Operators within the Jonah and Pinedale Anticline gas fields also must comply with permits issued by the Wyoming DEQ for all well completions and re-completions, which emphasize the implementation of flareless completion technology. In addition, the Wyoming DEQ is evaluating the permitting of drill-rig engines.

Emissions inventory and modeling

The Wyoming DEQ has undertaken an extensive analysis and modeling study designed to obtain the best possible estimate of the cumulative NO_2 PSD increment consumption from sources impacting southwestern Wyoming. The analysis focuses on the Bridger and Fitzpatrick wilderness areas, which are federally designated Class I areas, along with the surrounding Class II areas. The preliminary results of the modeling analyses indicate that the allowable NO_2 Class I and Class II increment levels and the NO_2 ambient air quality standard are not threatened. The final results of the modeling analyses will be available in early 2006. The Wyoming DEQ will continue to update the emissions inventory and modeling to evaluate cumulative NO_2 incrementation on a periodic basis.

Monitoring

Wyoming historically has required significant air quality monitoring of industrial activity. The Wyoming DEQ is furthering this legacy by expanding monitoring statewide, including in the Upper Green River Basin, in collaboration with industry. Since the fall of 2004, industry and the Wyoming DEQ have funded monitoring stations established in the Jonah Field, near Boulder, near Daniel, and in Pinedale. Monitoring stations are also being planned near Wamsutter, South Pass, Murphy Ridge, and in the Wyoming Range. The monitors are being strategically placed to assess actual ambient air quality impacts and also will serve as reality checks for modeling assumptions.

The Wyoming DEQ is increasing staffing and funding to expand upon and implement multiple air resource management strategies. The additional staffing and funding have been requested for the 2006–2007 budget, in addition to long-term funding from industry to directly support monitoring and modeling. Increased staffing in the Upper Green River Basin is also occurring as a direct result of mitigation commitments by industry in records of decision for environmental assessments and environmental impact statements.

Air quality monitoring programs and budgets in the Bridger-Teton and Shoshone national forests

The southwest Wyoming gas development activity is directly upwind of the Wind River Range, which contains two Class I and one Class II wilderness areas (the Bridger and Fitzpatrick wilderness areas and Popo Agie Wilderness Area, respectively); about 2,000 lakes; sensitive wilderness and air quality values; and high levels of wilderness recreation use. The USFS is mandated by the Clean Air Act and the Wilderness Act to protect AQRVs, including visibility, in Class I wilderness areas. Air quality monitoring within the Bridger-Teton and Shoshone national forests' Class I areas has been ongoing since the early 1980s. The current program consists of the following:

- **National Atmospheric Deposition Program (NADP):** Monitoring at Gypsum Creek

(Bridger-Teton National Forest) and South Pass (Shoshone National Forest).

- **Interagency Monitoring for Protected Visual Environments (IMPROVE):** An aerosol monitor and an optical monitor (transmissometer) located near Pinedale (above Fremont Lake) and at Dead Indian Pass northwest of Cody.
- **Long-term lakes:** Benchmark monitoring at five "long-term" lakes (Hobbs, Black Joe, Deep, Ross and Lower Saddlebag) in the Bridger, Fitzpatrick, and Popo Agie wilderness areas in the Wind River Range, sampled three times a year, and at another lake very sensitive to atmospheric deposition, Upper Frozen Lake, sampled once a year. Lake sampling protocols measure water chemistry, plankton, macroinvertebrates, and several physical parameters.
- **Bulk deposition:** Two bulk deposition collectors that collect snow, rain, and dry deposition, co-located with two of the long-term lakes (Black Joe and Hobbs). These sites are analyzed for chemical parameters.

The deposition monitoring data for the Wind River Range NADP and bulk deposition sites indicate that sulfates are decreasing while nitrates are increasing. This is a common trend across the western U.S., which makes it complicated to try to relate the nitrate increases directly to accelerated energy development activities in southwest Wyoming. The Wind River Range lake chemistry data indicate a decreasing trend of acid neutralizing capacity in some of the long-term lakes (i.e., lakes are becoming more acidic). Some long-term lakes are storing more nitrates, which may lead to eutrophic conditions (Baron et al. 2001). A rigorous analysis of the lake data is needed to determine the significance of these trends.

Prescribed-fire and wildfire smoke

Wildfire smoke is the most dramatic air quality impact, and prescribed fire is the predominant emission-producing management activity practiced by the USFS and NPS in the GYA. Emissions from fire (wildland and prescribed) are an important episodic contributor to visibility-impairing aerosols, including organic carbon, elemental carbon, and particulate matter. Wildfire impacts are increasingly difficult to manage due to excessive fuel loads, history of fire exclusion, and climate change (drought and increasing temperatures). Prescribed fire and fuel treatment projects include broadcast burns (area burns designed to reduce fuels in a contiguous area over a landscape) and pile burns (discrete piles of slash from timber harvest and/or thinning from fuel treatment projects). Prescribed burns are designed to reduce the size, frequency, and intensity of wildland fires and improve fire control, increase predictability of fire effects, and allow for smoke emissions management.

The SIS (smoke impact spreadsheet) model (Air Sciences 2003) was used to estimate smoke particulate emissions ($PM_{2.5}$) in the GYA. The SIS model uses the FOFEM5 fire effects model (Reinhardt 2003), the CONSUME fuel consumption and particulate emission generation model, and the CALPUFF dispersion model to estimate smoke emissions. Average spring and fall broadcast- and pile-burned acres and $PM_{2.5}$ smoke emissions were tabulated by GYA unit according to Society of American Foresters fuel code and vegetation type for 2002–2004. In addition, 10-year (2005–2014) estimates of broadcast- and pile-burned acres and $PM_{2.5}$ smoke emissions by GYA unit according to vegetation type and wildfire acres burned (2002–2004) were also modeled for smoke emissions (Table 2).

The Caribou-Targhee, Bridger-Teton, and Shoshone national forests had the largest numbers of acres of prescribed fires in 2002–2004, due mainly to large number of sagebrush-treatment acres. Estimated treatments for 2005–2014 include the Gallatin National Forest among the four largest prescribed-fire treatment programs in the GYA. All GYA units plan to increase prescribed fire treatment acreages and prescribed fire smoke emissions during the next 10 years.

Estimated smoke emissions ($PM_{2.5}$) are roughly proportional to prescribed burn acres (Figures 1 and 2). Per-acre smoke emissions on the Bridger-Teton National Forest were less for 2002–2004, and estimated to be less for 2005–2014 due to a high percentage of sagebrush in the prescribed fire treatment area, which produces fewer per-acre emissions than conifers (e.g., Douglas-fir, lodgepole pine, and spruce-fir). All GYA units would increase prescribed fire smoke emissions ($PM_{2.5}$) during the next 10 years. The highest estimated emissions would be for the Shoshone National Forest, where an average of 1,000 acres per year each of Douglas-fir and lodgepole pine are anticipated to be burned during the next decade. Over the entire GYA, yearly average prescribed fire emissions are anticipated to increase by about 58% during the next 10 years.

The number of acres burned and the amount

of smoke emissions ($PM_{2.5}$) produced by wildfire are much larger than the numbers of acres burned and the amount of smoke emissions produced by prescribed fire in all GYA units. On a per-acre basis, wildfire emissions produce more smoke than prescribed fire due to increased combustion from more favorable burning conditions (fuel moisture and meteorology). During 2000–2004, wildfire acreage exceeded prescribed fire acreage by five times and wildfire smoke emissions ($PM_{2.5}$) exceeded prescribed fire emissions by 24 times (Figure 3).

As prescribed fire treatment programs increase in the GYA, the differences between wildfire and prescribed fire smoke would be expected to decrease, but wildfire smoke will still be dominant in total smoke emissions. Total smoke emissions will de-

Figure 1. Average and Estimated Broadcast- and Pile-burned Acres

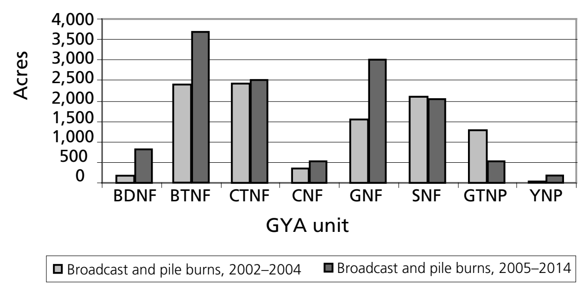


Figure 2. Average and Estimated $PM_{2.5}$ Tons/Yr from Broadcast and Pile Burns

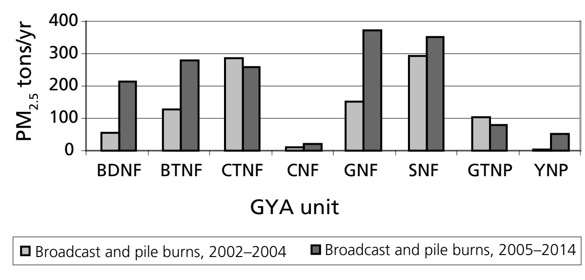
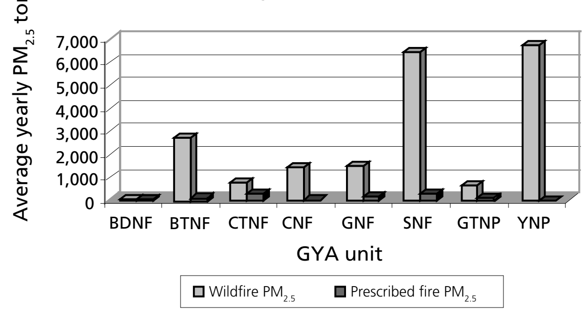


Table 2. Prescribed burn and wildfire acres and smoke emissions ($PM_{2.5}$) by GYA unit.

Unit	Average broadcast- and pile-burned acres, 2002–2004	Estimated broadcast- and pile-burned acres, 2005–2014	Average $PM_{2.5}$ tons/yr from broadcast and pile burns, 2002–2004	Estimated $PM_{2.5}$ tons/yr from broadcast and pile burns, 2005–2014	Average wildfire acres burned, 2002–2004	Average wildfire $PM_{2.5}$ tons/yr, 2002–2004
Beaverhead-Deerlodge NF (Madison Ranger District)	184	830	54	215	183	88
Bridger-Teton NF	2,380	3,670	129	279	11,945	5,782
Caribou-Targhee NF	2,416	2,503	287	260	2,672	1,293
Custer NF (Beartooth Ranger District)	364	514	9.4	20	2,091	1,012
Gallatin NF	1,546	3,000	153	374	11,359	5,498
Shoshone NF	2,093	2,040	294	351	9,383	4,541
Grand Teton NP	1,294	530	103	81	2,471	1,196
Yellowstone NP	27	161	2.6	53	11,397	5,516
Total GYA	**10,304**	**13,248**	**1,032**	**1,633**	**51,501**	**24,926**

Figure 3. Wildfire and Prescribed Fire $PM_{2.5}$ for 2000–2004



pend largely on wildfire acreage, which is managed primarily through fire suppression. Wildfire smoke is considered to be a temporary natural source by the EPA and the DEQs of Montana, Idaho, and Wyoming, and is therefore not directly regulated. Prescribed fire smoke, however, is subject to NAAQS, and is managed to minimize smoke encroachment on sensitive areas (e.g., communities, Class I areas, high-use recreation areas, and scenic vistas) during sensitive periods. In the GYA, smoke dispersion is generally quite robust, with strong ridgetop winds generally blowing west or southwest. The most sensitive areas are communities in valley locations such as Lander, Dubois, and Jackson, Wyoming, and Red Lodge, Big Sky, and West Yellowstone, Montana, which are downwind of forested areas subject to wildfires and prescribed burning. During low dispersion times such as night and morning, smoke can concentrate and elevate $PM_{2.5}$ levels to nuisance concentrations, but generally not in excess of the 24-hour $PM_{2.5}$ standard of 65 $\mu eq/M^3$. All of the highest smoke concentrations in the GYA in the last two decades have been due to wildfires—many from regional fires west of the GYA. The southern part of the GYA, particularly the Bridger-Teton and Caribou-Targhee national forests and Grand Teton National Park (GRTE), is subject to smoke from agricultural burning in the Snake River valley. These impacts are cumulative with smoke emissions in the GYA. NEPA analysis for prescribed burning projects considers the sensitivity of smoke impacts, and when appropriate, the use of mitigation measures such as per-day burn acreage limitations, burning during periods of good wind dispersion, and non-burning alternatives to minimize conflicts. A key factor in prescribed fire implementation is coordination with the DEQs in Montana, Idaho, and Wyoming, which have regulatory authority over smoke emissions and public health.

The Montana/Idaho State Airshed Group's Smoke Monitoring Unit (SMU) consists of the USFS, the states of Montana and Idaho, the BLM, the NPS, and private burners. The purpose of the group is to manage and limit the impacts of smoke generated from prescribed burning. Accumulation of smoke from controlled burning is managed through monitoring of weather conditions and formal coordination. Members submit a list of planned burns to the SMU in Missoula, Montana. For each planned burn, information is provided describing the type of burn to be conducted, the number of acres, and the location and elevation at each site. Burns are reported by airshed—geographical areas with similar topography and weather patterns. The program coordinator and a meteorologist provide timely restriction messages for airsheds with planned burning. The Missoula SMU issues daily decisions that can restrict burning when atmospheric conditions are not conducive to good smoke dispersion. Restrictions may be directed by airshed, elevation, or by special impact zones around populated areas. The SMU announces burning restrictions via 17 airshed coordinators located throughout Idaho and Montana. The operations of the Montana/Idaho State Airshed Group are officially recognized as BACT by the Montana DEQ. The Montana/Idaho State Airshed Group Operating Guide can be found at <www.smokemu.org/>.

In 2004, the State of Wyoming revised Chapter 10 of the Wyoming Air Quality Standards and Regulations and developed a new Section 4, "Smoke Management Requirements." The new Section 4 regulates large-scale vegetative burning—specifically, vegetative burns in excess of 0.25 tons of PM_{10} emissions per day—for the management of air quality emissions and smoke impacts on public health and visibility. Section 4 succinctly lists the specific requirements of burners under a range of circumstances. The requirements of Section 4 are effective for planned burn projects and unplanned fire events occurring on or after January 1, 2005.

In support of Chapter 10, Section 4, the Wyoming DEQ's Air Quality Division (WDEQ-AQD) developed the Wyoming Smoke Management Program Guidance Document to assist burners with implementation of the regulations. The guidance document contains a review and explanation of the regulation's requirements, and is structured to include comprehensive resource material into two major sections: Wyoming Smoke Management

Program and Forms and Instructions.

A copy of Chapter 10 is posted in the Standards and Regulations portion of the WDEQ-AQD website. The entire document, along with a quick reference version, is posted in the Open Burning and Smoke Management portion of the WDEQ-AQD website, at <http://deq.state.wy.us/aqd/smokemanagement.asp>.

Snowmobile emissions detected in Yellowstone snowpacks, 1996–2004

Seasonal snowpacks accumulate throughout the winter in the Rocky Mountains without significant melt, storing airborne pollutants deposited during snowfall until snowmelt begins. In cooperation with the NPS and the USFS, the U.S. Geological Survey (USGS) has been collecting seasonal snowpack samples each spring since 1993, in a network of 50 regular sampling locations throughout the Rocky Mountain region. Nineteen snowpack sampling locations are located in the GYA. Seasonal snowpack samples were analyzed for concentrations of major ions to establish background and elevated concentrations representative of the region (Turk et al. 2001; Mast et al. 2001). Within this regional network, the USGS also investigated local effects of the acidifying ions ammonium and sulfate produced by snowmobile emissions on snowpack chemistry at Yellowstone National Park during 1996, and in 1998–2004. Results of snowpack sampling at locations with variable snowmobile usage annually showed clear patterns linking snowpack chemistry to snowmobile traffic.

Concentrations of ammonium and sulfate measured in snow samples taken directly from packed snowmobile routes in Yellowstone were substantially (up to three times) larger than concentrations of ammonium and sulfate measured in off-road snowpacks at least 30 meters away from snowmobile traffic. The relationship between concentrations of these ions and volumes of snowmobile traffic was reported by the USGS in earlier studies of the 1996 and 1998 snowpacks (Ingersoll et al. 1997; Ingersoll 1999). During these two years, concentrations of ammonium and sulfate and numbers of snowmobiles operating were highest near Old Faithful and the West Entrance. Concentrations of the two ions were lowest near areas with the least snowmobile usage: Lewis Lake Divide, the South Entrance, and Sylvan Lake. Similar patterns in concentrations of ammonium and sulfate were measured in snowpacks in 1999, 2000, and 2001, using the same protocols. Thin snowcover and deteriorating snow conditions prevented sampling of the snow-packed roadway at the West Entrance during the drier years of 2000 and 2001, so alternate locations were chosen at a low- and at a high-traffic site: the South Entrance and the West Parking Lot at Old Faithful, respectively. In all cases observed from 1996 to 2002, concentrations of ammonium and sulfate in snow-packed roadways increased with proximity to snowmobile usage at the high-traffic locations of West Yellowstone and Old Faithful. At these locations, off-road snowpack concentrations typically ranged from 5.1 to 14.0 microequivalents per liter (μeq/L) for ammonium and 3.5 to 7.6 μeq/L for sulfate. In-road sample concentrations at these sites ranged from 7.2 to 34.3 μeq/L for ammonium and 2.1 to 28.8 μeq/L for sulfate.

Decreases in concentrations of ammonium and sulfate began in 2002, and continued through 2004. Snow sample concentrations from off-road and in-road sites for the winters of 2003, and especially 2004, showed smaller differences and were considerably lower than in previous years. All ammonium and sulfate concentrations for samples from the paired off-road and in-road sites at West Yellowstone and Old Faithful in 2004 were less than 10 μeq/L. The decreases in concentrations of ammonium and sulfate in 2003 and 2004 coincided with expanded use of four-stroke snowmobiles, limited use of two-stroke snowmobiles, and overall reductions in snowmobile numbers.

Snowmobile use, management, air monitoring, and clean technology trends in Yellowstone and Grand Teton national parks

The burgeoning popularity of snowmachines in and around the GYA in the late 1980s and early 1990s led to concerns about air pollution, noise, wildlife harassment, and reduction in the quality of winter visitor experience. Snowmobile use in YNP generated the most widely publicized controversy. By the year 2000, visitors were making about 75,000 snowmobile trips and 1,300 snowcoach trips into the park during a 90-day winter season. More than 60% of those visitors entered the park through the West Entrance, from West Yellowstone. On peak days, more than 1,000 two-stroke snowmobiles used the West Entrance, where winter inversions often confine dense, cold, stable air that concentrates air pollution.

The traditional two-cycle engine snowmobiles being used released high hydrocarbon (HC), CO, and PM emissions, as well as a variety of gases classified as toxic air pollutants, including benzene, 1,2-

butadiene, formaldehyde, and acetaldehyde. In addition, 20–33% of the snowmobiles' fuel was emitted as unburned aerosols.

Monitoring by the Montana DEQ documented that the air quality at the West Entrance was, at times, very close to being in violation of the eight-hour NAAQS for CO, usually on calm winter days when there was little air dispersion.

The controversy about snowmobile emissions and access to U.S. national parks and other public lands has prompted studies, rulings, lawsuits, and technological innovations aimed at producing cleaner, quieter snowmobiles. One of the most significant technological changes has been the development of commercially available four-stroke snowmobiles, especially those that meet the NPS's BACT requirements. Laboratory testing of snowmobile emissions concluded that commercially available BACT four-stroke snowmobiles are significantly cleaner than two-stroke snowmobiles. Compared to previously tested two-strokes, these four-stroke snowmobiles emit 95–98% fewer HC, 90–96% less PM, 85% less CO, and 90% fewer toxic HC such as 1,3-butadiene, benzene, formadehyde, and acetaldehyde than two-stroke engines. The four-stroke engines, however, emit 7–12 times more NOx (Lela and White 2002).

To address historical concerns of snowmobile use and types, including air quality, the NPS has adopted a multifaceted approach for Yellowstone and Grand Teton national parks that includes limiting snowmobile numbers, requiring that snowmobilers use commercial guides, and requiring that snowmobiles be BACT, which are the cleanest and quietest four-stroke snowmobiles available. The commercial guide requirement helps ensure that the snowmobiles meet the BACT requirements, comply with speed limits, and stay on designated roads. Reduction in overall snowmobile numbers also has resulted in fewer emissions and better compliance with winter air quality objectives.

In November 2004, the NPS approved temporary winter use plans for Yellowstone and Grand Teton national parks and the John D. Rockefeller, Jr., Memorial Parkway (JODR). This decision allows 720 commercially guided recreational snowmobiles per day in YNP. In GRTE and JODR, 140 snowmobiles per day are allowed. With minor exceptions, all snowmobiles are required to meet NPS BACT requirements. The plan will be in effect for three winters, allowing snowmobile and snowcoach use through the winter of 2006–2007.

In addition to switching to BACT snowmobiles, YNP is using ethanol-blend fuels and low-emission lubricating oils to further reduce emissions. Ethanol-blend and biodegradable low-emission lubricating oils in two-stroke engines reduce CO emissions by 7–11%, PM by 25–70%, and HC by 16–38% (Montana DEQ 2005). Use of 10%-ethanol blend requires no engine modifications or adjustments; it is now the only unleaded "regular" fuel sold at the YNP gas stations. Snowmobile and snowcoach rental operators in and around YNP have taken similar steps to protect air and water quality, using 10%-ethanol-blend fuel and synthetic lubricating oils in their machines.

Winter season gasoline sales in the park dropped 82% from 2001 to 2005 (Guengerich 2005). Typical four-cycle engine snowmobiles get significantly better mileage (25–30 mpg) than typical two-cycle snowmobiles, at 9–13 mpg (H. Haines, pers. comm.). Thus, snowmobilers can now complete their trips in one tank of gas and typically no longer have to refuel in YNP.

Air quality monitoring began at YNP's West Entrance in the winter of 1998–1999, and at the Old Faithful development area in the winter of 2002–2003. A significant decrease in air pollutant concentrations for CO and $PM_{2.5}$ has been measured at both sites. A 60% decrease in CO and a 40% decrease in $PM_{2.5}$ were recorded at the West Entrance in 2003–2004, compared with the previous winter. A 23% decrease of CO and a 60% decrease in $PM_{2.5}$ were recorded at Old Faithful for the same time period. This closely tracks with a 56% decrease in the number of snowmobiles entering the West Entrance and a 53% decrease in the snowmobiles counted at Old Faithful (Ray 2005). Carbon monoxide has been decreasing at the West Entrance since 1998. Mean monthly CO levels at the West Entrance show an annual cycle, with the highest concentrations in winter and summer and lowest in spring and fall. Winter CO levels are now similar to those of July and August. This represents a substantial change from 1998–2002, when winter CO levels were much higher than summer levels.

Monitoring in winter 2004–2005 (Bishop et al. 2005) revealed a substantial finding: snowcoaches have higher emissions than individual snowmobiles, and the increase in snowcoach use is offsetting some of the snowmobile emission reductions. On a per-passenger basis, snowcoach emissions nearly equal four-stroke snowmobile emissions. Bishop (et al. 2005) measured emission rates and reported that older snowcoaches, such as the fuel-controlled carburetor Bombardier and fuel-injected, gasoline-van

Xanterra snowcoaches, had high CO and HC emissions. Newer snowcoaches, such as the fuel-injected MPI Bombardier used by Yellowstone AlpenGuides, and the NPS diesel van, had CO and HC emissions that were only 1–2% of that of older snowcoaches. Bishop (2005) discouraged the use of vintage, fuel-controlled carburetor engines in snowcoaches. This could substantially reduce overall snowcoach emissions.

Summary of management implications and recommendations

Air quality in the GYA remains generally excellent, as the GYA is largely undeveloped and has limited emissions sources and predominantly robust dispersion. Emission sources on NPS and USFS lands in the GYA primarily consist of prescribed fire smoke, transportation and recreational sources, and management activity sources such as mining, road construction, and ski areas. These sources are indirectly managed by the NPS and USFS, and are usually not significant air quality issues, except for snowmobile emissions at concentrated winter use areas such as the West Entrance. The NPS has greatly reduced winter emissions related to park management with the use of "green" fuels and products, and by requiring four-stroke snowmobile engines in YNP and GRTE.

Wildfire emissions are the most significant emissions within and around the GYA, but are not controllable by management except indirectly, by fire suppression. During the last three years, prescribed fire emissions in the GYA have increased due to the Healthy Forests Initiative legislation; they are anticipated to continue to increase by about 58% over the next 10 years. Overall smoke emissions (wildfire and prescribed) are expected to remain about the same, but with the major variable of weather conditions. Because much of the GYA, like most of the American West, has an accumulation of fuels resulting from wildfire suppression, wildfire levels are expected to be high during dry summer periods for the next several decades.

The greatest threat to air quality in the GYA is from anthropogenic sources upwind and adjacent to national park and national forest boundaries. Urban and industrial air pollution, although moderate compared to that in much of the U.S., has a persistent impact, because many of these emissions occur year-round, including during winter inversion periods. These sources are managed primarily by the DEQs in Montana, Wyoming, and Idaho, with collaboration from the NPS, USFS, and BLM for major sources such as PSD. The largest cities around the GYA, such as Billings/Laurel and Bozeman, Montana; Cody, Lander, and Jackson, Wyoming; and Idaho Falls, Idaho, are substantial sources of multiple emissions.

Currently, the largest air quality concerns in the GYA come from gas field development in southwest Wyoming and emissions from energy-related industries. The southwest Wyoming gas fields, primarily on BLM lands, are expanding at a very high rate because this area provides a significant contribution to the U.S. energy supply. The Clean Air Act requires the NPS and USFS to identify, monitor, and protect AQRVs in adjacent Class I areas. Visibility, lake chemistry, and biota in the Bridger-Teton Wilderness Area are being subjected to increasing levels of air pollution impacts from the gas field development. The Fitzpatrick and Popo Agie wilderness areas are also affected. Grand Teton National Park personnel would like to establish NADP/NTN (National Atmospheric Deposition Program/National Trends Nework), CASTNet (Clean Air Standards and Trends Network), and IMPROVE monitoring sites in Grand Teton National Park for at least five years, to compare with the network sites in Yellowstone National Park and determine if it is appropriate to augment the YNP air quality monitoring sites with more specific monitoring information from GRTE.

Compliance with NAAQS and protection of AQRVs will require continued close coordination between the NPS, USFS, BLM, and the DEQs in Wyoming, Montana, and Idaho. The GYACAP has been a useful forum to facilitate coordination between the GYA air quality management agencies.

Recommendations

1. Comply with NAAQS, PSD increments, and AQRV thresholds.
2. Cooperate with the Wyoming DEQ, BLM, and energy companies to manage southwest Wyoming oil and gas energy impacts.
3. Continue the system of air quality monitoring throughout the GYA. Air-quality-related-value monitoring of lakes, deposition, and visibility in the Wind River Range is critical.
4. Continue to encourage cleaner snowmobiles and snowcoaches, and to manage their winter use impacts.
5. Aggressively pursue fuel reduction projects and disclose smoke impacts and NAAQS compliance in NEPA documents.

6. Continue GYACAP annual meetings, coordination, and information exchange.

References

Air Sciences, Inc. 2003. User's guide: Smoke Impact Spreadsheet model. Prepared for the U.S. Department of Agriculture, Forest Service, Region 1; project No. 189-1.

Baron, J., T. Rutkowski, and S. Merrill. 2001. Assessing surface water sensitivity to atmospheric deposition in wilderness areas of Nevada, Idaho, Utah, and Wyoming. Colorado State University and U.S. Geological Survey.

Bishop, G. A., D. A. Burgard, T. R. Dalton, D. H. Stedman, and J. D. Ray. 2005. Winter vehicle emissions in Yellowstone National Park. University of Denver. Presented at Greater Yellowstone Area Clean Air Partnership meeting, Gardiner, Montana, October 5, 2005.

Greater Yellowstone Area Clean Air Partnership (GYACAP). 1999. Greater Yellowstone Area air quality assessment document. Bozeman, Mont.: GYACAP.

Guengerich, J., Operations Manager, Yellowstone Park Service Stations, Inc. 2005. Letter to M. Murphy, Yellowstone Business Management Office, March 9.

Ingersoll, G. P., J. T. Turk, C. McClure, S. Lawlor, D. W. Clow, and M. A. Mast. 1997. Snowpack chemistry as an indicator of pollutant emission levels from motorized winter vehicles in Yellowstone National Park. Pages 103–113 *in Proceedings of the 65th Western Snow Conference*, Banff, Alberta, May 4–8, 1997.

Ingersoll, G. P. 1999. Effects of snowmobile use on snowpack chemistry in Yellowstone National Park, 1998. U.S. Geological Survey Water Resources Investigations Report 99-4148. 23 pp. <http://water.usgs.gov/pubs/wri/wri994148/>.

Lela, C. C., and J. J. White. 2002. Laboratory testing of snowmobile emissions. San Antonio, Texas: Southwest Research Institute, report number SwRI 08.05486. <http://www.deq.mt.gov/CleanSnowmobile/publications/index.asp>.

Mast, M. A., J. T. Turk, G. P. Ingersoll, D. W. Clow, and C. Kester. 2001. Use of stable sulfur isotopes to identify sources of sulfate in Rocky Mountain snowpacks. *Atmospheric Environment* 35:3303–3313.

Montana Department of Environmental Quality (DEQ). 2005. <http://www.deq.state.mt.us/CleanSnowmobile/faq/index.asp>.

Ray, J. D. 2005. Overview of the Yellowstone Winter Air Quality Study, 2003–2004. Denver, Colo.: National Park Service Air Resources Division.

Reinhardt, E. D. 2003. Using FOFEM 5.0 to estimate tree mortality, fuel consumption, smoke production and soil heating from wildland fire. Included in the *Proceedings of the Second International Wildland Fire Ecology and Fire Management Congress and Fifth Symposium on Fire and Forest Meteorology,* Orlando, Florida, November 16–20, 2003. <http://fire.org/downloads/fofem/5.2/FOFEM5Using.pdf>.

Turk, J. T., H. E. Taylor, G. P. Ingersoll, K. A. Tennessee, D. W. Clow, M. A. Mast, D. H. Campbell, and J. M. Melack. 2001. Major-ion chemistry of the Rocky Mountain snowpack, USA. *Atmospheric Environment* 35:3957–3966.

Wyoming Department of Environmental Quality (WYDEQ). 2004. Jonah & Pinedale Anticline Gas Fields: Additions to Oil and Gas Production Facility Emission Control and Permitting Requirements. <http://deq.state.wy.us/AQD/sec21/JONAH%20INFILL%20GUIDANCE%20FINAL%207-28-04.pdf>.

U.S. Environmental Protection Agency (EPA), 2004a. Facility emissions report. <http://www.epa.gov/air/data/netemis.html>.

______. 2004b. Non-attainment areas for criteria pollutants. <http://www.epa.gov/oar/oaqps/greenbk/ancl2.html>.

Montana Challenge: Remaining The Last Best Place for Fish and Wildlife in a Changing West

Cindy S. Swanson

Watershed, Wildlife, Fisheries and Rare Plant Staff, USDA Forest Service, Northern Region, P.O. Box 7669, Missoula, MT 59807 (cswanson@fs.fed.us)

Abstract

Montanans' relationship to fish and wildlife is reflected in countless family scrapbooks that lovingly chronicle the passage of outdoor traditions from generation to generation. Our ties to the natural landscape are a defining characteristic of the state and its people. But if you read the newspaper or have noticed business comings and goings on our main streets, you know that times are changing. Our natural resources are attracting a great many people from other parts of the country. For decades, our landscapes have been valued for timber, mining, and agriculture. Now these landscapes have additional value as lifestyle amenities, attracting people who are building fast-growing sectors of the economy. Long-time Montanans and newcomers alike want good jobs and unsurpassed outdoor recreation opportunities. That's the Montana Challenge: to protect our cherished relationship with natural resources as we harvest their full economic benefit. This paper looks at the changing demographic and economic patterns of the state and the role that fish and wildlife play in these changing socioeconomic patterns.

Summary

This chapter provides an overview and interpretation of wildlife- and fish-related tourism travel patterns and expenditures. This will be accomplished in three sections. The first section looks at general recreation trends in the United States over the last several decades. Next, these patterns are compared to recreation travel patterns in the Rocky Mountain West. Finally, travel patterns in Montana are explored to see how Montana fits into national and western recreation travel patterns.

A primary finding indicates that nature-related tourism and recreation are growing trends nationally, regionally, and within the state of Montana. Comparatively, a higher percentage of Montana residents participate in nature-related recreation—in particular, hunting, fishing, and wildlife viewing—than participate nationally or regionally. Non-resident travel is also closely linked to wildlife and fish; wildlife viewing is one of the top two reasons for travel in all "travel countries" within Montana.* Expenditures for travel and tourism in the state are greatest around Glacier and Yellowstone national parks, but throughout the west and central front, non-resident expenditures are significant. The 9.8 million visitors to Montana represent 10 times Montana's resident population and result in 43,300 jobs, for an economic impact of $2.75 billion (ITRR 2002a). Hunting, fishing, and wildlife viewing are primary activities for residents and non-resident visitors both in national forests and in the various travel countries. Hunters, anglers, and wildlife viewers had a total economic effect of more than $680 million and 9,800 jobs in 2001 (Niccolucci 2002). Repeat hunters and anglers cited lodging and road conditions as improved (ITRR 2002d). However, open space and environmental conditions were cited as being worse (ITRR 2002d).

Clearly, the importance of wildlife, fish, and natural places cannot be ignored when considering the demand and values of both residents and non-residents of Montana. These resources contribute to the reasons why people live in and are attracted to the state.

Methods

The studies discussed here examined participation patterns and associated recreation travel expenditures. Expenditure data is used in economic impact analysis (also known as regional economic analysis). An economic impact analysis traces flows of

*TravelMontana, the state's tourism agency, divides Montana into six tourism regions: "Custer Country," "Glacier Country," "Gold West Country," "Missouri River Country," "Russell Country," and "Yellowstone Country." See <http://visitmt.com/tripplanner/wheretogo/region.htm>.

spending associated with changes in the purchases by the consumer of a good or service for a region or state to identify changes in sales transactions, tax revenues, personal income, and jobs caused by changes in sales relative to final demand activity. The principal empirical techniques for economic impact analysis are business or visitor spending surveys, analysis of secondary data from government economic statistics, the economic base model and input-output models, and multipliers. At the state level, this information shows movement of jobs and income within the state as well as leakage out of the state. Because economic impact analysis only shows the change in financial transactions in an economy, it does not answer the question of whether public welfare has increased or decreased as a result of a proposed policy. As such, economic impact analysis should not be confused with economic efficiency analysis, which considers the allocation of resources to generate the highest net benefit to society over time.

Background

Pursuit of and interest in recreation can be traced far back in U.S. history. Perhaps the establishment of Yellowstone National Park in 1872 is the first benchmark in the American public's love of the great outdoors. The legacy of policies addressing outdoor recreation shows an increasing interest in recreation settings and opportunities. The National Park Service was established in 1916, marking the entry of the federal government in the recreation management business. Congress articulated a major concept for public land management when it passed the Multiple Use Sustained Yield Act of 1960, which recognized the value and equal importance of timber, water, wildlife, range, and recreation on national forest lands. Today, national forests provide more recreation opportunities than any other federal land management entity (Figure 1). In the 1960s, Congress passed a series of legislative documents related to recreation: the Wilderness Act (1964), the Wild and Scenic Rivers Act (1968), the National Trails System Act (1968), the Outdoor Recreation Act (1963), and federal policy governing the selection and administration of National Recreation Areas (1963). In addition, under the Land and Water Conservation Fund Act of 1965, Congress provided for the acquisition of recreation lands.

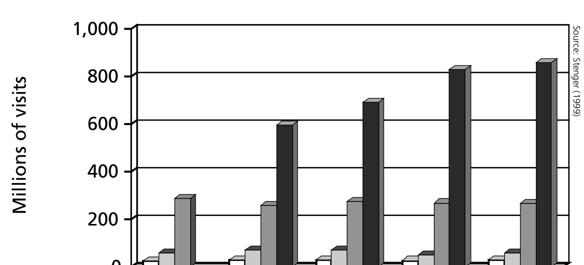
States have followed the same path as the federal government in recognizing and developing recreation opportunities. Increased demand for state park lands between 1960 and 1990 fueled the development of state facilities and recreation programs. Today, every U.S. state has a park system, and state parks host an estimated 700 million annual visitors on just over 11 million acres of public land (Douglass 1999).

People recreate in the outdoors for many reasons. Some seek solitude and a reprieve from the noise and stress of everyday life, while others seek excitement and opportunities for socialization. The benefits of outdoor recreation are diverse, and include better physical and mental health, reduced stress, time with family and friends, an appreciation for the natural world, and an understanding of natural systems. In fact, "The evidence strongly suggests that participation in outdoor recreation at any time of life, but particularly as a child, leads people to have more satisfying and fulfilling lives" (Pandolfi 1999). Another important value of outdoor recreation not often considered is its effect on mental and physical health. Studies show that the economic benefits of exercise include less work absenteeism, higher productivity in the workplace, and decreased medical bills as a result of better health and less stress (Pandolfi 1999).

National recreation trends

The U.S. population now totals more than 280 million people, and is expected to grow to twice that number by the year 2100 (Cordell 2004). This growth is largely occurring in the 13 western states (Rocky Mountain Region: Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming; Pacific Region: California, Oregon, and Washington; and Alaska and Hawaii), which have gained a share of the national population in every decade since 1850. Throughout the 1990s, the West's population grew

Figure 1. Recreational Visits to Federal Lands



	1988	1990	1992	1994	1996
USFWS	25.31	27.88	29.97	27.09	29.47
BLM	57.84	71.82	69.42	50.74	58.92
NPS	286.16	259.77	273.29	268.64	265.79
USFS		597.61	691.18	829.84	859.21

6% faster than the national average (15.2% growth versus 9.3%), and the mountain states grew nearly twice as fast as the average for the entire West during that same period (Masnick 2001).

It is important to understand the dramatic changes that population growth will have on recreation in Montana, because "Population has been, is, and will be the major driver of outdoor recreation participation growth in this country" (Cordell 2004). When assessing recreation trends, it should be noted that due to population growth, an activity with steady participation rates over time will experience a substantial increase in numbers of participants.

Much of the information summarized in this section is from the National Survey on Recreation and the Environment (NSRE) (Cordell 2004), the nation's most comprehensive recreation survey available. The NSRE does not distinguish recreation activities by land type (private, state, or federal); however, the activities summarized below require large tracts of land and natural landscapes. An estimated 94.5% of the U.S. population 16 and older participated in some form of recreation within the 12 months previous to the 1994–1995 NSRE. Since 1960, the number of people aged 12 or older who engaged in recreation activities at least once a year has increased 75%, to more than 229 million people in 2000–2001 (Cordell 2004). The western states are expected to receive the bulk of recreation pressure on public lands by 2020; western Montana will see moderate-to-moderately heavy recreation pressure (Cordell and McKinney 1999).

Fastest-growing activities from 1982–1983 to 2000–2001

The activities with the fastest growth rate by participation from 1982–1983 to 2000–2001 are shown in Figure 2 (Cordell 2004). These activities may not have the greatest number of participants, but their rates of growth are significant, and highlight potential future trends. Wildlife viewing increased 231.4% since the 1982–1983 NSRE, growing from an estimated 22 million participants to nearly 73 million participants aged 12 and older by 2001. Day hiking increased more than 193% during the same period, from 26 million to more than 76 million by 2001. Backpacking and primitive camping also increased more than 100% during the 19 years between surveys (Cordell 2004). Figure 3 further highlights the growth in birdwatching. Birding festivals grew in number from 12 in 1993 to 70 in 1997 (Cordell 2004).

Figure 2. Fastest-Growing Activities (percent increase since 1982)

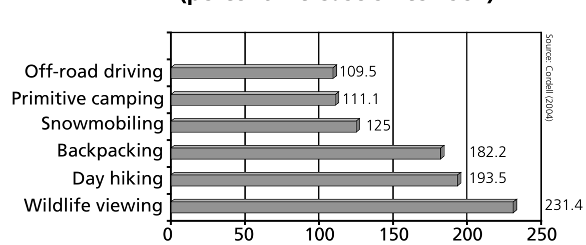
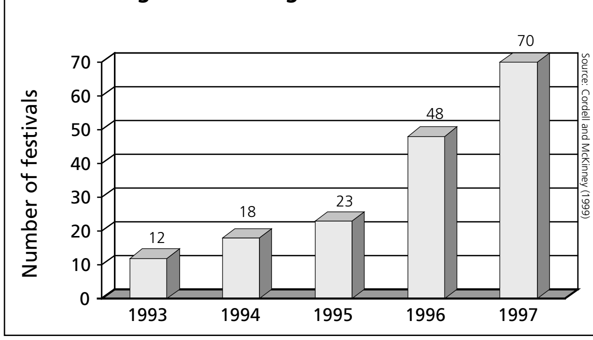


Figure 3. Birding Festival Trends



Two motorized activities also saw significant growth (Figure 2). In 1982–1983, 3% of the population participated in snowmobiling; the 2000–2001 NSRE showed 6% participating. Off-road driving participation, which includes all-terrain vehicles, sport utility vehicles, and other four-wheel drive vehicles, increased more than 100% during that same period (Cordell 2004). Although the number of snowmobilers and off-road drivers is relatively small (5.9 million and 18.3 million, respectively) such motorized activities are clearly gaining popularity.

The increasing popularity of these dispersed recreation activities is in large part the result of new equipment technologies, such as faster and more versatile all-terrain vehicles, that allow people to go farther into the backcountry, stay out longer, and access previously remote, untrammeled places in a matter of hours. Such technological advances will continue to influence the type of recreation opportunities demanded in the future.

Popular activities nationally in 2001: number of activity days

Percent-growth in participation gives an indication of how many people participate in an activity, but not a sense of intensity of use, because a person who participates once is given the same percent-weight as one who participates more than once or frequently. Figure 4 shows the most popular activities nationally according to millions of recreation days. Walking for

Figure 4. Most Popular Activities

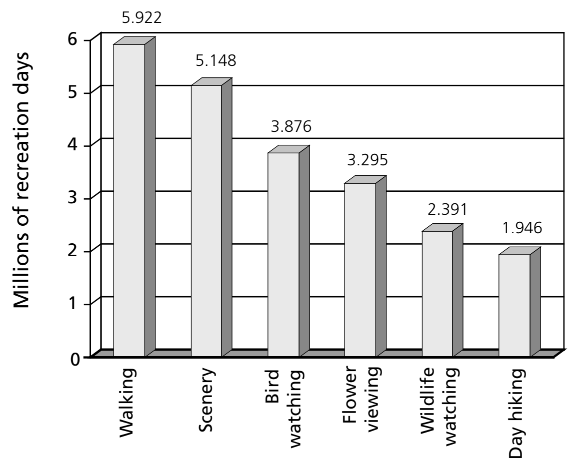


Figure 5. Visits to Designated Wilderness (2000)

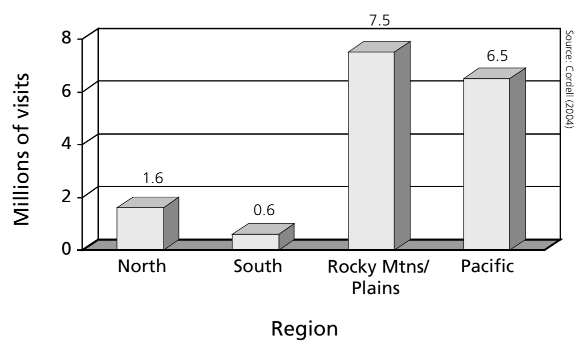


Figure 6. Economic Impacts of Recreation

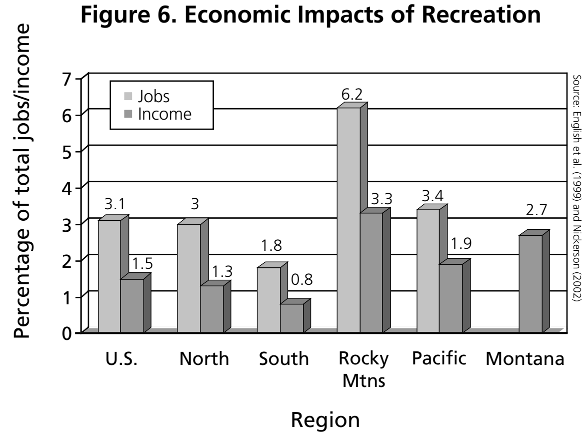


Figure 7. Percentage of Population Participating in Hunting (2001)

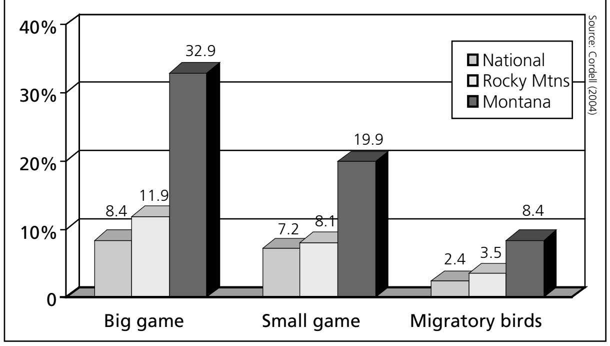
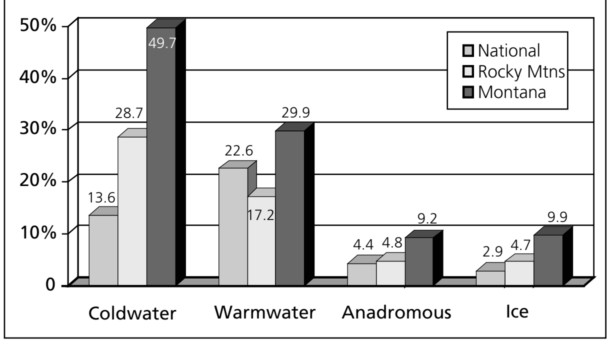


Figure 8. Percentage of Population Participating in Fishing (2001)



pleasure, scenery, bird viewing, wildflower viewing, wildlife viewing, and day hiking are the most popular activities when expressed by intensity of use or days of participation. Hence, although motorized activities are gaining in popularity, their intensity of participation remains far less than that associated with non-motorized activities. The top six activities according to participation days are more often associated with wilderness lands than those measured by percent-participation. Figure 5 shows the number of visits to designated wilderness by region. The Rocky Mountain West and the Great Plains receive the majority of visits.

Contribution of recreation to income and employment

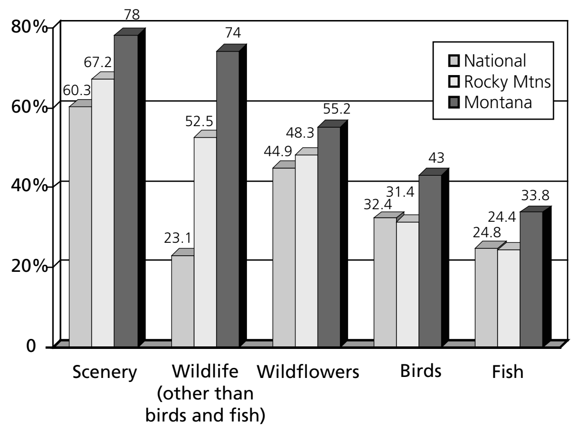
Recreation is a critical component of community health and vigor. Across the nation (Figure 6), recreation accounts for a strong component of employment and income, ranging from 1.8% of jobs in the South to 6.2% of jobs in the Rocky Mountains. From the standpoints of both jobs and employment, recreation accounts for the highest percentage of jobs and income in the Rocky Mountains.

Trends in fish and wildlife recreation

Figures 6, 7, and 8 show national, regional, and Montana trends specific to fish and wildlife recreation. While participation in hunting is declining slightly nationally, as shown in Figure 7, the percentage of the population participating in hunting in the Rocky Mountain region and Montana is significantly larger than in the nation as a whole (8% nationally, 12% in the Rocky Mountain region, 33% in Montana). The same is true for fishing (particularly coldwater fishing) (Figure 8) and viewing activities

(Figure 9), other wildlife viewing (non-bird viewing), and bird viewing. Based on the percentage of households participating in wildlife- and fish-related recreation, it may be appropriate to conclude that some individuals move to and stay in Montana for its wealth of wildlife and fish resources.

Figure 9. Percentage of Population Participating in Viewing Activities (2001)



Non-consumptive wildlife recreation is popular nationwide. According to the U.S. Fish and Wildlife Service's 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation, wildlife watchers age 16 or older spent more than $38.4 billion in 2001 on trips, equipment, and other items related to watching wildlife (USDI 2001).

Statewide recreation participation

In 2003, 9.9 million individuals (4.0 million groups) visited Montana. They spent $1.86 billion in direct expenditures, which resulted in a combined economic impact of $2.75 billion. These expenditures supported 29,600 direct jobs (jobs such as restaurant staff, outfitters and guides, and hotel staff) and 43,300 combined jobs (jobs that supply the goods used by restaurants, outfitters, and hotels, for example). Combined state and local taxes of $135 million resulted (Nickerson and Wilton 2004).

Throughout the 1990s, the Montana travel industry saw a steady increase in growth (Nickerson et al. 2003). Today, it is an industry on an equal level with construction, agriculture, and transportation. In terms of employment, it is ranked sixth in the state, supporting 29,900 jobs in 1999 (Dillon 2000). Concerns regarding the low average wages in the tourism industry have some basis in truth; however, it should be kept in mind that these are good entry-level jobs and are needed most in the summer, when high school and college students are looking for work (Dillon 2000). The addition of any job is an economic benefit to Montana.

National trends show that nature-based recreation is increasing, and this is especially the case in Montana, illuminated by the steady increase in nonresident visitors to the state who watch wildlife, day hike, and camp, as well as by dramatic population growth in amenity-rich areas. Thus, outdoor recreation expenditures contribute greatly to Montana's economy, leading the Institute for Tourism and Recreation Research to conclude, "Montana's amusement and recreation industry is outpacing all the other travel-related service industries in terms of employment growth" (ITRR 2002a).

Montana residents

The Rocky Mountain region is home to nearly 52% of all National Forest System (NFS) lands in the nation (Cordell and McKinney 1999), and in Montana, NFS lands are concentrated in the western half of the state. Areas near these public lands are experiencing the highest population growth. Montana's population grew 13% throughout the 1990s, and the state is now home to more than 902,000 people (MTFWP 2003). Four of the six fastest-growing counties in Montana during the 1990s (Ravalli, Missoula, Flathead, and Lake) are in the western part of the state.

With such a vast amount of public lands, outdoor recreation is an important activity in the state. According to the Institute for Tourism and Recreation Research, "Of all pleasure trips taken by Montana residents, 44 percent are day trips within the state, 29 percent are overnight trips within the state, and 27 percent of trips are to destinations outside of Montana." Nearly three-fourths of Montana residents vacation within the state. Many participate in outdoor recreation activities (ITRR 1999).

According to the Montana Department of Health and Human Services (2004), nearly one in five Montanans will be age 65 or older in all but seven counties by 2025. In the western half of the state, only Gallatin (8%) and Missoula (10%) counties are expected to have fewer than 18% of their population 65 or older, along with five counties in eastern Montana (MTHHS 2004). Montana currently has the fourth-oldest population in the nation (MTFWP 2003).

Managers must be aware of this portion of the population, as older recreationists seek different opportunities than younger people. Older people

generally prefer less strenuous forms of recreation, such as birdwatching, driving forest roads, and walking (MTFWP 2003). Birdwatching is the fastest growing activity nationally, and Montana already has the highest birdwatching participation rate in the nation, at 44% (compared to the national average of 31%) (Cordell 2004).

Montana non-resident visitors

In 2002, non-resident travel to Montana increased 30% from 1991, topping 9.8 million travelers, 41% of whom listed "vacation" as their primary reason for visiting (ITRR 2002a). This represents more than 10 times Montana's resident population. Non-resident travel expenditures, which introduce new dollars into the economy, have grown steadily since 1992 ($1.5 million, growing to $1.8 million in 2002) (Nickerson et al. 2003). The top three attractions for those non-resident visitors were mountains and forests, open space/uncrowded places, and rivers and lakes (ITRR 2002b). These visitors enjoy the same nature-based activities as Montana residents and the rest of the nation.

In 2002, Montana's non-resident visitors spent $1.8 billion on items such as gasoline, food, lodging, retail, and auto rental and repairs (ITRR 2002d). These visitors also spent $106 million in direct expenditures on recreation use: $65 million on outfitter and guide services and $41 million on campgrounds and RV parks, amounting to 6% of all non-resident visitor expenditures that year (ITRR 2002c). However, total recreation use value far exceeded the direct expenditures on outfitter/guide services and camping, and included portions of expenditures in all other categories, such as lodging, food, and gas. The majority of visitors came from Washington and California.

In 2001, an estimated 5.6 million non-residents visited Montana during the summer months of June, July, August, and September (ITRR 2002b). Visitation for these four summer months accounted for nearly 59% of all non-resident visitors to the state for the entire year. Wildlife watching was the most popular outdoor recreational activity, with 36% participation. Nearly one in three visitors (33%) day-hiked while in Montana, and one in four (23%) camped in a developed area. During the winter (December–March), wildlife watching (17%) was the most popular activity after shopping, and 12% of visitors enjoyed day hiking and downhill skiing (ITRR 2002b).

Recreation tourism is closely linked to scenic, natural landscapes, and many Montana towns bordering public lands are aware of the economic opportunities such landscapes provide. The Gateway to Glacier report acknowledges that people are drawn to the Flathead Valley for its "rural feel, clean water, wide-open spaces, wildlife, scenic beauty and outdoor recreation opportunities" (Swanson et al. 2003). Indeed, the valley's communities recognize that these natural amenities are "largely responsible for the quality of life and economic vitality [the communities] enjoy" (Swanson et al. 2003).

Fish and wildlife recreation in Montana

Outdoor recreation is, for many, a lucrative business. Estimates of expenditures and regional economic impacts show that recreational activities contribute billions of dollars to the national economy annually. As shown in Figures 6, 7, and 8, more Montana households (by percentage) participate in hunting, fishing, and viewing activities than participate nationally or regionally. Between 1996 and 2001, resident participation in hunting, fishing, and viewing day use increased (Table 1). Non-resident participation increased in hunting and viewing, and while fishing day use decreased, an overall use increase of 14% was still experienced in the state. The economic effects of hunting, fishing, and viewing activities also showed an increase between 1996 and 2001 (Table 2). Even with a slight drop in fishing effects, overall effects increased by 18%, and jobs by 17%.

In 2003, non-resident hunters and anglers were

Table 1. Montana day use, 1996–2001.

	Resident days		Non-resident days	
	1996	2001	1996	2001
Hunting	1,731,639	2,052,000	367,335	390,000
Fishing	1,771,310	3,515,000	845,790	554,000
Wildlife viewing	1,558,371	2,813,000	1,138,627	1,799,000
Totals	**5,061,320**	**8,380,000**	**2,351,752**	**2,743,000**

Niccolucci et al. 2002

Table 2. Total economic effects of hunting, fishing, and viewing activities, 1996–2001.

	Hunting	Fishing	Wildlife viewing	Total
Total effects on economy				
1996	$136,295,775	$236,312,004	$183,466,024	$556,073,803
2001	$150,602,424	$227,918,623	$301,696,797	$680,217,844
Wages and salaries				
1996	$34,784,504	$59,566,416	$48,215,566	$94,353,632*
2001	$38,366,525	$56,748,222	$79,123,964	$95,119,188*
Jobs				
1996	2,051	3,331	2,712	8,094
2001	2,253	3,114	4,441	9,808

*Because a single job may support multiple industries, these dollar amounts are not equal to the sum of the numbers shown.

Niccolucci et al. 2002

surveyed about their trips (Nickerson et al. 2003). The majority of hunters and anglers visited western Montana, were repeat visitors (85% of hunters, 84% of anglers), and planned to return within two years (94% of hunters and 88% of anglers). When asked what had improved since their last visit, both hunters and anglers stated, "lodging availability" and "road conditions." "Amount of open space" and "condition of the environment" were cited by repeat hunters and anglers as conditions that had worsened since their last visit. Thirty-seven percent of hunters and 34% of anglers claimed yearly incomes of more than $100,000.

Non-resident travelers were asked what attracted them to Montana, and what their primary activities were while in the state (ITRR 2002c). Mountains, open space, rivers, wildlife, and national parks were the top attractions. Shopping, viewing wildlife, visiting historic sites, and day hiking were the major activities.

Results from the 2001, 2002, and 2003 National Visitor Use Monitoring survey of recreation use on national forests in Montana further demonstrated the popularity of such activities (Kocis et al. 2003). The recreation activities common to all forests were relaxing and escaping noise, viewing natural features, and viewing wildlife. This study supports national and statewide data showing that recreationists value public lands as places to relieve stress and connect with nature, and also supports national recreation participation data showing the popularity of activities like birdwatching and wildlife viewing. Montana's vast wilderness of roadless and undeveloped areas available for wildlife viewing activities is a defining characteristic of recreation opportunities within the state. Fishing and hunting were also commonly cited as primary reasons to use the national forests.

Summary

National and statewide recreation participation rates demonstrate the popularity of nature-based recreation activities. Recreation activities offer economic value, and nature-based tourism holds promise for local economies. The uniqueness of Montana lies in its vast open spaces and high proportion of public lands offering high-quality, nature-based recreation opportunities such as wildlife viewing. All regions within the state play an important role in providing these opportunities.

References

Cordell, H. K. 2004. Recreation and the environment as cultural dimensions in contemporary American society. *Leisure Sciences* 24(1):13–41.

Cordell, H. K., and S. M. McKinney, eds. 1999. *Outdoor recreation in American life: a national assessment of demand and supply trends*. Champaign, Ill.: Sagamore Publishing.

Dillon, T. 2000. *Employment and wages: the travel industry in Montana*. Missoula: Institute for Tourism and Recreation Research (University of Montana).

Douglass, R. W. History of outdoor recreation and nature-based tourism in the United States. Pages 15–24 *in* H. K. Cordell and S. M. McKinney, eds., *Outdoor recreation in American life: a national assessment of demand and supply trends*. Champaign, Ill.: Sagamore Publishing.

English, D. B. K., H. K. Cordell, and J. M. Bowker. 1999. Implications of this assessment. Pages 433–440 *in* H. K. Cordell and S. M. McKinney, eds., *Outdoor recreation in American life: a national assessment of*

demand and supply trends. Champaign, Ill.: Sagamore Publishing.

Institute for Tourism and Recreation Research (ITRR). 1999. Recreation participation patterns by Montana residents, Research Report 68. Missoula: Institute for Tourism and Recreation Research (University of Montana).

______. 2002a. An economic review of nonresident travel industry in Montana. Missoula: Institute for Tourism and Recreation Research (University of Montana).

______. 2002b. Non-resident all-year and four-season comparison: visitor profile. TR2002-12. Missoula: Institute for Tourism and Recreation Research (University of Montana).

______. 2002c. Non-resident economic impacts and expenditures, 2002. Missoula: Institute for Tourism and Recreation Research (University of Montana).

______. 2002d. Non-resident trends: visitation and expenditure, 1993–2002. Missoula: Institute for Tourism and Recreation Research (University of Montana).

Kocis, S. M., D. B. K. English, S. J. Zarnoch, R. Arnold, and L. Warren. 2003. National visitor use monitoring results: forests of the Northern Region, 2001–2003. Asheville, N.C.: USDA Forest Service, Southern Research Station.

Masnick, G. 2001. America's shifting population: understanding migration patterns in the West. *The Rocky Mountain West's Changing Landscape* 2(2). Winter/Spring.

Montana Department of Fish, Wildlife, and Parks (MT-FWP). 2003. *Montana Statewide Comprehensive Outdoor Recreation Plan, 2003–2007*. <http://fwp.mt.gov/parks/admin/scorp.html>.

Montana Department of Health and Human Services (MTHHS). 2004. The state of aging in Montana. <http://www.dphhs.mt.gov/sltc/services/aging/Reports/2004%20agingreportfinal.pdf>.

Nickerson, N., and J. Wilton. 2004. Travel industry outlook, economics, and marketing. Governor's Conference on Tourism. Missoula: Institute for Tourism and Recreation Research (University of Montana).

Nickerson, N., B. Sutton, and J. Wilton. 2003. Niche news: anglers and hunters country travel region visitor characteristics. Missoula: Institute for Tourism and Recreation Research (University of Montana).

Niccolucci, M. J., S. A. Winter, F. S. Stewart, and J. Barranger. 2002. Economic effects of fishing, hunting and watchable wildlife activities in the Northern Region of Montana, North Dakota and North Idaho for 1996, with an update to 2001. USDA Forest Service, Technical Report No. 102.

Pandolfi, F. 1999. Perpetual motion, unicorns, and marketing in outdoor recreation. Pages ix–xii *in* H. K. Cordell and S. M. McKinney, eds., *Outdoor recreation in American life: a national assessment of demand and supply trends*. Champaign, Ill.: Sagamore Publishing.

Stenger, R. 1999. Trends in visits to federal lands. Pages 282–284 *in* H. K. Cordell and S. M. McKinney, eds., *Outdoor recreation in American life: a national assessment of demand and supply trends*. Champaign, Ill.: Sagamore Publishing.

Swanson, L., N. Nickerson, and J. Lathrop. 2003. Gateway to Glacier: the emerging economy of Flathead County. National Parks Conservation Association. <http://www.npca.org/across_the_nation/npca_in_the_field/northern_rockies/gateway/default.asp>.

U.S. Department of the Interior (USDI). 2001. The 2001 national survey of fishing, hunting, wildlife associated recreation. Washington, D.C.: U.S. Fish & Wildlife Service.

Ancient Corridors: The Trapper's Point Story of the Prehistoric Path of the Pronghorn

Meredith Taylor

Wyoming Outdoor Council, 6360 Hwy 26, Dubois, WY 82513 (307-455-2161, metaylor@wyoming.com)

Abstract

"Ancient Corridors" is the Trapper's Point story of the pronghorn antelope and the prehistoric American Indians dependent on hunting them in the longest big game migration corridor in the lower 48 United States. The archeological record suggests seasonal hunting more than 7,000 years ago at the Trapper's Point "bottleneck" —a narrow route through the hourglass-shaped migration route along this corridor west of Pinedale, Wyoming. Ancient hunters and animals traveled from Grand Teton National Park through the Trapper's Point bottleneck as they migrated to winter in the sagebrush steppe of the upper Green River Basin. The pronghorn migration and early human occupation of Greater Yellowstone were documented in the 1992 archeological excavation of Trapper's Point. Humans and wildlife have been interacting for at least 12,000 years in Wyoming, and prehistoric hunters would have adapted to pronghorn migration patterns. As hunters became familiar with game movements, migration landscapes, and intercept points, they established key hunting sites, such as archeologists found at Trapper's Point. The interaction between pronghorn and humans along this migration corridor continues to this day, but the route is now impacted by human encroachment in the form of fences, roads, housing, and mineral development that have all narrowed and may eventually block the bottleneck. In areas of low human population, such as Wyoming, pronghorn antelope still succeed as one of the remaining New World long-distance migrators. However, according to a recent study by the Wildlife Conservation Society, there is reason for concern in the upper Green River Basin: few remaining long-distance migrations (LDMs) have good long-term prognoses if current land management practices continue. In the interest of protecting this LDM, conservationists recommend that this longest big game migration corridor in the continental U.S. be made the world's first National Migration Corridor.

The Trapper's Point story is about *Antilocapra americanus*—the American pronghorn, which dates back more than 20 million years. Inhabiting the sagebrush plains from Canada to Mexico, there once were at least 40 million pronghorn, the fastest land mammal in North America. At the time when Lewis and Clark came West two centuries ago, pronghorn were allegedly as abundant as bison, but historians claim that a century later they were reduced by habitat fragmentation and overhunting to fewer than 5,000 in Wyoming. Now, with proper habitat management and hunting regulations, they have recovered; they outnumber people in Wyoming, with a population of almost 500,000.

Recent research has shown that pronghorn travel about 160 miles each way on the longest migration route in the lower 48 United States. The pronghorn migration corridor addressed in this paper passes through the southern Greater Yellowstone Ecosystem (GYE). Research by the Wildlife Conservation Society shows that more than 75% of the historic migration corridors in the GYE have already been lost to habitat fragmentation, so it is especially important that the pronghorn are still able to travel along this longest big game migration route today.

Since the last ice age, wildlife have followed their ancient migration paths each year. The 1,500–2,000 pronghorn from the portion of the Sublette herd unit that migrate along this long distance migration (LDM) corridor each year still use the same route from their winter range on the Red Desert and Little Colorado Desert (Wyoming) up the Pinedale Mesa to Trapper's Point through the Green River Basin. Only about 200–300 actually get through to Grand Teton National Park, according to radiotelemetry surveys.

In 1898, Dr. Frank Dunham submitted a proposal to *Recreation* magazine to protect this prehistoric migration route for the tens of thousands of pronghorn, elk, mule deer, and moose that, according to eyewitness accounts, migrated through each spring and fall. This historic proposal documented the need for habitat protection for all migratory big game.

The Trapper's Point map (Figure 1) shows the prehistoric path of the pronghorn north along this

Figure 1. The Trapper's Point bottleneck (at arrow).

ancient corridor as they funneled through this natural geographic bottleneck at the Cora Y junction. As the animals negotiated this exceptionally narrow bottleneck, early American Indian hunters may have hidden behind sagebrush blinds to hunt them as the pronghorn migrated north each spring. In 1992, the Office of the Wyoming State Archaeologist surveyed Trapper's Point in preparation for the reconstruction of U.S. Highway 191. In that excavation, archeologists discovered three layers estimated to be 4,690–7,880 years old by radiocarbon dating. The site revealed 87,000 pieces of stone artifacts, 86,000 pieces of bone artifacts, 400 bone tools, 300 projectile points, and 27 adult and 3 fetal pronghorn skeletons. The size of the pronghorn fetal bones indicated that pronghorn migrated through Trapper's Point in late March–April. Lithic tools, including chert and obsidian found from Rock Springs to Jackson, Wyoming, indicated that these native hunters followed the pronghorn from the Red Desert to Grand Teton National Park. This route has also been called the People's Trail.

The archeological survey also revealed how Early Archaic hunters strategized to use the seasonal spring/fall migration route through the naturally narrow geographic bottleneck. The sheer numbers of bones found led archeologists to conclude that prehistoric hunters may have corraled the pronghorn and killed them with atlatls or other projectile weapons, then butchered the meat on site. Petroglyphs found south of the area may have been carved by the same native peoples.

Today, both pronghorn and mule deer migrate along the prehistoric route at this bottleneck that has now become another obstruction along a difficult route. The Trapper's Point bottleneck, once 1.5 miles wide, has now been reduced to less than 0.75 mile wide by roads, fences, and development along U.S. Highway 191, where thousands of pronghorn and mule deer migrate bi-annually. Like pieces of a puzzle, the land is chopped up into a checkerboard of different ownership patterns where the animals must cross land managed by the Bureau of Land Management, the Bridger-Teton National Forest, the state of Wyoming, and private individuals. In addition, the high natural gas potential demonstrated in the Pinedale Mesa and Green River Basin is an increasing threat to the pronghorn winter range and migration corridor on the Pinedale Mesa.

As the pronghorn leave the bottleneck, they stage on the ridges north of Trapper's Point at Cora Butte. The pronghorn encounter yet another bottleneck at the Bridger-Teton National Forest boundary, now called the Funnel, where they literally wind down the driveways between summer homes. Once they have skirted snowbanks along the upper Green River, they reach Mosquito Lake Flats. There the pronghorn break trail across snow-covered meadows to small bare patches where they can forage. They then cross a huge expanse of open space at Union Pass and the upper Green River on their way to their summer range in the high country, and continue north over the triple hydrographic divide at Union Pass that separates the headwaters of the Green, Snake, and Wind rivers. These rolling slopes offer pronghorn a high-altitude summer range of rich sagebrush grasslands, but many (200–300 annually) continue over the Green River Divide and north down the Gros Ventre.

The route down the Gros Ventre is a well-established, ancient trail. The pronghorn move down Bacon Creek on the Gros Ventre drainage, but soon the open space becomes an obstacle course of dozens of fences and roads. Another bottleneck occurs on the Gros Ventre at the Red Cliffs, where pronghorn literally go single-file along the riverbed and the sagebrush slopes above Slide Lake. They continue down until they reach their goal in Grand Teton

National Park, the northernmost terminus of the migration route, where they will have their fawns. Recent Wildlife Conservation Society research has shown poor fawn survival and reduced recruitment here; a doe/fawn study is underway to determine the cause of the mortality.

In Greater Yellowstone is one of the last intact ecosystems in the temperate zones of Earth. In order to ensure that the connectivity of these migration route linkages along this ancient corridor continue to function in the future, conservationists are coordinating efforts to designate a National Migration Corridor so that together we can keep our native history and wildlife heritage alive. The National Migration Corridor Protection Proposal would be the first designated migration corridor in the world; maintain Ancient Corridors protection for the longest big game migration route in the continental U.S.; keep migration bottlenecks open for connectivity; protect the ecological integrity of Greater Yellowstone Ecosystem; and preserve the American Indian history and wildlife heritage of the West. Where else could this visionary proposal be better accomplished than in Greater Yellowstone, where Wyoming is home to the first national park, the first national forest, and the first national monument?

At the end of the day, the question remains, "What can we do to help protect this longest migration corridor in the lower 48 states, the second longest in North America only after the Porcupine caribou herd, to ensure connectivity in perpetuity?" The National Migration Corridor is a vision for the future.

References

Bennet, L. 1998. *Wildlife and ecological conditions in Sublette County, Wyoming: a historical and contemporary perspective*. Laramie, Wyo.: Ultra Petroleum, Inc., and Wyoming Cooperative Fish and Wildlife Research Unit.

Berger, J. 2003. Is it acceptable to let a species go extinct in a national park? *Conservation Biology* 17:1451–1454.

Berger, J. 2004. Can we save the last of the great long-distance migrations? *Wild Earth* (Fall/Winter).

Blair, N. 1987. *The history of wildlife management in Wyoming*. Cheyenne, Wyo.: Wyoming Game and Fish Department.

Clark, T. W., and Harvey, A. 1989. *Rare, sensitive, and threatened species of the Greater Yellowstone Ecosystem*. Jackson, Wyo.: Northern Rockies Conservation Cooperative.

Dorn, R. 1986. *The Wyoming landscape, 1805–78*. Cheyenne, Wyo.: Mountain West Publishing.

Dunham, F. 1898. Proposal for a winter game preserve on the Red Desert. *Recreation* IX (October):271.

Hecox, R. D. n/d. *Memories of Kendall Valley*. Self-published.

Knight, D. H. 1994. *Mountains and plains: the ecology of Wyoming landscapes*. New Haven: Yale University Press.

Larson, M. 1996. *Archaeological research issues in southwest Wyoming*. Technical Report No. 2. Laramie, Wyo.: University of Wyoming Department of Anthropology.

Larson, T. A. 1978. *History of Wyoming*. Lincoln: University of Nebraska Press.

Miller, J. C., and S. Kornfeld. 1996. *Excavations of 48sW4141 Dodge Bottom Interpretive Road*. (Sweetwater County, Wyoming). Technical Report No. 13. Laramie, Wyo.: University of Wyoming Department of Anthropology.

Sanders, P. H. 2000. Trappers Point. *Wyoming Wildlife* (May).

Sawyer, H., and D. McWhirter. 2000. The long trail. *Wyoming Wildlife* (May).

Sawyer, H., and F. Lindzey. 2000. *Jackson Hole pronghorn study*. Laramie, Wyo.: Wyoming Cooperative Fish and Wildlife Research Unit.

Seedskadee National Wildlife Refuge. 1995. *A historical perspective*. Washington, D.C.: U.S. Government Printing Office.

Seedskadee National Wildlife Refuge. 2000. Comprehensive conservation plan. Washington, D.C.: U.S. Fish and Wildlife Service.

Sublette County Guild. 1985. *Seeds Ke-Dee reflections: historical lore of Wyoming's Green River Valley*. Laramie, Wyo.: Modern Printing.

Sublette County Guild. 1998. *Seeds-Ke-Dee revisited, land of blue granite and silver sage. historical folklore of Wyoming's Green River Valley*. Sioux Falls, S.D.: Pine Hill Press, Inc.

Federal Agencies in the Greater Yellowstone Ecosystem

Jack Ward Thomas

Former Chief, U.S. Forest Service

A. Starker Leopold Lecture, October 18, 2005

Jack Ward Thomas holds a BS in Wildlife Biology from Texas A&M University, an MS in Wildlife Science from West Virginia University, and an MF and PhD in Forestry from the University of Massachusetts. He has been honored as a Distinguished Alumni by each of those institutions. He worked 10 years for the Texas Parks and Wildlife Department (as both a management and research biologist) and 30 years for the U.S. Forest Service (27 years as a research scientist and 3 years as chief). He retired as the Boone and Crockett Professor of Conservation at the University of Montana, where he taught for seven years, in spring 2006. He has authored or co-authored more than 400 publications spread across a number of specialty areas, including ecology, conservation biology, forestry, range management, threatened species management, ethics, philosophy, economics, fish and wildlife management, and natural resource planning. He has received numerous awards, including the Aldo Leopold Medal from The Wildlife Society, the Award for Distinguished Service from the Department of Agriculture, Fellow of the Society of American Foresters, the Gulf Oil Conservation Award, Distinguished Achievement Award of the Society for Conservation Biology, and honorary doctorates from Lewis and Clark College and Lakehead University (Canada).

Just how this address will turn out is something of a mystery—even to me. I arrived from Europe at the Missoula, Montana, airport this morning at 10:30. At this point I have slept three hours out of the last 36. My wife, Kathleen, prevailed upon my stalwart graduate student, Alex Sienkiewicz, to drive me down here from Missoula. And during intermittent moments of consciousness, I wrote my speech on the way. So I would ask each of you to cross your fingers and let's all hope it turns out all right.

I was sound asleep when we arrived in the parking lot just outside this room. A day and a half ago I was salmon fishing and stalking red deer in Scotland. At the end of the hunt we were saying goodbye to our hosts when Lord Wigan laughed and asked if I had ever considered that God might be a salmon or an elk. I was dreaming about that when I was awakened by a huge bull elk bugling and giving me an intent look. I came wide awake in a hurry.

Well, any time I make a talk that involves folks from a national park, I try to establish a bit of rapport with a story from my days as Chief of the U.S. Forest Service (USFS). All federal land management agencies run what public relations staffers call "tracking polls" that are intended to reveal public opinion on one question or another. The folks who did that sort of work in the headquarters of the USFS showed up in my office for their regular monthly meeting [one day, and] the team leader started off with the old saw, "Chief, I have the summary from our latest tracking poll, and there is good news and bad news. Which do you want to hear first?" I opted for the good news.

He continued, "The U.S. Forest Service is the most highly respected agency in the federal government." I was elated with that wonderful news and cautiously asked for the bad news. He went on, "The bad news is that the public doesn't know the difference between the National Park Service and the forest service."

Now, when I have a chance to talk about Yellowstone National Park (YNP) and about the National Park Service (NPS), to some extent I base my comments on my experiences involving Yellowstone and its employees. I was with the National Academy of Sciences team that was here during the big fires that caused the huge and ongoing changes in how both federal scientists and administrators in all federal land management agencies think about wildfires and their "management." The "management" of that fire was more about backing up and praying for rain [than anything else]! I have lived long enough as a natural resources management professional to see the humor in the myths that grow up quickly around such dramatic events. For example, I remember the accusations that the NPS was "letting Yellowstone burn." The firefighters, in most cases, were wisely backing up as fast as they could go. That was a fire that nobody—no how, no way—was going to "control" until circumstances of weather and exhaustion of fuel allowed that to happen. Just being there as an observer was an enlightening, interesting, and educational experience. It gave me a chance to become

acquainted, and develop respect and admiration for, many of Yellowstone's personnel.

My next close association with Yellowstone was a different matter and left a bitter taste in my mouth that still lingers. That bad taste emanates from the fiasco that swirled around the proposed New World Mine that took place in 1996. A Canadian mining company acquired the mining rights to some USFS land in a drainage off of—not adjacent to—the eastern edge of Yellowstone. As was their right, the mining company announced their intention to resume mining in a drainage that had been ecologically devastated by mining in the early twentieth century, and from which there had been only slight recovery. The USFS, as was required by law, partnered with the State of Montana to prepare the environmental impact statements on the mining company's proposed alternatives. The work was reaching its final stages when, out of the blue and with no consultation or discussion with the USFS, Yellowstone Superintendent Michael V. Finley accused the USFS of rigging the outcome of the environmental impact statements. That statement, made without warning or consultation, made headlines all over the country. Without investigation or contact with the USFS or the State of Montana, some of the powers in the Clinton administration took Finley's statement at face value. When I called my friend, NPS Director Roger Kennedy, he was as shocked and irritated as I was. Clearly, Finley was a fair-haired boy with the administration, and they would entertain no discussion of this—if nothing else—breach of protocol. The mining company, in my opinion, was pursuing a "can't lose" strategy: mine the mine or mine the U.S. Treasury. They were now set up to do the latter, which they ultimately did.

I checked things out and concluded that the USFS/State of Montana effort relative to the preparation of the required environmental impact statements was being properly conducted, as required by law. However, just to be sure, I had the USFS contract with the best private environmental impact outfit in North America for a review and critique of the ongoing process.

However, in the meantime, the press and environmental activists grabbed onto Finley's statement and painted him as a great hero standing alone against the evil mining company and the USFS. Finley, along with some allies of the environmentalist persuasion who should have known better, had managed to paint a picture in the public's mind of a pristine watershed that was about to be torn to shreds on the very boundary of Yellowstone National Park, which was downstream of the coming devastation. None of that was true. But it provided a political platform for President Clinton to establish his bona fides with the environmentalist camp. Without consultation with the USFS, or attaining a thorough understanding of what that agency was required by law to do, the administration bought Finley's fairy tale.

In the meantime, the consulting firm I had engaged delivered its assessment of the USFS/State of Montana's environmental impact statement relative to the matter. Their conclusion was not only that the effort was proper and thorough; it was among the very best they had ever examined. Katie McGinty, Director of the Council on Environmental Quality, was scheduled to testify before a congressional committee the very next day and tell them how the administration, tipped off by Finley's courageous stand against the USFS's "flawed" efforts at an environmental impact statement, intended to "save Yellowstone" by trading off national forest lands in exchange for mining rights. That decision also had been made without consultation with the USFS.

I informed her about the consulting firm's report. She was not appreciative. She had forgotten all about the ongoing evaluation. I sent her the report via messenger, and she immediately cancelled her scheduled appearance. I think she considered what I had done to be treacherous, though she had been informed of the ongoing review.

That summer, President Clinton and his family vacationed near Yellowstone, and the president, in a ceremony in the park, announced that the U.S. Government would buy out the New World Mine—that is, the mining company would mine the Treasury instead of the mine. The platform was filled with dignitaries—none of whom were from the USFS, upon whose lands the New World Mine would have been located. I, along with the regional forester, forest supervisor, and others, was ordered to attend the ceremony—in uniform, no less. We were seated in the peanut gallery.

In order for the president to keep his word without increasing federal expenditures, some political operative came up with the really swell idea of swapping some National Forest System lands near YNP for the mining rights. That was, simply, too damned much for me to swallow. I was simultaneously aggravated by an order to fire five of my top staff for what I thought were clearly political reasons. It was time for me to step down. However, I made arrangements to make several speeches over the next several

months—really the same speech to several different audiences. Foremost among the audiences was a meeting of the Outdoor Writers and the North American Wildlife and Natural Resources Conference in Washington, D.C., in March 1997. With the secretaries of agriculture and interior in attendance, I delivered what, in retrospect, I consider the best and most heartfelt speech of my career. The speech focused on the equally sacred trust of the national forests relative to the national parks. I bore down on the dangers of establishing a precedent of using public lands as chips in political wheeling and dealing. The crowd came to its feet in loud and sustained applause and cheering. The secretaries of agriculture and interior and other political appointees standing in the back of the hall got the message. The New World Mine was bought out using Land and Water Conservation funds.

I did enjoy, for my three years in Washington as Chief of the USFS, a close personal and professional relationship with NPS Director Dr. Roger Kennedy. He was, and is, a scholar and a gentleman. I spent many hours in the Kennedy's home, especially in the days immediately after my wife died. We spent many hours discussing public land issues and the relationships between national forests and national parks.

Sally Fairfax, a social scientist at the University of California–Berkeley, recently published an article in the *Journal of Forestry* suggesting that the USFS, NPS, and the Bureau of Land Management (BLM) be combined in the Department of Interior. Her rationale was that the missions of the three agencies had more or less evolved to be centered around protection of environmental values (preservation) and recreation.

Such is not a new concept. Secretary of Interior Harold Ickes made the same determined pitch during the administration of Franklin D. Roosevelt in the late 1930s. His thrust was defeated, largely by the actions of the USFS chief and top staff—which, understandably, shortened their careers. Likely, they were not surprised. Ickes retaliated by engineering massive transfers of land from the USFS to the NPS. President Jimmy Carter's government reorganization proposals in the 1980s included some aspects of the same plan, and it failed again.

Why did those efforts fail? Agencies have constituencies, and those constituencies may, from time to time, consider the agency with less than total enthusiasm. However, the old adage, "the devil you know is better than the devil you don't know" applied, and those constituencies have consistently raised their voices—and power—against consolidation. So historically, at least, the Department of Interior has been seen as the one more focused on preservation of the public lands as opposed to conservation ("wise use") of lands under their jurisdiction, the BLM being the exception. The Department of Agriculture was the "use" agency when it came to public lands. Gifford Pinchot, the first chief of the USFS, had once headed the forestry operations in the Department of Interior, which he considered to be corrupt at that time. He worked long and hard to have the forest reserves, and all forestry operations, transferred to the Department of Agriculture. Pinchot, I think correctly for that moment in history, did not believe that large withdrawals of public lands from the public domain to form the U.S. Forest Reserves would stand if the lands were not actively managed to produce goods and services in a sustainable fashion.

I think it is just as likely that Pinchot wanted to establish the USFS in the Department of Agriculture because, he reasoned, the secretary of agriculture would be focused on production of agricultural commodities (e.g., cotton, corn, and livestock), and would have not have the expertise or interest to guide the USFS. That guidance would be left to the chief of the USFS. And that was largely true until some 20 years ago. Today, the primary spokesman for the USFS is not the chief of the USFS, but the undersecretary of agriculture. What does that mean, and what does it portend? Time will tell if that condition persists after the current administration leaves power.

It is well to recall the conflicts during the early years of the USFS (1905–1910) between John Muir, the preservation guru, and Gifford Pinchot, the "wise use" guru. Even today, it is possible to visit the offices of those involved in the ongoing saga of the public land management game—those in government and those in lobbying groups—and see pictures of Pinchot hanging on the wall of those interested in active land management and pictures of Muir on the walls of the preservationists. When I was chief of the USFS, I ordered that pictures of Muir, [Aldo] Leopold, [Arthur] Carhart, and [Bob] Marshall be hung in the "Hall of USFS Heroes." So far as I know, they hang there still. I thought there was a need for and room for both focuses, and both sets of heroes, on the public's lands.

There are differences in mission between the federal land management agencies. The mission for the USFS was set out in its Organic Act of 1897. It

called for the management of the forest reserves for three purposes: protection of the forest reserves, production of a sustained flow of water, and provision of a flow of timber for the use of the American people. That mission was not modified until the passage of the Multiple Use Sustained Yield Act of 1960, which added livestock grazing, fish and wildlife, and recreation to the mandate.

In 1905, the forest reserves were transferred from the Department of Interior to the Department of Agriculture. Gifford Pinchot was appointed the first chief of the USFS. He had maneuvered for this change and this appointment for more than a decade. The chance came when his friend Theodore Roosevelt became president with the assassination of President McKinley.

Pinchot firmly established direction for the USFS when, early on, he wrote a letter for Secretary of Agriculture [James] Wilson to send to the chief of the USFS. That letter told the new chief how and for what the new agency would be managed. That direction still stands after 100 years. Sometimes it pays to know history, as such knowledge can provide a playbook for use in the political games of today—and tomorrow. In 1993, I had the opportunity to write a letter for President Clinton to send to me describing how we were going to deal with ecosystem management on public lands in the Pacific Northwest. Those instructions still stand.

The NPS, of course, has had its share of mixed messages over the last century. The primary confusion has been over achieving a politically correct balance between the mixed, and sometimes incompatible, messages of preservation and satisfying increasing recreational use.

Pinchot's USFS wanted to increase the amount of lands in the National Forest System. In order to do that, it was essential to assure local people, and their politically elected officials, that these lands were not to be "locked up," but were to be actively managed to provide goods and services in an equitable fashion. For Pinchot, that dictated application of "practical forestry" (forestry that would make money and be sustainable) and the regulation of livestock grazing in a fashion that was equitable and would help repair damaged range conditions. In doing so, Chief Pinchot had to take on both the "timber barons" and the "cattle barons," not to mention the miners. They were formidable opponents that he considered to be future allies.

Wanting into the business of "practical forestry" and actually achieving that objective turned out to be two very different things. The USFS, by and large, did not have control of the most productive forest lands. In fact, many of the national forests were composed of what might be called marginal timberlands, which made it difficult for the USFS to make money in the "practical forestry" business. And the USFS was competing against a very powerful timber industry not constrained by any lofty ideas of actually practicing sustainable forestry. Worse yet, that industry did not want any competition from "cheap government timber" and, by and large, they made sure that such did not happen until 1929. The Great Depression began in 1929 and, as a result, there was very little demand for wood products. Demand picked up during World War II (1939–1945), but the "cost plus 10%" contracts being passed out to private timber companies kept the USFS largely on the sidelines relative to timber production.

The USFS, during the period 1910–1945, concentrated on bringing grazing under control, building roads and trails into the vastness of the National Forest System to facilitate management (largely efforts at fire control), and fighting wildland fires. The idea was to protect the forests from fires until, at some future date, the nation would need the wood and turn to the National Forest System as a source. And, sure enough, when World War II ended in late 1945, the moment finally came when the timber from the National Forest System was in high demand at prices that made "practical forestry" a reality. There was a pent-up demand for housing that had been building since the onset of the Great Depression in 1929 and had lasted through the end of 1945—a hiatus of 16 years in home- and other construction. The timber supply from much of the private lands had been expended during the war years. The nation turned to the National Forest System and the USFS to supply much of the skyrocketing demand for timber and other wood products. Timber cut from the National Forest System increased continuously from less than 2 billion board feet/year in 1945 to some 13 billion board feet/year in 1990. Then there was a collision with a changing public will and the environmental laws passed in the period of the 1960s and 1970s.

Beginning in the 1970s, there was a gradual shift relative to the way fire was considered in the forested landscape. The "10:00 AM fire policy," which called for the extinguishing of any wildfire on the national forests by 10 AM on the day after its discovery was put in place in 1911 and was now being questioned on both ecological and economic grounds.

By 1990, timber yields from the national forests

began to drop due to a public backlash against "industrial-strength forestry" which included broad-scale application of pesticides, road densities exceeding four miles per square mile, even-aged timber management involving clear cutting, planting of monocultures of single species of trees, and harvesting of trees at "economic maturity." "Old growth" had essentially disappeared from private lands and was being rapidly logged on USFS and BLM lands. The attitude toward fire in the forest was also changing. Fire became more and more recognized as a natural part of the ecology of forests. This was taking place at the same time that fuel loadings, due to 80 years of increasingly effective wildfire suppression efforts, were increasing on both national forest and national park lands. Managers began to wonder how to incorporate fire into forest management.

The new approaches were complicated by several factors. First was the simple fact that forests come in a variety of ownerships—federal, state, other government, and private. Though these landowners had different management objectives, wildfires do not respect property lines. To make matters worse, homes were and are, and at an increasing rate, being built in locations where they are susceptible to being destroyed by wildfires in adjacent forests.

It is common today to hear and read castigation of the federal land managers of yesterday for their attitudes toward wildfire—and even for their success in, to some extent, controlling wildfires. We tend to forget that their intention, in the case of the USFS at least, was to preserve the forests in their care until the wood could be harvested and used to benefit the American people. No one could have foreseen the shift in public attitudes that would dramatically alter the management of public lands more toward preservation and away from active management for the production of wood. The early forest managers thought of the green trees in the forest as products in a warehouse to be accessed and utilized at some future date. It seemed only prudent to keep the warehouse from going up in flames. It is hard to argue against that logic, given the knowledge of the time. Now, during a period when we have decided that burning up such a warehouse, for some reason or other, has its good points, the original concept appears stupid to some. Is it? Was it?

We are beginning to learn that living with wildfire, including its intentional use in forest and range management, is much easier in theory than it is in the overall political and economic sense. The NPS's fire managers had the great misfortune to be responsible for the first large-scale "controlled burn" that became so "uncontrolled" as to have burned up a significant portion of a town: Los Alamos [New Mexico]. But if the truth be known, anyone who has dealt with controlled burning could view that scene, shudder, and mouth the worn words, "There, but for the grace of God, go I." My prediction is that in the end, we will find that [policies of] "controlled fire" and "let-it-burn" will have much less application than some visualize at the moment. That is particularly true when we consider the increasingly mixed ownerships as one large timber company after another gets out of the timber business and sells to or becomes a real estate investment trust—i.e., land developer.

Global warming is now accepted—by scientists, at least—as a reality. The National Academy of Sciences has concluded that the phenomenon is responsible for increases in the number, size, and extent of wildfires in North America. There are, to be sure, holdouts in industries that will be adversely influenced by any attempt to deal with the situation, and they hold more influence in the political arena than scientists. But they will be overwhelmed by developing evidence. Such is merely a matter of time and, now, cascading evidence.

Beginning in the 1920s, the NPS became the USFS's primary competitor for allocations of land out of the public domain and for the purchase of land for inclusion in the federal estate. The NPS has a founding father, and icon, that matches the USFS's Gifford Pinchot. Things began to change for NPS with the arrival of Stephen T. Mather as director. He was just as charismatic, just as ego-driven, just as shrewd, just as ambitious, and just as focused as Pinchot. But Mather's focus was on land preservation as opposed to Pinchot's (and his successors') doctrine of wise use. Mather's objective was to build a national system of parks. Given that the USFS had a significant head start in acquiring lands from the public domain, and that the agency had "cherry-picked" the best, most beautiful, and most productive of the lands available, what was Mather to do? The answer was simple. Mather would, on a selective basis, raid the National Forest System for the lands he wanted for national parks. And he was to prove to be a most successful pirate, from the view of the USFS. In the view of the preservation community, he was a most successful crusader for keeping vast stretches of wild lands forever protected in their pristine state. That was, frankly, a little hokey, and not in keeping with ecological realities, but it sold, and it still sells.

The USFS mandate was too narrow to allow a

successful defense of the lands desired by Mather and [his] associates. The USFS's narrow mandate to protect the forest and assure water flows and a supply of timber for the American people left the NPS to seize the mission of protection of natural landscapes, provide havens for plants and wildlife, and provide pleasuring grounds for the American people. Clearly, those mandates are to some degree contradictory, and are increasingly so. But, as some would say, whatever works. And it did work. Director Mather and his successors were every bit as successful in their quest for what they thought was the best future for the public lands of the United States as Gifford Pinchot and his successors were in terms of the National Forest System. But, understandably enough, [Mather was] viewed with animosity and suspicion; acceptance required a painful adjustment for the USFS. Those "raids" stimulated the USFS to bring forth the Multiple Use Sustained Yield Act of 1960. Passage leveled the playing field between the NPS and the USFS. NPS success in raiding the National Forest System for new park lands essentially stopped.

Now, I fast-forward to the end of World War II in 1945. The USFS entered what some, especially those enamored by the production of goods from federal lands, consider its glory years. The nation had been overwhelmingly successful in World War II, vanquishing Germany and the Empire of Japan in a two-front war. Millions of GIs were coming back from the war, many of whom had suffered through the Great Depression. Those veterans, most drafted into military service, had not gone into combat on a rotation basis; they went overseas and did not come home until victory was achieved. Casualties were not in the thousands or tens of thousands, but in the hundreds of thousands. The nation had two feelings about those returning veterans: (1) they were owed a tremendous debt, and (2) unless they were appropriately recognized, rewarded, and appreciated, and quickly reintegrated into a society that had changed much in their absence, political and social unrest was possible or even likely.

In a stroke of genius, Congress passed, and President Truman signed, the most successful social legislation in the history of the United States: the G.I. Bill. That bill made two promises to returning veterans. First, through guaranteed low-interest loans, it became possible for veterans to own a home (keep in mind that essentially, there had been no homes built in the United States since the onset of the Great Depression in 1929). Second, it was made possible—through stipends and tuition payment—for veterans to enhance their education in ways ranging from vocational training to university education. Home ownership became common for middle- and lower-class Americans, and the new surge in an educated work force set off prosperity never before known.

And as far as the NPS was concerned, there was a huge surge in outdoor recreation. The war was over. The economy was booming. Cars were rolling off the assembly lines and into garages and onto driveways. Gasoline, which had been rationed, was readily available at low prices. Recreation, particularly outdoor recreation, was booming.

The USFS provided a great deal of the wood that fueled the housing boom. Examination of newspapers and magazines for the period 1946–1980 reveals story after story extolling the virtues of the agency's performance. The USFS was the agency that "could do the job," "the Marine Corps of the civil service," "the only agency that pays its way," and so on. Budgets climbed, personnel numbers increased, and applause was common. These were heady times for the USFS. The USFS, in 1960, finally got the mandate it wanted to deal with range, fish and wildlife, and recreation. Now, they could beat off additional raids for lands from the NPS—and they did.

The 1960s and 1970s gave rise to both the modern environmental movement and a plethora of environmental laws. These laws had markedly delayed effects, as it was about 10 years after their passage before they were commonly used as the basis for legal actions against federal agencies. In the meantime, the timber cut on the national forests was inching up to 13 billion board feet/year. And it was becoming clear, through experience and research results, that if the USFS was to continue "practical (money-making) forestry," it must be done through the avenue of even-aged management, with its built-in efficiencies of road construction and maintenance, harvesting, stand regeneration (natural or planted), and stand tending.

The USFS was still suffering from a hangover from the Progressive Era, under which it was anticipated that the technological elite, when given responsibility and authority, would make the best decisions, and then execute those decisions so as to maximize the greatest good for the greatest number for the longest time. The Progressive Era was long gone, yet the USFS and several other federal agencies, such as the Bureau of Reclamation and the Army Corps of Engineers, proceeded as if that were not so. The USFS was faced with increasing public backlash and, now,

there were environmental laws that could be used to force attention to the public will.

There was nothing wrong with the research relative to even-aged timber management. It worked quite well if the manager's objective was the maximization of wood production per unit of area. Otherwise, it has some rather nasty, if short-term, attributes—one being that from the time of cutting for a decade or two afterward, the result is just plain ugly. Only a forester can see the beauty of a clear-cut in its infancy. Then, to make matters even worse, silviculturalists commonly laid out the cutting units in 40-acre squares that were clearly visible marching up the hillsides with the roads, while granting motorized access of timber managers and recreationists into the backcountry, which was adding up to an economic and environmental liability. Then, in Montana, the ugly factor was multiplied by terracing hillsides within clear-cut areas to maximize "water capture" and speed tree growth. That was referred to as "ugly squared." It didn't matter to the public, the owners of the national forests, that these practices might have been quite effective for their intended purpose: maximization of wood production. The USFS pressed ahead.

When I went to work for the USFS in Morgantown, West Virginia, in 1966, I was quickly embroiled in research relative to the reaction of wildlife and hunters to even-aged timber management. White-tailed deer, turkeys, and ruffed grouse responded positively, but hunters, most decidedly, did not. A retired shoemaker in Gauley, West Virginia, was working part-time as the head of the Chamber of Commerce for that small town. He and a number of his constituents were aficionados of turkey hunting, and were appalled by the clear-cutting of hardwood forests. By happenstance, he was also an influential member of the West Virginia Chapter of the Izaak Walton League. When he and his friends protested to the USFS about clear-cutting, they were, at least in their minds, paternalistically brushed off, with the implication that such matters should be left to the experts—by definition, the USFS.

The Izaak Walton League went to federal court and charged the USFS with violating the USFS Organic Act of 1897, which specified that any trees cut for commercial purposes on national forests had to be "mature" and individually marked for cutting. The USFS maintained that in spite of what the law said, they were the experts, and times had changed relative to knowledge about the most appropriate silvicultural treatments; therefore, they had the right and obligation to proceed with forest management as they deemed appropriate. The judge ruled that the USFS was in clear violation of a clearly written statute. Further, the judge said the law might be antiquated, but it was the law until modified. Ergo, the USFS would cease and desist so far as clear-cutting was concerned.

Meanwhile, out in Montana, a committee of forestry professors from the University of Montana came forth with the Bolle Report (named for Arnold Bolle, the chairman and dean of the school's School of Forestry), which took the USFS to task for the clear-cutting and terracing in the Bitterroot National Forest. It was a second staggering punch for the USFS's timber management program.

Congress jumped into the fray and sought clarifications from the applicable laws (primarily, the simple instructions in the Organic Act) that guided management of the National Forest System. Two primary pieces of legislation vied for consideration in the Senate. The first was the so-called "Randolph Bill," named for its sponsor, Senator Jennings Randolph of West Virginia. That proposed legislation, written with assistance from the developing and growing environmental community, was very prescriptive in nature as to what the USFS could and could not do in forest management. The USFS saw the Randolph Bill as a significant encroachment on the managerial prerogatives of its professionals, and worked with Senator Hubert Humphrey of Minnesota on an alternative. That alternative restored managerial flexibility to the USFS and mandated that the agency should prepare 10-year management plans—whereby, at least in theory, appropriations could be controlled or, at least, strongly influenced.

Senator Humphrey's legislation prevailed as the National Forest Management Act of 1976. In retrospect, it might have been better if the agency had held its collective nose and swallowed the Randolph Bill. The old caution comes to mind, "Be careful what you ask for; you may just get it."

The USFS also maneuvered to get the Forest and Rangeland Renewable Resources Planning Act of 1974, which directed the agency to do three things: assess all the potential actions of the federal land management agencies; assess the best alternatives for the expenditure of federal funds; and prepare plans for the most efficient use of federal funds in federal land management. As a sideline, it is interesting to note the act also provided for the following (emphasis added): "an analysis of the potential effects of ***global climate change*** on the condition of

renewable resources on the forests and rangelands of the United States; and an analysis of the rural and urban forestry opportunities to mitigate the buildup of atmospheric carbon dioxide and to reduce the risk of ***global climate change***." Congress recognized and acknowledged, 32 years ago, that global warming was a reality.

The USFS's intent in guiding the preparation and passage of the act was to put the agency in the driver's seat relative not only to the multiple-use management of the national forests, but also to other federal lands, as well. The Multiple Use Sustained Yield Act of 1960 gave the USFS license to expand its mission to include timber, water, recreation, range, fish and wildlife, and minerals. The National Forest Management Act of 1976 restored managerial flexibility and required national forest planning. The Forest and Rangelands Renewable Resources Planning Act of 1974 directed the USFS to assess the best alternatives for expenditures on all the public lands. It was, in concept, brilliant from the standpoint of the USFS. The USFS now had a wide-ranging mission, a direction to carry out, national forest by national forest, on a 10-year basis. And the USFS could, on a regular basis, assess and point out to Congress the best opportunities for effective additional spending on the federal estate.

It was a brilliant bureaucratic maneuver, but it didn't work in practice. The USFS seemed to have missed the point that Congress does what Congress does in terms of allocations of federal dollars, more in light of political expediency than in terms of what is logical or efficient. As former house speaker Tip O'Neill of Massachusetts once said, "Everything is political, and all politics are local."

Then, to drive the last nail in the coffin of the independence of federal land management agencies, the Equal Access to Justice Act arrived on the scene, and things were never the same. This act allowed citizens to "sue the Crown" if they thought any entity of the Executive Branch violated the laws under which it operated. And in the event of a victory by the plaintiff, the government was to pay all of the plaintiff's costs. The land management agencies were now vulnerable to lawsuits under a number of federal statutes if their actions were believed to be in non-compliance. Not only could citizens sue a government agency and have their expenses paid in the case of victory, there also was no penalty involved in a loss, outside of sunk costs. Compliance with the Endangered Species Act, National Environmental Policy Act, and the National Forest Management Act were the source of most such lawsuits.

During the period 1945–1990, the USFS, in general, seemed quite insensitive to the concerns of the NPS relative to the management of national forests adjacent to national parks. In fact, some of those actions went beyond the bounds of insensitivity to "in your face" management actions. The one such action that leaps to were clear cuts on a park's [Yellowstone's] boundary delineated by straight lines that could be seen from outer space. Such was, in retrospect, as stupid as it was insensitive. If the intent was to draw a clear contrast between federal land management agency missions and actions, it was certainly achieved.

By the 1960s, two differing constituencies were developing around the USFS and the BLM relative to the NPS. The NPS received support from the "greenies—" folks of the protectionist/preservationist branch of the conservation community. Greenies were little-courted by the land management agencies prior to 1960, but by 1980, the greenies were a force to be reckoned with. So the NPS got the support of the greenies; the USFS was supported by conservationists of the old school, that is, those who believed in "wise use" (with emphasis on "use"). This group included those involved in active forest management, livestock grazing, mining, commercialized recreation, outfitting, and hunting and fishing. Many gave active support to both agencies with full appreciation of their differing missions. But in general, the body politic that was interested in natural resources began to fracture along the green/brown line.

The Endangered Species Act of 1973, a decade after its passage, emerged as a turning point in how public lands of all kinds were to be managed. One of the species and places that received immediate attention under the Endangered Species Act was the grizzly bear, with the Yellowstone ecosystem (Yellowstone National Park and surrounding national forests) being the focus of this attention. There was an initial focus on what became known as "charismatic megafauna," and [the grizzly bear] was, and is, a sterling example. Wolves were soon added to the mix in the Yellowstone ecosystem.

But there was a new star emerging in the ongoing saga—or is it a tragedy—of application of the Endangered Species Act. It was a cryptic little known species of owl—the northern spotted owl—that would produce the biggest conflict relative to public land management of the last half of the twentieth century.

I was appointed director of the USFS's Range

and Wildlife Laboratory in La Grande, Oregon, in 1972. In those days, federal agencies, at the end of the fiscal year, had to deal with what was internally referred to as "year-end money—" budgeted dollars that were left unspent at the end of the fiscal year after all the obligations had been paid. Any money that was unspent was returned to the U.S. Treasury (and it was likely that the next year's budget was reduced by the unspent amount). The director of the Northwest Forest and Range Experiment Station called me out of the blue and announced that I was to be assigned some year-end funds. He wanted me to contract for some research with the U.S. Fish and Wildlife Service Cooperative Research Unit at Oregon State University, thereby healing over some irritations that had been festering for a few years. This healing was to be accomplished by means of a couple of small research grants to the unit to carry out research of mutual interest. So I called my friend Howard Wight, who was the co-op unit leader, and told him the good news. I asked him to have a half-dozen young graduate students who were scratching for research support present me their proposals. If warranted, I could support a couple of studies.

A week or so later, I journeyed to Corvallis [Oregon] to listen to the presentations. All of the six presenters did an excellent job, and all of the proposed studies were within the parameters of research that I could legitimately fund. So I put the onus on Professor Wight, and told him he could pick the studies to be undertaken. Howard's first pick was a study proposed by Eric Forsman to determine the habitat associations of the northern spotted owl. I don't remember the second. But I do remember whispering to Howard Wight, "Howard, that's O.K. with me, but what's the bag limit on the damned things?" Our profession of wildlife management, in those days, focused almost entirely on species that were hunted or were predators of species that were hunted.

Nobody laughed, save for maybe the greenies, when Forsman's study indicated that the primary habitat of the northern spotted owl was old-growth forests—the very same old-growth forests that had been essentially eliminated from private lands and reduced by more than 80% on public lands through logging. Forsman's initial report triggered a number of other studies that added to understanding of the ecology of the northern spotted owl and it s habitats.

Those of the hardcore environmentalist persuasion saw an opportunity to significantly reduce the rate of cutting of old growth, particularly on public lands. Here was a relatively slow-breeding bird with a large home range that is dependent on old-growth forests that were being steadily logged and simultaneously fragmented in the process. This added up to a "perfect storm" relative to, first, the owl's listing as "threatened," and, then, dramatic reductions in the harvest of old-growth forest from public lands. They did not take long to exploit that opportunity. As one of their leaders later remarked, "If the northern spotted owl had not existed, we would have had to invent it."

All of this added up to a mega-voltage jolt to the federal agencies involved. The USFS went through two iterations of plans to provide habitat for the northern spotted owl while continuing to cut old-growth forests at a rapid pace. But the economic/political consequences of these plans on timber harvest and jobs in the timber industry were just too tough to face, and the efforts failed. Finally, the handwriting was clear on the wall: the northern spotted owl would be listed by the U.S. Fish and Wildlife Service (USFWS) as "threatened," and it would be necessary to cobble together a recovery plan as required by the Endangered Species Act. In the meantime, logging of old growth would be held in abeyance. The four federal agency heads concerned (F. Dale Robertson of the USFS, Cyrus Jamison of the BLM, John Turner of the USFWS, and James Ridenour of the NPS) created a team (the Interagency Scientific Committee, or ISC) to create, within six months, a plan for the management of the northern spotted owl. Clearly, the four agencies would have to cooperate if a political meltdown was to be avoided. I was assigned the team leader and given carte blanche to pick the scientists who would make up the team and make the necessary expenditures. The team was to include scientists from all four of the agencies, the California and Oregon departments of wildlife, private industry, and academia.

Whatever federal land management agencies were to do relative to cutting old-growth had little direct effect on the NPS. To this point the NPS had been standing around watching as the USFS, BLM, and USFWS were sweating blood. But now, the NPS had been drawn into a game they preferred to avoid. Boundaries between agencies were crumbling—just a little.

In the meantime, President George H. W. Bush attended the Rio summit in South America relative to the worldwide environment. He needed to make some dramatic announcement that would show the leadership of the United States relative to the

environment, and his staff was coming up short. A call was made to the chief of the USFS asking for a statement that was heavy with meaning, yet nebulous enough to afford some wiggle room if and when push came to shove at some time in the future. They suggested "ecosystem management" to the president's aides, and they grabbed onto it. From today's vantage point, I am not so sure that what they had in mind at the time was what we consider ecosystem management today, but nonetheless, the commitment was made. So the management plan for the northern spotted owl was based on principles of ecosystem management, and lands of the USFS, NPS, BLM, and USFWS were all in the pot.

Similar things were happening elsewhere in the United States with different triggers. But it was the northern spotted owl that made the news. And no wonder, for no matter which way the struggle turned out, there would be 30,000–40,000 jobs lost, damaged or disappearing communities, and severe social disruption. Politicians do not appreciate such scenarios.

In desperation, the Bush administration essentially put the ISC and their work on public trial in Portland, Oregon. This was accomplished using the provisions of the Endangered Species Act (ESA). The ESA allows for the institution of an Endangered Species Committee, all political appointees of the president, to determine if the consequences of attempting to save a species are simply too great. The ISC, and the results of their work, survived unscathed when, in a humiliating defeat for the administration, all the members of the Endangered Species Committee, save for Secretary of Interior Manuel Lujan, upheld the work and recommendations of the ISC.

My first night home after the trial, the phone rang in the middle of the night. I was sound asleep and groped around for a moment or two before encountering the telephone. "This is Jack Thomas." The caller, who had obviously been drinking, asked, "Are you the spotted owl guy?" His words were more than a bit on the slurred side. "Well, I'm going to burn down your house, blow up your car, kill your dog. . . ."

When he paused for breath, I said, "Now, wait just a minute! Look, Mister, I have rules that govern my reactions in a situation like this, and with which I must comply. I simply cannot accept death threats at home. I would like to make an exception in this case, but I can't do it. I can only accept death threats at the office between 8:00 and 12:00 on Mondays, Wednesdays, and Fridays. My number is 406-273-3040." All I could hear was heavy breathing. I said, "Let me repeat that number." I could visualize the drunk writing down the number. I repeated it slowly and distinctly. Needless to say, I had bodyguards off and on for a while.

While there were ongoing drops in timber harvests across the entire United States, the most severe, with the greatest political backlash and the most public involvement, took place in the Pacific Northwest with the spotlight on the northern spotted owl. But similar patterns were developing on national forests across the United States. The timber cut from national forests dropped from some 13 billion board feet/year in the late 1980s to some 2 billion board feet/year in 2000, where it has hovered since.

In late 2005, I was in Washington, D.C., to attend the ceremonies celebrating the hundredth anniversary of the establishment of the USFS. As a result, I had occasion to visit with the undersecretary of agriculture about the USFS. He had served as the chief of staff for the Senate Committee on Natural Resources during my tenure as chief of the forest service. Before that, he had been head of a lobbying outfit for the timber industry. We had known each other for many years, and were friends in spite of some significant disagreements over the years. He was a hired gun, and a very good one. He fed the Republican members of the Natural Resources Committee questions intended to beat me up over declining timber harvests on the national forests. The committee insisted that we were simply not doing our job relative to timber harvests, that is, the USFS was not "getting out the cut." My response was, always, that Congress made the laws and the USFS carried out budget directions under the laws.

I said, "Mark, what's happening? You and the Republicans (presidency, House, and Senate) have been in charge for almost six years, and the timber cut from the national forests per year hasn't changed appreciably." He just smiled. Ah, the games that people play.

Where do we stand today relative to management of federal lands? Things have not really changed very much since the departure of the Clinton administration and the advent of the George W. Bush administration, except for the continuation of declining budgets relative to inflation and erosion in employee numbers. No big changes seem to be looming on the horizon. There does seem to be an increasing recognition that the federal land management agencies must increase their cooperation. Who could disagree with that?

I don't think, for example, that the NPS, with any semblance of a straight face, can continue to cling to the wreckage of the failed policy of "natural regulation." Migratory elk, deer, and buffalo that move in and out of national parks continue to make that concept a fairy tale. Any discussion of natural regulation as a land management policy should begin with the words, "Once upon a time. . . ."

A new cooperative era of management of federal lands is, or at least should be, dawning. It will be increasingly necessary to fully appreciate what is entailed when we talk about "ecosystem management" or such places as the "Greater Yellowstone Ecosystem." That will require the abandonment of fairy tales and a longing for circumstances that no longer exist and, most likely, can never exist again. The most-intact ecosystems that exist, or will exist, in the United States exist where large blocks of federal land, regardless of the agency in charge of the pieces, exist. If ecosystem management has any place and any chance to be successful, it is in those places. That will require increased attention to what might be called "conservation across boundaries."

I know that USFS Chief Dale Bosworth spoke to you earlier. I think that in the circumstances of the moment, he is doing a most excellent job. He, and the rest of the USFS leadership, knows that a new day has emerged requiring new approaches to address the oldest of human problems: how to live well in this world and maintain its ability to support life—our life form included—forever. Such will require accelerated learning and adaptation—adaptive management of the most astute sort. What an incredible challenge.

Chief Bosworth puts it this way—he has a way of making the complex simple and understandable—in exploiting our environment, what we leave is more important than what we take. There is both keen perception and wisdom in that message. When USFS personnel are working in and around YNP in the Greater Yellowstone Ecosystem, or in other areas around national parks, that adage of what we leave being the most important factor in our management is even more important. Clearly, it is doubtful that we will see a new, straight-edged clearcut along a national park boundary in the future. That, at least, is some progress. But more is required. The aesthetic quality of roads, roadsides, and watersheds leading into the parks is being more carefully addressed. Plans for dealing with population numbers of migratory ungulates should be more in touch with reality, with shared responsibility for actions and consequences. New thinking, and increasingly cooperative approaches, to dealing with fire—wildfire and managed fires—across boundaries is well underway. Demands for coordinated management will continue to increase.

There is one immediate issue in the management of national forests to which USFS and NPS personnel, and the constituencies of both agencies, should ensure maximum attention and maximum exposure. Near the end of the Clinton administration, all "roadless areas" of 5,000 or more acres were placed off-limits to the construction of new roads. Many of those areas are adjacent to and complementary to national parks. That rule was negated by the George W. Bush administration. The states have been asked to recommend, on a case-by-case basis, which of those areas should remain in roadless status and which should be considered for road construction. As a pretty good old wildlife biologist—certainly old—I can not think of any benefits to fish and wildlife of road construction; ditto water quality. Will the quality of the national parks adjacent to such roadless areas be enhanced by a change in their land use allocation?

So was Dr. Fairfax right? Is it time to simply amalgamate the three federal land management agencies?

There is a myth in the USFS that maintains that the agency's first chief, Gifford Pinchot, left a sealed letter in the middle drawer of his (and successive chiefs') desk with detailed instructions of the course of action to be taken if there were ever a serious effort to meld the federal land management agencies into the Department of Interior. I have had dozens of inquiries over the years as to whether such a letter actually exists. My first reply is that "If I tell you, I will have to have you killed." Joking aside, so far as I know, no such letter exists—at least, I could never find it.

If that letter exists, it wouldn't mean much today. Too much water has gone under the bridge. Times change, and managers of the federal lands must change with them. Pinchot said that the national forests should be managed for "the greatest good of the greatest number for the longest time." He thought he knew what that meant for the national forests in his time. But he also knew and appreciated that new knowledge and new circumstances would require change in focus and day-to-day operations. There is no going back, and who would really want to? Increased cooperation and coordination between federal land management and regulatory agencies will

be the order of the days to come. And once past the pain of change, such will be challenging, exciting, taxing, and maybe even fun.

I started this rambling talk with that story about the good news and the bad news—that the USFS is the most respected agency in government but the public can't tell the difference between the two agencies. With that in mind, I would suggest that the two agencies are increasingly less different than in the past. But they are also not the same; they are siblings born of Theodore Roosevelt and the Boone and Crockett Club, but not twins.

Matters relative to natural resource management never stay the same for long. Let me use timber as a surrogate for all natural resource products. Timber yields from federal lands are down 80% over a 15-year period. During that same period, the number of large timber holdings has declined to two or three, with the remainder sold into real estate investment trusts. Mills have closed by the hundreds.

But if you go to the lumberyard, wood products are plentiful, and at more-or-less reasonable prices. Where did the wood come from? Where will it come from in the future? What are the ecological consequences?

That wood is coming, and will come for the foreseeable future, from "elsewhere." In most cases, it is a good bet that elsewhere does not have the same environmental laws nor the cutting-edge expertise to do the same level of environmentally sensitive forestry that is, or can be, practiced in the United States. Yet we use more and more wood in toto and per capita than any other nation in the world. Upon consideration, such circumstances legitimately could be classed as morally bankrupt. And along with the importation of such huge amounts of wood, we increase our already soaring balance of trade deficits; such could be labeled as fiscally irresponsible. Then, to top things off, we export the jobs that are associated with growing, tending, harvesting, transporting, manufacturing, and distributing wood products. Such exports are largely from rural areas, where good-paying jobs are in short supply. That could be called socially callous. Decisions relative to how we manage our natural resources have consequences—both locally and worldwide.

Circumstances can change quickly. September 11, 2001, brought us a war on terror. Stock markets plunged and have recovered, but just barely, and are bouncing along sideways. Energy prices have, and likely will continue to, soar. Balance-of-trade deficits are spiraling upward, and budget deficits stretch ahead as far as the eye can see. Adjustments will be required, including how we deal with natural resources. We will, sooner or later, discover, and then come to grips with the fact, that we can't buy everything we want from somebody else with a dollar that is dropping in value as debts and balance-of-payment deficits increase inexorably. We will, sooner or later, have to resume producing more of what we use, while—on the flip side—conserving as much as we can.

The struggle for appropriate management of natural resources is always present; failure results in destitution. Conservation is always of paramount importance. For most of us in this room, it is our calling—a noble and worthwhile calling. I will retire at the end of this year after 50 years as a professional conservationist in various roles: 10 years with the Texas Parks and Wildlife Department, 27 years as a USFS research scientist, 3 years as chief of the USFS, and 10 years as professor at the University of Montana. I cherish the teaching part, because I could pontificate endlessly and, in the end, not have to be responsible for what I said and did. But that is not quite true, because those students who listened and learned are going forth to continue the struggle—I hope a little better prepared for what they learned.

An interviewer asked me a while back if I'd do it all over again—the 50 years as a professional conservationist. I didn't have to ponder. I answered, "In a heartbeat!"

Analysis of 1988 Post-Fire Forest Conditions in Yellowstone National Park from the 2002 Forest Inventory and Analysis of Wyoming

Michael T. Thompson

U.S. Forest Service, Rocky Mountain Research Station, Forest Inventory and Analysis, Ogden Forestry Sciences Lab, 507 25th Street, Ogden, UT 84401 (801-625-5374, mtthompson@fs.fed.us)

Jock Blackard

Same address (801-625-5394, jablackard@fs.fed.us)

Abstract

In the summer of 1988, during the driest period in Yellowstone National Park's history, large-scale fires burned more than one-third of the park's area. The 2002 inventory of Wyoming's forest conducted by the U.S. Forest Service's Forest Inventory and Analysis (FIA) program marked the first comprehensive forest inventory of Yellowstone National Park. Information was collected on each FIA sample that identified sample plots with evidence of burn in 1988. This information allows for summaries and statistical analysis of current forest conditions in Yellowstone that had evidence of fire in 1988. Forest area attributes such as forest type, stand size, stand age, stand density index, and basal area class are presented in this paper. Tree-level attributes such as species, numbers of trees, diameter class distribution, growth, and mortality are also presented. FIA's estimate of the amount of forest area that burned in 1988, based on the 2002 plot burn history, is 803,000 acres. The most dramatic effect is the heavily skewed age class distribution toward the youngest age class. Sixty-four percent of the burned area is currently classified as a lodgepole pine forest type, and another 19% is non-stocked. Spruce-fir types account for 7% of the burned area; the remaining 10% is comprised of aspen, Douglas-fir, Engelmann spruce, whitebark pine, and limber pine types. More than 58% of the burned area is classified as a sapling/seedling stand size class, 18% is sawtimber stands, and 5% is poletimber stands.

Introduction

In the summer of 1988, the driest recorded period in the history of Yellowstone National Park, large-scale fires burned more than one-third of the park's area. The fires created a unique forest ecosystem that has been extensively studied in subsequent years to evaluate how forests and wildlife recover from severe disturbance. Ecological succession, spatial heterogeneity, herbaceous production, and effect on mammal populations are some examples of studies conducted on the areas burned in 1988.

The U.S. Forest Service's Forest Inventory and Analysis (FIA) program recently completed a comprehensive forest inventory for the state of Wyoming that included Yellowstone National Park. The data from this inventory included information about those sample plots that had evidence of burn in 1988. The forest inventory estimates from sample plots that burned in 1988 provide an opportunity to examine forest area attributes, population estimates of live trees, and stand dynamics from a broad-scale perspective about 11 years after the fires occurred.

Methods

FIA's extensive, sample-based inventory includes a systematic grid of permanently established field plots across all lands in the interior West. The FIA program uses a mapped, fixed-plot design as part of its national core sampling protocols (Hahn et al. 1995). Each ground plot contains a cluster of four points spaced 120 feet apart. Each point is surrounded by a 24-foot, fixed-radius subplot where trees 5.0 inches diameter at breast height (d.b.h.) and larger are measured. All four subplots total approximately 1/6 of an acre. Each subplot contains a 6.8-foot, fixed-radius microplot where saplings (1.0–4.9 inches d.b.h.) and seedlings are measured. All four microplots total approximately 1/75 of an acre.

To divide the forest into various domains of interest for analytical purposes, the tree data recorded on these plots is properly associated with the area classifications. To accomplish this, plots are mapped

by condition class. Field crews assign an arbitrary number (usually 1) to the first condition class encountered on a plot. This number is then defined by a series of predetermined discrete variables attached to it: land use, forest type, stand size, regeneration status, tree density, stand origin, ownership group, and disturbance history. Additional conditions are identified if a distinct change occurs in any of the condition-class variables on the plot.

Sometimes a plot straddles two or more distinct condition classes. Boundaries between condition classes can bisect the subplots, or they can be located between the subplots. Microplots are mapped in a similar fashion. Thus, for each ground plot, the microplot and subplot area in each condition class is known, as are the location and condition class of every tree tallied.

Fieldwork began in Wyoming in 1998, and was completed in 2003. Most of Yellowstone National Park was inventoried in 1999. The most recent inventory of Wyoming marks the first wall-to-wall coverage inventory of Yellowstone National Park. Previous forest inventories did not install sample plots on reserved public land. For each inventory plot that sampled forest land, field crews recorded evidence of fire and the year in which it occurred. Figure 1 illustrates those inventory plots that sampled forest land with evidence of burn in 1988, overlaid with ancillary coverage of the 1988 burned area. Figure 2 illustrates those inventory plots that sampled forest land with no evidence of fire in 1988. A total of 132 inventory plots had evidence of burn in 1988, and a total of 131 inventory plots had no evidence of burn in 1988.

Forest area

Forest Inventory and Analysis estimated the total land area (excluding census water) in Yellowstone National Park to be 2.0 million acres. Eighty percent of the total land area was classified as forest land. About 803,000 acres were estimated to have evidence of fire in 1988; 795,000 acres were estimated to have no evidence of fire in 1988.

Forest type is a classification of forest area based on the predominant tree species in a stand. It affects wildlife habitat, timber supply, and other forest eco-

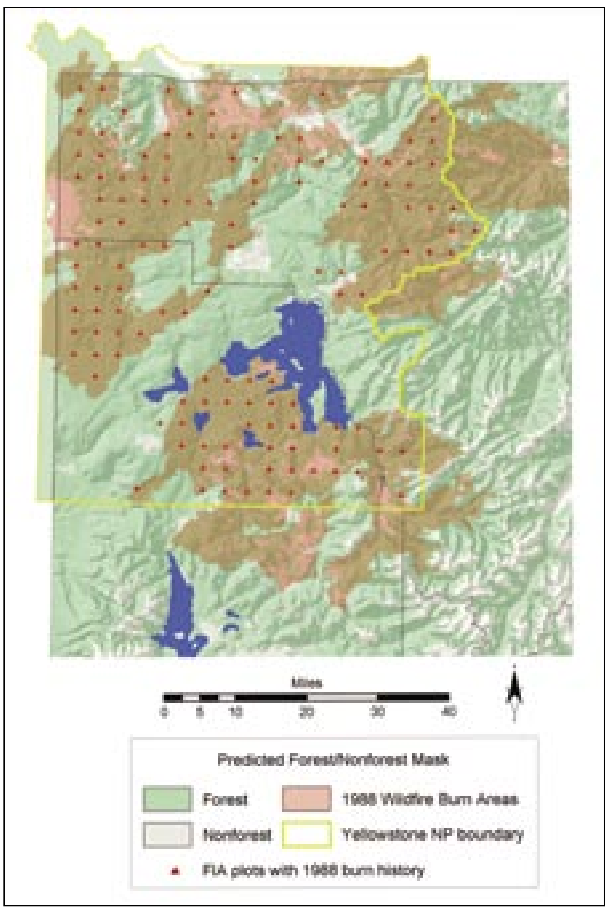


Figure 1. Forest inventory plots that sampled forest land with evidence of fire in 1988, Yellowstone National Park, in Wyoming, 2002.

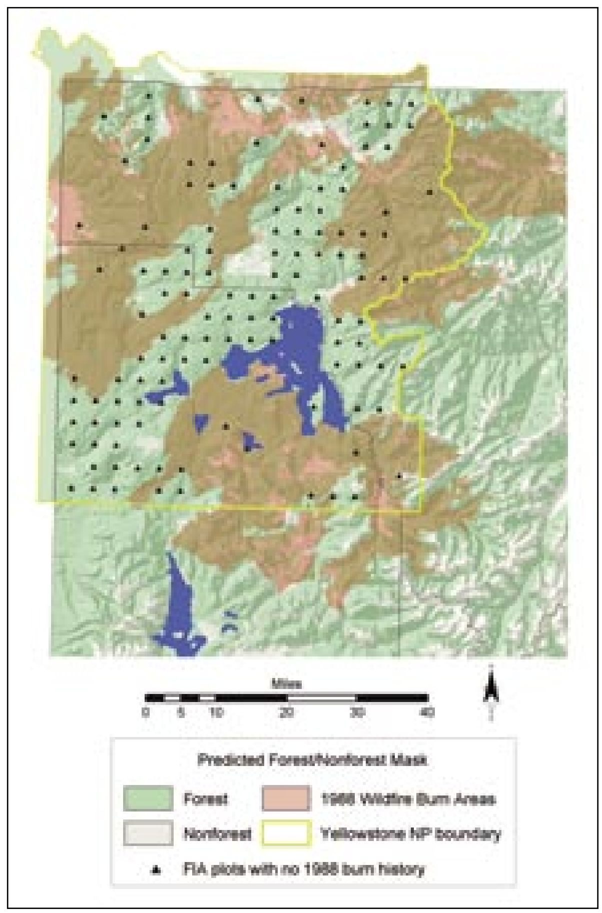


Figure 2. Forest inventory plots that sampled forest land with no evidence of fire in 1988, Yellowstone National Park, Wyoming, 2002.

system goods and services. Lodgepole pine occupies the largest amount of forest area burned in 1988, at 64% (513,000 acres) (Figure 3). Second in abundance is non-stocked timberland at 19% (149,000 acres). Non-stocked timberland refers to land that is less than 10% "stocked" (covered) with live trees but has the potential to support live tree cover at or above 10%. Third, the spruce-fir type accounts for 7% of the burned area, followed by aspen forest types at 3%.

Comparisons of forest inventory estimates on burned and unburned forest land illustrate some striking differences in forest cover type in Yellowstone National Park. Figure 4 compares the area burned in 1988 against the area with no evidence of burn in 1988 by major forest type. Lodgepole pine predominates on the unburned area at 55% (441,000 acres). There is significantly less non-stocked timberland on the unburned area compared to the burned area, where non-stocked timberland accounts for 20,000 acres, or 3%. Spruce-fir, Englemann spruce, and whitebark pine types on the unburned area are more than double that recorded on the burned area. Also noteworthy is the absence of aspen forest types recorded on the unburned area.

The most significant impact of the 1988 fires from a macro-forest land condition perspective is the effect on stand-age class. Stand age is a computed variable using only those ages of trees within a computed stand-size class and weighted by trees per acre. If a computed stand-size class is non-stocked, the age class is defined as non-stocked/unclassified. Figure 5 shows 50-year stand age classes for the burned and unburned areas. Fifty-seven percent of the burned forest area is concentrated in stands less than 50 years of age, and nearly 77% of the burned stands classified as lodgepole pine forest type are less than 50 years of age. Most of these young stands, especially lodgepole pine, are newly regenerated stands that reestablished following the 1988 stand-replacing fires. In contrast, only 13% of the unburned forest area in Yellowstone National Park is in stands of 50 years and younger. The forest area in the unburned area is more normally distributed than the burned area, with the majority (50%) in stands 100–200 years old.

Several studies suggest that all forest types across all stand ages were affected by the 1988 fires (Christensen et al. 1989). Initially the public and some ecologists assumed that the 1988 fires would result in a uniform landscape of exclusively even-aged stands similar to what would be expected following a large,

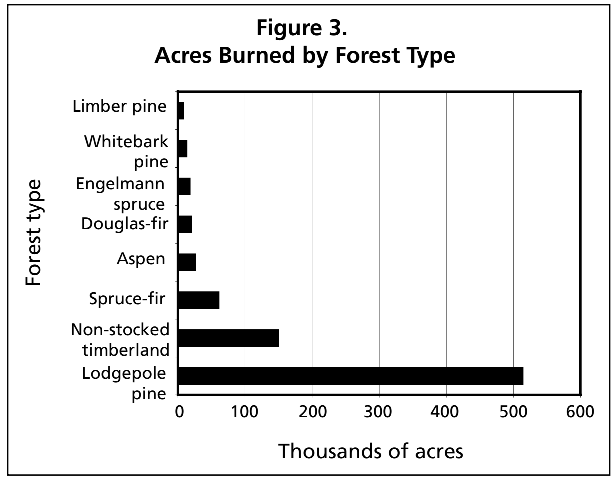


Figure 3. Area of forest land with evidence of burn in 1988 by forest type, Yellowstone National Park, Wyoming, 2002.

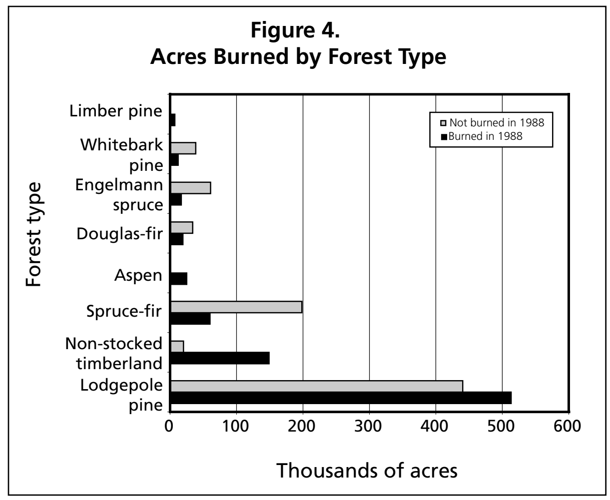


Figure 4. Area of forest land by forest type and 1988 burn status, Yellowstone National Park, Wyoming, 2002.

Figure 5. Area of forest land by stand-age class and 1988 burn status, Yellowstone National Park, Wyoming, 2002.

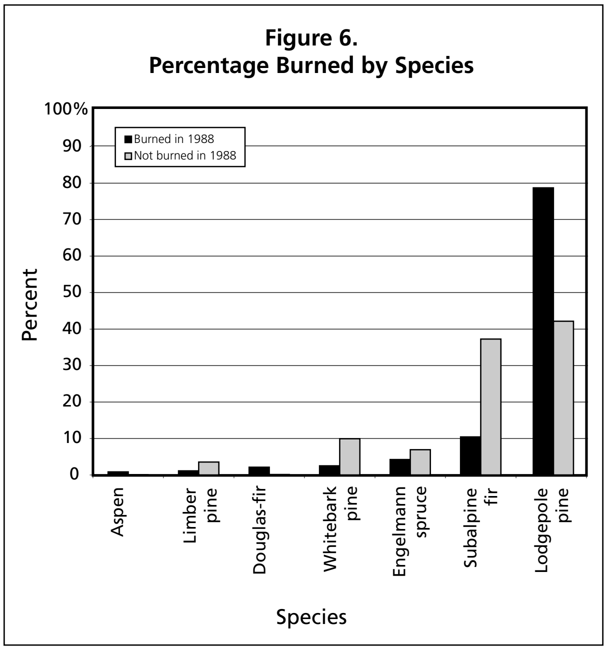


Figure 6. Distribution of all live trees by 1988 burn status, Yellowstone National Park, Wyoming, 2002.

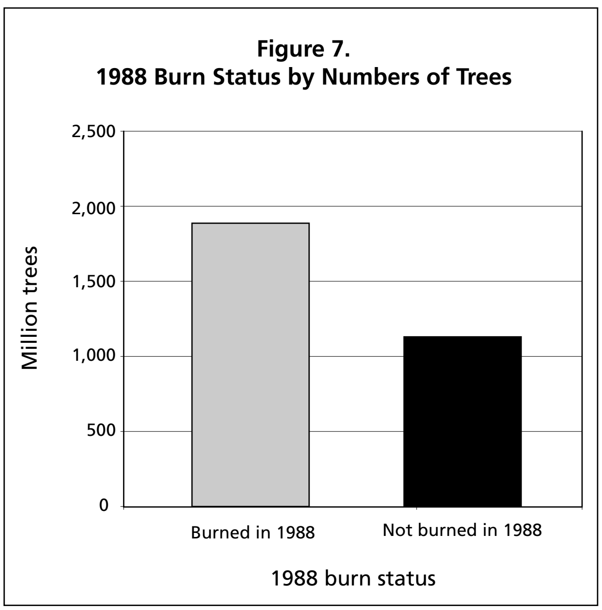


Figure 7. Number of live lodgepole pine seedlings on forest land classified as lodgepole pine forest type by 1988 burn status, Yellowstone National Park, Wyoming, 2002.

human-caused disturbance such as clear cutting followed by natural or artificial regeneration. However, the fires actually created a spatially complex mosaic of unburned and burned patches as the result of a wide range of burn severities (Turner et al. 2003). Within the burned area, the amount and spatial distribution of the forest area classified as non-stocked/unclassified suggest that the fires created patches of marginally stocked forest land. These non-stocked forest conditions are widely distributed spatially in the burned areas and are not concentrated in any one geographic location. The large numbers of these forest areas with low live-tree density are probably the result of patch size, burn severity, and pre-fire cone serotiny. Small patches, low intensity of surface burns, and small percentages of pre-fire stand serotiny (measured by percentage of lodgepole pine trees bearing serotinous cones) are strongly correlated with post-fire lodgepole pine seedling density (Turner et al. 2003).

Numbers of live trees

Forest Inventory and Analysis generates population-level estimates of numbers of live and dead trees. These estimates are used for species diversity measurements, timber supply studies, old-growth analysis, and stand density assessments. On the forest area burned in 1988, the estimate of all live trees, including seedlings, is 2.6 billion trees. Lodgepole pine accounts for 79% of all live trees on the burned area, at 2.0 billion trees. Next in abundance is subalpine fir at 10%, followed by Englemann spruce at 4%, whitebark pine at 2%, Douglas-fir at 2%, and limber pine at 1%. Lodgepole pine also predominates on the unburned area, at 1.4 billion trees or 42% of the live tree total. Subalpine fir is second in abundance at 37%, followed by whitebark pine at 10%, Engelmann spruce at 7%, and limber pine at 4%. Figure 6 illustrates the distribution of all live trees on the burned and unburned forest areas.

Lodgepole pine regenerated well in most forest areas following the 1988 fires. Figure 7 compares the estimate of live lodgepole pine seedlings on forest areas classified as lodgepole pine between the burned and unburned areas. Figure 8 compares the estimate of live lodgepole pine trees on lodgepole pine stands between the burned and unburned areas. These illustrations indicate the significant differences in number of lodgepole pine stems by diameter class and also underscore the slow-growing nature of lodgepole pines in the subalpine plateau. Most lodgepole pine stands that burned in 1988 still remain in the seedling/sapling stage despite 11 years between the date of the fires and date of inventory.

The 1988 post-fire dynamics of aspen were surprising to many ecologists who discovered seedling regeneration in areas where aspen did not previously exist. From a broad-scale perspective, aspen is a minor component in Yellowstone National Park, accounting for less than 1% of the live tree population. However, there is a striking difference in the

estimate of live aspen stems between the burned and unburned areas. The number of live aspen trees on the burned areas totals 22 million trees, all of which are in the seedling and sapling size class. This figure is more than 22 times the number of live aspen trees in the non-burned areas, where the estimate of live aspen trees is 965,000 trees (Figure 9). Turner et al. (2003) also found that aspen regenerated successfully throughout the burned forests and well beyond the pre-fire range of aspen.

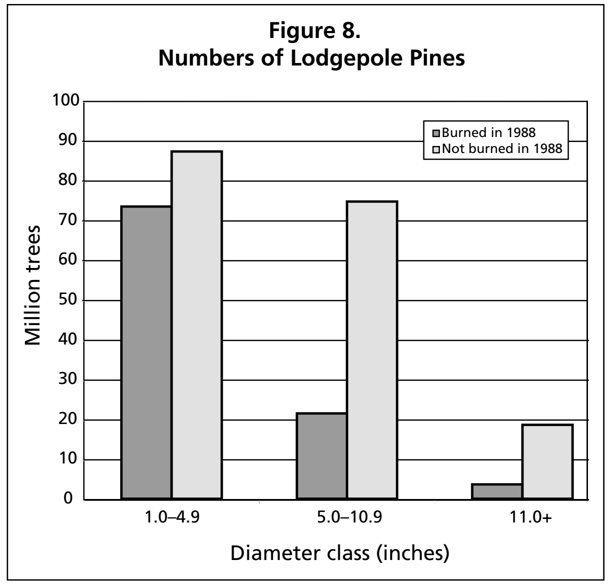


Figure 8. Number of live lodgepole pine trees 1.0 inches in diameter at breast height and larger on forest land classified as lodgepole pine forest type by 1988 burn status, Yellowstone National Park, Wyoming, 2002.

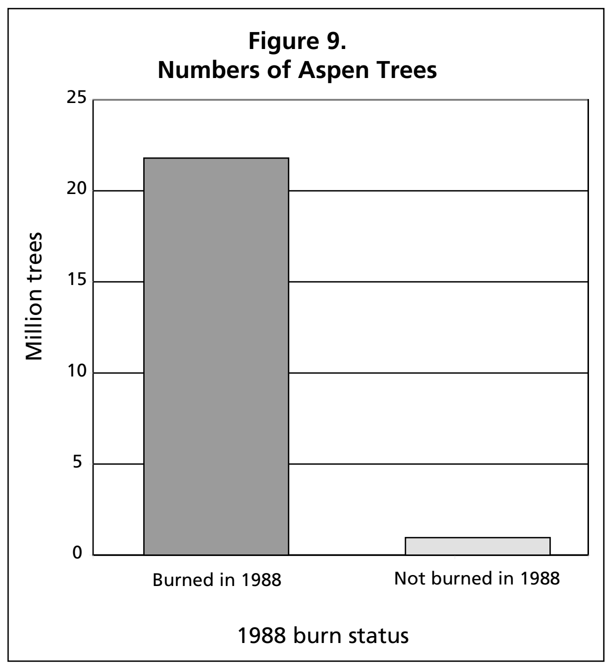


Figure 9. Number of live aspen trees on forest land by 1988 burn status, Yellowstone National Park, Wyoming, 2002.

Summary

The 1988 Yellowstone fires produced spatially complex patterns of succession in what a casual observer might consider a homogeneous landscape dominated by lodgepole pine. The large proportion of non-stocked forest conditions on the burned area are areas with low stand density where gradual recruitment may or may not continue. The heavily skewed stand age distribution on the burned areas is a classic macro-scale example of stand structure following a major stand-replacing disturbance. Aspen appears not only to have established itself successfully following the fires, but also to be appearing in areas where it previously did not exist.

Estimates from FIA inventories are broad-scale in nature. These estimates of forest area and numbers of trees in Yellowstone National Park are coarse compared to many of the site-specific studies conducted after the 1988 fires. However, FIA can be used to verify many of these studies conducted at a much finer scale. The difference between population estimates of live aspen stems on the burned and unburned areas is an example of how FIA inventories may be used to verify the findings of other studies.

The FIA program of the U.S. Forest Service is rapidly implementing an annual inventory system that features a nationally consistent plot configuration; a nationally consistent sample design; integration with the ground sampling component of the Forest Health Monitoring program; a complete, statewide, systematic, annual sample of each state; and new reporting requirements. These new systems will be implemented in future inventories of Wyoming, and will greatly enhance the timeliness, quality, and usefulness of estimates on unique ecosystems such as Yellowstone National Park.

References

Christensen, N. L., J. K. Agee, P. F. Brussard, J. Hughes, D. K. Knight, J. M. Minshall, J. M. Peek, S. J. Pyne, F. J. Swanson, S. Wells, J. W. Thomas, S. E. Williams, and H. A. Wright. 1989. Interpreting the Yellowstone fires of 1988. *BioScience* (39):678–685.

Hahn, J. T., C. D. MacLean, S. L. Arner, and W. A. Bechtold. 1995. Procedures to handle inventory cluster plots that straddle two or more conditions. *Forest Science Monograph* (31):12–25.

Turner, M. G., W. H. Romme, and D. B. Tinker. 2003. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment* 1(7):351–358.

Wildlife at a Crossroads: Energy Development in Western Wyoming

Janice L. Thomson

The Wilderenss Society, 1424 4th Ave., Suite 816, Seattle, WA 98101 (206-624-6430, jthomson@twsnw.org)

Tim S. Schaub

HyPerspectives, 2048 Analysis Drive, C, Bozeman, MT 59718 (406-556-9880, schaub@hyperspectives.net)

Nada Wolff Culver

The Wilderness Society, 1660 Wynkoop Street, Suite 850, Denver, CO 80202 (303-650-5818, nada_culver@tws.org)

Peter C. Aengst

The Wilderness Society, 503 W. Mendenhall, Bozeman, MT 59715 (406-586-1600, peter_aengst@tws.org)

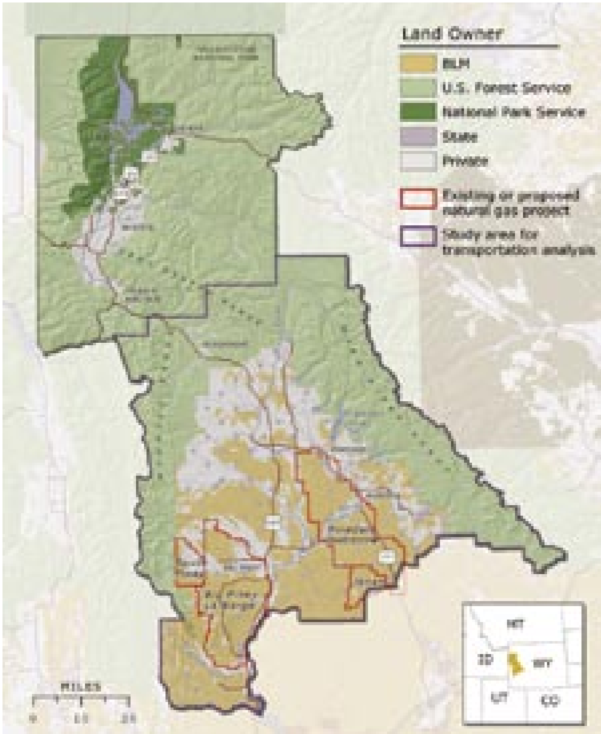
Abstract

The Upper Green River Basin of Wyoming supports the largest block of publicly owned winter range in the Greater Yellowstone Ecosystem (GYE) and some of the fastest-growing natural gas developments in the West. The Bureau of Land Management has the opportunity, in an ongoing management plan revision, to maintain the ecological integrity of winter range, a critical link for wildlife that migrate across national forest, national park, state, and private lands in the GYE. A landscape analysis of the transportation network was conducted to assess the spatial impacts of energy development on pronghorn, mule deer, elk, and greater sage grouse habitat. Landscape fragmentation metrics were measured for the entire landscape, for gas fields, and within species habitat boundaries. A comparison of the results with biological field literature describing road and energy impacts on wildlife suggests that impacts are significant. For example, 80% of pronghorn crucial winter range has route densities higher than a 1-mi/mi^2 threshold, which has been shown to cause adverse effects on pronghorn. In addition, all sage grouse leks are within three miles of a route—a distance from surface disturbance that is recommended for seasonal closures to preserve breeding functions. Specific transportation and energy development management recommendations were crafted based on the findings. A few examples include (1) closure and reclamation of routes to increase core area to more than 1,542 feet from a route in mule deer crucial winter range, (2) reduction of transportation route densities to less than 1 mi/mi^2 within elk crucial winter range, and (3) ensuring directional drilling and cluster development to minimize habitat fragmentation.

Introduction

The Upper Green River Valley, in western Wyoming, contains a prime example of the vital and threatened sagebrush ecosystem of the western United States (Knick et al. 2003; WYG&F 2004). Sagebrush steppe and grassland habitats in the lower elevations of the valley are surrounded by the forested slopes of the Wyoming Range to the west, the Wind River Range to the east, and the Gros Ventre Range to the north. Much of the valley falls within the Bureau of Land Management (BLM)'s 4.8-million-acre Pinedale Resource Management Area (RMA) (Figure 1).

The Upper Green River Valley contains crucial habitat for big game species including pronghorn (*Antelocarpa americana*) (Figure 2), mule deer (*Odocoileous hemionus*) (Figure 3), elk (*Cervus elaphus*) (Figure 4), bighorn sheep (*Ovis canadensis*), and moose (*Alces alces*). Wyoming has by far the greatest concentration of pronghorn of any North American state or province, and the Green River Valley holds the highest concentration of this animal in Wyoming (BLM 2000). More than 100,000 big game animals winter in the Upper Green River Valley (Berger 2004a), the largest block of publicly owned winter range for big game in the 19-million-



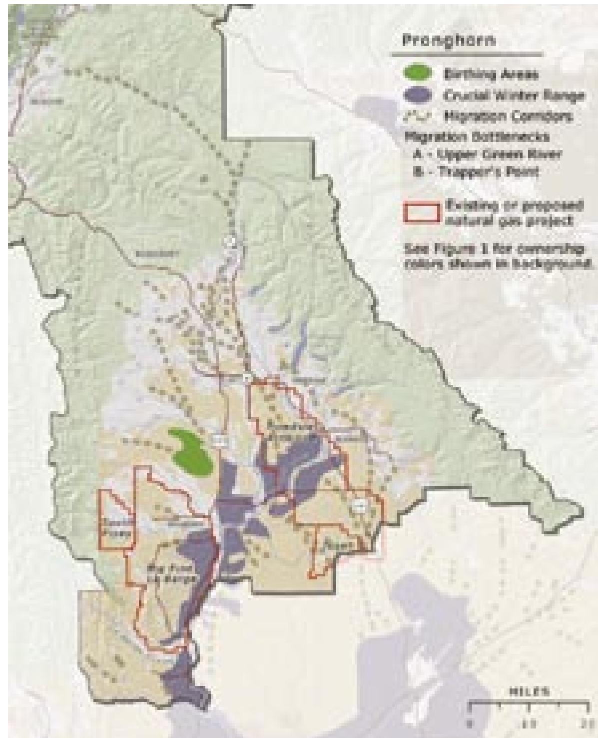


Figure 1 (left). Surface ownership within the Pinedale Resource Management Area.

Figure 2 (right). Pronghorn in the Pinedale Resource Management Area: migration routes, crucial winter range, and birthing areas. More than 170,000 acres of the Pinedale RMA have been designated as pronghorn crucial winter range by the Wyoming Game and Fish Department. More than 125,000 acres of that winter range fall on BLM lands. Another 23,000 acres of the RMA are designated as birthing areas, of which 22,000 acres fall on BLM lands.

acre Greater Yellowstone Ecosystem. The valley also contains birthing areas used by pronghorn and mule deer.

The Upper Green River Valley contains important big game migration routes. Round-trip migration distances documented in the valley range from 62 miles for moose and 137 miles for elk to 186 miles for mule deer and 311 miles for pronghorn (Berger 2004b). The annual journey of herds of mule deer and pronghorn from Grand Teton National Park and nearby national forest lands to snow-free areas of the Upper Green River Valley containing crucial winter forage represents North America's longest big game migration outside the Arctic (Sawyer and Lindzey 2000; Berger 2004a). Archeological evidence indicates that the pronghorn migration has continued uninterrupted for more than 6,000 years (Sawyer and Lindzey 2000). Berger (2004a) has proposed formally designating a national migration corridor to acknowledge and protect this unique phenomenon.

The Pinedale RMA also contains one of the largest populations of greater sage grouse (*Centrocercus urophasianus*) in the western United States (Braun 1998). This species has recently declined throughout western North America, and in Wyoming, in particular (Braun 1998; Connelly and Braun 1997). The BLM has demonstrated its concern for the species by establishing a National Sage Grouse Habitat Conservation Strategy, a comprehensive approach to the management of sage grouse habitat on public lands.

Because sagebrush is slow to regenerate following disturbance, conservation of sagebrush habitat is critical for the success of sage grouse (Knick et al. 2003). Sage grouse are a meaningful indicator of the ecological health of sagebrush steppe habitat because they depend on sagebrush throughout their life processes. During the winter months, for example, sage grouse are totally dependent on sagebrush for food and cover (Lyon 2000). The Pinedale RMA provides important winter habitat for sage grouse, with wind-scoured slopes and ridgetops that ensure year-round sagebrush exposure. The Pinedale RMA also contains important complexes of sage grouse breeding habitat, the availability of which limits populations of sage grouse in many areas (WYG&F 2004). Sage grouse habitat and lek courtship and mating locations in the Pinedale RMA are shown in Figure 5.

In addition to its importance for wildlife species,

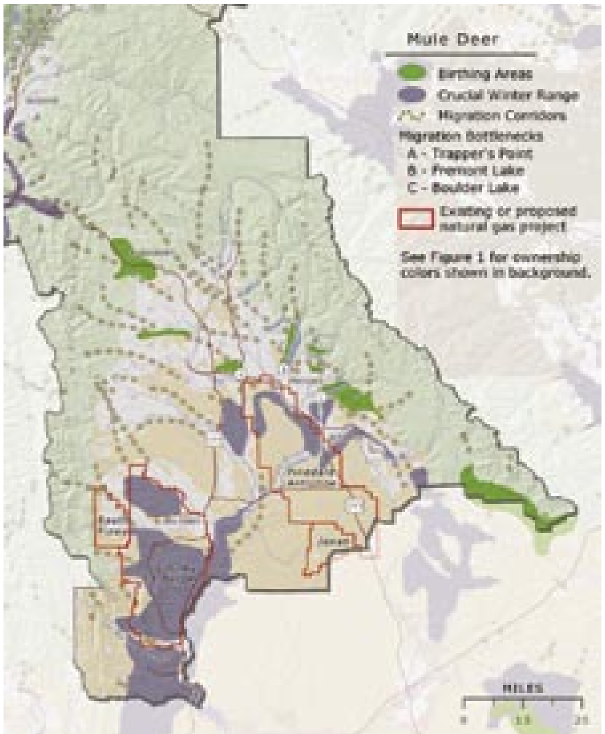


Figure 3 (left). Mule deer in the Pinedale Resource Management Area: migration routes, crucial winter range, and birthing areas. Nearly 350,000 acres of the Pinedale RMA have been designated as mule deer crucial winter range by the Wyoming Game and Fish Department. More than 200,000 acres of crucial winter range fall on BLM lands. More than 80,000 acres in the RMA serve as birthing areas, with 14,000 of those acres on BLM lands.

Figure 4 (right). Elk in the Pinedale Resource Management Area: migration routes, crucial winter range, and birthing areas. More than 198,000 acres of the Pinedale RMA have been designated as elk crucial winter range by the Wyoming Game and Fish Department. More than 105,000 acres of that winter range fall on BLM lands. Another 354,000 acres of the RMA are designated as birthing areas, of which 62,000 acres fall on BLM lands.

the sagebrush ecosystem in Wyoming also supports the region's cultural heritage; scientific research; hiking, hunting, and other recreational pursuits; and the local economy. Notably, wildlife-associated spending is Wyoming's second-largest source of income, bringing in $500 million annually (WYG&F 2004).

However, the same Upper Green River Valley lands that provide this outstanding wildlife habitat and important cultural values also contain some of the largest and most productive onshore natural gas fields in the nation. With escalating pressures to develop domestic energy supplies, oil and gas production in southwestern Wyoming has grown rapidly. More than 8,500 well sites have already been drilled on public lands in the region, and another 10,000–15,000 are forecast over the next decade (Berger 2004a). In fact, energy production in the Pinedale RMA is further accelerating due to Executive Order 13212, which requires federal agencies to expedite permitting and other reviews for approval of energy development projects (Berger 2003).

Substantial infrastructure and human activity are associated with energy development in the Pinedale RMA. For example, the environmental impact statement (EIS) for the Pinedale Anticline Natural Gas Project (BLM 2000) projects that up to 276 miles of roads will be built or upgraded during development of the Pinedale Anticline Field. The EIS estimates traffic at 702 round-trips per well over the 80-day drilling and construction phase, followed by 100 trips per year during the production life of the well, or 168 trips per day for the entire field of 500 wells. Similarly, the Jonah II Natural Gas Project EIS projects up to 180 miles of new or upgraded access roads, with 421 round-trips per well during construction and another 739 trips over each well's production life (or a total of 521,900 trips for the 450-well field over its 20-year life) (BLM 1998). The road mileage for the Jonah Field is expected to increase substantially under a new development plan in preparation at the time this report went to press.

Surface ownership of the lands in the Pinedale RMA is held by a variety of entities. The higher-elevation lands are primarily managed by the U.S. Forest

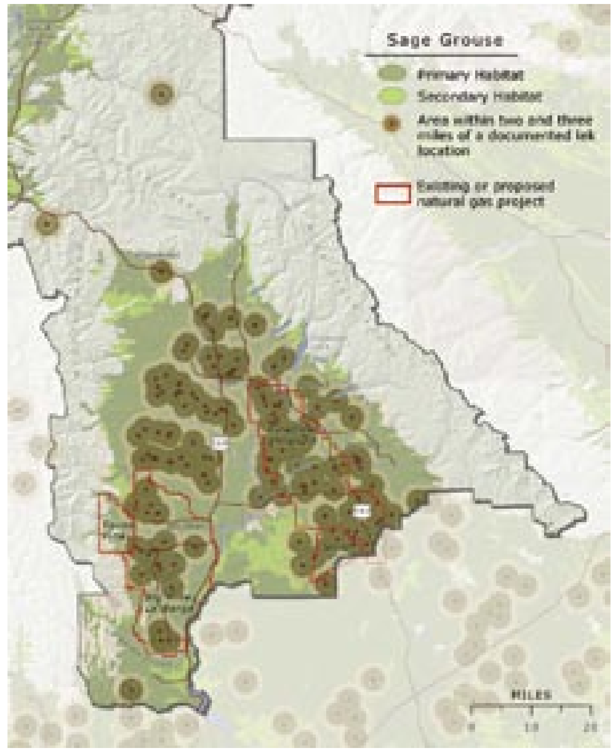


Figure 5. Sage grouse in the Pinedale Resource Management Area: habitat and leks. The Pinedale RMA includes more than 1.5 million acres of primary sage grouse habitat and about 200,000 acres of secondary habitat. Forty-nine of the 151 documented lek locations in the area fall within the Pinedale Anticline and Jonah gas field boundaries. In addition, more than 470,000 acres of BLM land in the area are within two miles of a lek, and 595,000 acres of BLM land are within three miles of a lek.

Service (USFS), while the lower-elevation areas are a patchwork of BLM and private ownership, with limited state holdings. However, across surface ownerships, the BLM controls substantial portions of the subsurface mineral rights and the development of oil and gas resources in the Pinedale RMA.

The BLM has a responsibility to manage the landscape for wildlife, energy development, and many other purposes. The agency is in the process of revising its Resource Management Plan (RMP) for the Pinedale RMA, which will set the terms for management over the next 15 to 20 years. The planning process will require the BLM to assess various alternatives for management and use of the public lands within the Pinedale RMA, and is guided by the BLM's obligations under the Federal Land Policy and Management Act (FLPMA) and the National Environmental Policy Act (NEPA).

FLPMA requires the BLM to "manage the public lands under principles of multiple use and sustained yield" in a manner that will "minimize adverse impacts on the natural, environmental, scientific, cultural, and other resources and values (including fish and wildlife habitat) of the public lands involved" (43 USC §1732). In developing management plans, the BLM must take into account physical, biological, economic, and other sciences; give priority to the designation and protection of Areas of Critical Environmental Concern (ACEC); and give consideration "to the relative values of the resources and not necessarily to the combination of uses that will give the greatest economic return" (43 USC §1712; 43 CFR §1601.0-5(f)). NEPA dictates that the BLM take a "hard look" at the environmental consequences of a proposed action, and the requisite environmental analysis "must be appropriate to the action in question" (42 USC §4321 et seq; *Metcalf v. Daley,* 214 F.3d 1135, 1151 (9th Cir. 2000); *Robertson v. Methow Valley Citizens Council,* 490 U.S. 332, 348 (1989)). The impacts and effects that the BLM is required to assess include "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative" (40 CFR §1508.8).

Oil and gas development in the Upper Green River Valley could threaten wildlife populations by fragmenting and causing disturbance in the crucial winter habitat, birthing areas, and migration corridors of big game species, and in the winter habitat, lekking areas, nesting sites, and rearing areas for sage grouse. For example, compromising winter habitat for big game in the valley could affect ungulate populations in five surrounding western Wyoming mountain ranges (Sawyer et al. 2004). Migration corridors are also vulnerable, particularly at "pinch points" where physiographic constrictions force herds through relatively narrow corridors (Berger 2004a). Loss of habitat continuity due to human activity along migration routes would severely restrict the seasonal movements necessary to maintain healthy big game populations (Sawyer and Lindzey 2000; 2001). In addition, unguided energy development would further depress declining sage grouse populations throughout the West. Prudent management that limits habitat fragmentation and disturbances from human activity along roads could give the species an opportunity to maintain, if not increase, its numbers. However, the direct and indirect impacts of energy development on wildlife are poorly understood (Sawyer and Lindzey 2004). Continued research and monitoring by wildlife management agencies, the BLM, and biologists at other institutions will be critical to designing a sustainable

wildlife management strategy for the Pinedale RMA.

This report documents the intensity, extent, and spatial arrangement of wildlife impacts of the transportation network associated with oil and gas development in the Pinedale RMA. While the direct impacts from oil and gas drilling may be limited to the physical footprint of roads and well pads, the complex web of these structures across the landscape causes much broader, indirect effects on habitat quality and connectivity. Thus, a full understanding of the impact of oil and gas development on the region's wildlife requires an assessment of the spatial distribution of roads and other transportation routes (in both the areas subject to BLM management and the areas outside the agency's jurisdiction), combined with the latest wildlife research on the effects of roads and other infrastructure on specific wildlife species.

The methods and results of this report represent one of the major topics of information needed to design future management strategies in the Pinedale RMA. This report details a recommended process for assessing the ecological impact of roads on big game and sage grouse, shows the feasibility of performing such an analysis as part of the Pinedale RMP revision, and demonstrates the importance of using the results in evaluating management alternatives.

The Pinedale RMA was selected for this spatial evaluation of the impacts of energy development on wildlife because of its abundant and actively studied wildlife populations, its highly developed oil and gas fields, and the ongoing public planning process that will set the terms for energy development over the next 15–20 years. The analysis used to create this report, and the results generated, can be used by the BLM in revising the Pinedale RMP, in designating or limiting areas for further development, and in determining those areas where transportation routes should be closed or subject to limited use. The methods also serve as an example for other energy development sites.

Methods

Study area

This study focuses on the impact of roads and other transportation routes on wildlife in the lower-elevation areas of the Pinedale RMA that encompass most BLM surface ownership. The study area is roughly the southern half of the Pinedale RMA, which includes what residents and land managers consider the Upper Green River Valley. The study area accounts for about 2.9 million acres of BLM, USFS, state, and private lands within the 4.8-million-acre Pinedale RMA. It encompasses the portion of the Pinedale RMA within Lincoln, Sublette, and Fremont counties. The full Pinedale RMA, the study area boundaries, and surface ownership patterns within the Pinedale RMA are shown in Figure 1. The acreage of surface lands by ownership type within the study area is shown in Table 1.

The BLM has subsurface management authority, and thus authority over energy development, over 1.2 million acres of the study area. This includes the 992,370 acres that the agency manages at the surface, as well as additional "split estate" lands managed by state or private entities at the surface and by the BLM for subsurface energy development. Gas fields evaluated in this study include Jonah, Pinedale Anticline, and South Piney. These three gas fields are the current focus of industry development. They are either recently permitted or, in the case of South Piney, soon to be permitted.

Table 1. Acreage and percentage of the landscape within the four major land ownership categories in the study area.

	U.S. Forest Service	BLM	Private	State
Area in acres	1,252,815	922,370	609,134	86,501
Percent of study area	44%	32%	21%	3%

Data collection

Data representing the transportation network in the Pinedale RMA were obtained from the BLM Pinedale Field Office. This dataset is an updated version of the Topologically Integrated Geographic Encoding and Referencing (TIGER) data for transportation routes from the U.S. Census Bureau road dataset and includes additional routes digitized by Geographic Information System (GIS) staff at the BLM. Significant edits were made to the BLM dataset to remove duplicate records. The BLM is in the process of updating the dataset. Because this dataset

includes roads and some, but not all, additional transportation routes that may not legally be considered "roads," we will use the more inclusive term "routes" or "transportation routes" when discussing this dataset (see sidebar, "Defining a Road.") Though the agency has digitized some user-created two-tracks and other routes, this dataset has not been completed, and thus our analysis represents a conservative assessment of the actual transportation network. Additional administrative data were collected from the Pinedale BLM Field Office, including the field office boundary, surface ownership boundaries, and gas field development area boundaries.

All data for big game species originated from the Wyoming Game & Fish Department (WYG&F). Winter range boundaries were used directly as supplied by WYG&F. Big game birthing areas and migration routes were updated with guidance from a local wildlife biologist with experience in the Pinedale area. The locations of occupied sage grouse leks were collected by WYG&F, and predicted distribution of sage grouse habitat originated from the Wyoming Gap Analysis Project, an interagency mapping effort. While these data layers were the best available at the time this work was conducted, WYG&F will continue to refine many of the habitat boundaries. The statistics documenting the impacts of transportation routes and habitat fragmentation on specific wildlife species that were used to guide our spatial analysis were collected from the scientific literature and will be cited throughout this document.

Defining a "road"

In this report, the terms "routes" and "transportation routes" refer to all linear features used by motorized vehicles, including "roads." However, the term "road" holds a precise legal definition with important management implications. Many but not all routes in the BLM's transportation dataset used in this analysis meet the definition of a road.

Within the Pinedale RMA, roads must meet criteria established in Title 43, Part 19.2(e) of the Code of Federal Regulations: "an improved road that is suitable for public travel by means of four-wheeled, motorized vehicles intended primarily for highway use." In addition, the legal definition of a road, according to the U.S. Department of the Interior, is derived from the definition of "roadless" in the legislative history of FLPMA: "roads which have been improved and maintained by mechanical means to insure relatively regular and continuous use. A way maintained solely by the passage of vehicles does not constitute a road" (H.R. Rep. No. 94-1163 at 17 (1976)).

Habitat fragmentation metrics

Fragmentation of habitat affects the ecological composition, structure, and functions of a landscape. Habitat fragmentation has been defined as the "creation of a complex mosaic of spatial and successional habitats from formerly contiguous habitat" (Lehmkuhl and Ruggiero 1991). Although fragmentation can be difficult to measure, we have chosen three landscape metrics to show the degree of fragmentation and the condition of the landscape, and applied them to available data regarding the distribution of wildlife and habitat. The metrics below were calculated for the entire landscape, as well as for areas within specific surface ownership types, gas fields, and critical wildlife habitat areas. Wildlife habitat boundaries were also used to calculate some basic habitat acreage figures and, for sage grouse, acreages within two and three miles of leks.

Route density. Route density is a measure of the number of miles of transportation routes per unit area, and is a common metric in quantitative assessments of ecological impacts of development from a landscape perspective. The density calculation involves measuring the length of linear transportation features in a given sub-area at regular intervals. For this analysis, the BLM transportation dataset was used to construct a "continuous" measure of route density across the Pinedale RMA. A sample spacing of 1,500 feet was used to measure route length within a 4-mi^2 circular sub-area. The result is a grid of density measurements where the value in each 1,500 × 1,500-foot cell is the total length of all routes in the nearest 4 mi^2, divided by 4 mi^2. Route density distribution curves were plotted to document the percent of the landscape with route densities greater than or equal to any given route density value. Density measurements are reported as miles of routes per square mile (mi/mi^2).

Core area. In order to characterize the degree of habitat fragmentation, the distribution of unroaded areas, or core areas, was measured for the entire Pinedale RMA. Core areas are defined as

land beyond a given distance, or effect zone (Forman 1999), from transportation routes. Different wildlife species respond to disturbances related to a transportation network at varying distances. Thus, the size distribution of core areas was determined for effect zones of 100 ft, 500 ft, ¼ mile, ½ mile, and 1 mile from all routes in our dataset. A map of core areas was then plotted for one of these effect zones, 500 ft.

Distance to route. Wildlife-related restrictions on road or infrastructure construction and use are commonly given in terms of the distance by which the feature or activity must be separated from a given wildlife habitat of interest. Measuring the amount of land within a given distance to a transportation route (or route effect zone) is the reverse of measuring core areas. These two habitat fragmentation metrics complement one another and will be discussed together in later sections. To illustrate the amount of land that lies within various distances from transportation routes in the Pinedale RMA, we generated cumulative distance-to-route distribution curves for specific surface ownership types, gas fields, and wildlife habitat areas.

Other considerations. Note that all measures of habitat fragmentation in this report are conservative, because they do not take into account all of the undocumented routes visible in digital air photos of the landscape (Weller et al. 2002), other human infrastructure (e.g., well pads, pumping stations, pipelines, power lines) or natural breaks in the landscape (e.g., steep topography, rivers or washes, breaks in vegetation types). Actual infrastructure densities are likely higher, and core area sizes and distances to routes lower, than those captured in this analysis.

In addition, the varying speeds and volumes of traffic on different roads were not taken into account, because these attributes were not available for the BLM route dataset. These factors do affect wildlife, and are reflected in recommendations in this report. Similarly, seasonal access restrictions were not addressed in the analysis, because this information was not in the GIS data and because of imperfect enforcement of and exemptions granted to restrictions. For example, WYG&F has noted, "Seasonal stipulations are only effective if actually applied on the ground. To date, these stipulations have been inconsistently applied among BLM resource areas. Exceptions are routinely granted by some BLM resource areas, at times under what our Department believes are inappropriate circumstances" (WYG&F 2004). Specific access restrictions are suggested in the recommendations section.

Results

Route density analysis

Route densities vary considerably within the Pinedale RMA (Figure 6). A few key statistics characterize the differences in route densities across various land ownership types. The distribution of route densities is similar for state, private, and BLM lands, but route densities are markedly lower on USFS lands (Figure 7). Eighty percent of BLM lands have route densities of more than 1 mi/mi^2, and 36% of BLM lands have route densities of more than 2 mi/mi^2. By contrast, only 17% of USFS lands have route densities of more than 1 mi/mi^2.

Route densities within the crucial winter ranges of different ungulate species vary (Figure 8). For example, 66% of elk crucial winter range has route densities of more than 1 mi/mi^2. In addition, 80% of pronghorn and 89% of mule deer crucial winter range has route densities of more than 1 mi/mi^2.

The size and permit year of the Jonah, Pinedale Anticline, and proposed South Piney natural

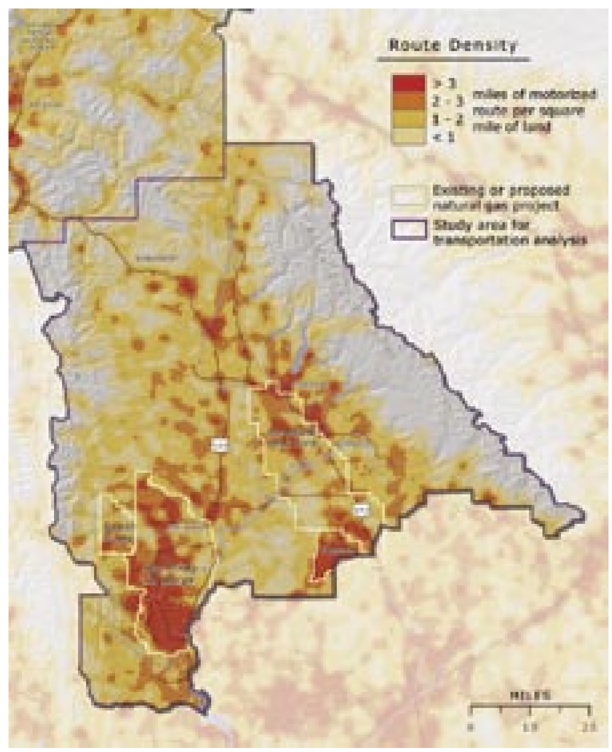


Figure 6. Transportation route densities in the Pinedale Resource Management Area. Eighty percent of BLM lands in the Pinedale RMA have route densities of more than 1 mi/mi^2. More than 35% of BLM lands have densities of more than 2 mi/mi^2. Fifty percent of the mule deer and pronghorn crucial winter range on BLM lands have route densities of more than 2 mi/mi^2. Fifty-four percent of the sage grouse leks on BLM land fall within areas with route densities of more than 2 mi/mi^2.

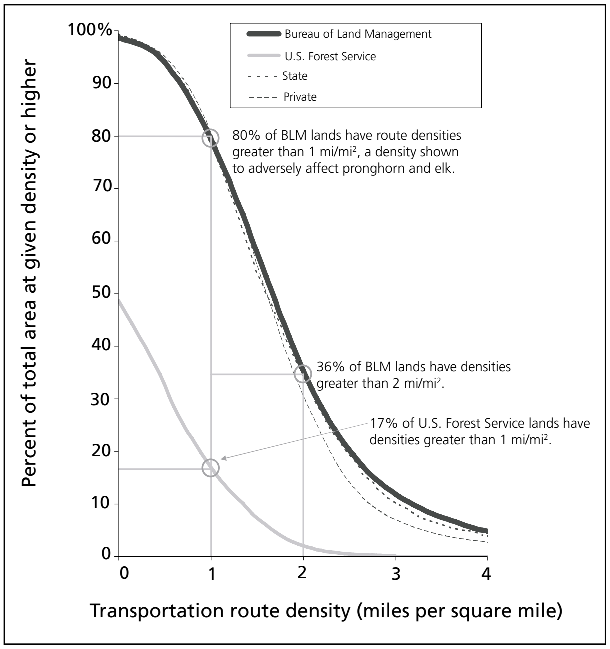


Figure 7. Transportation route density by land ownership type.

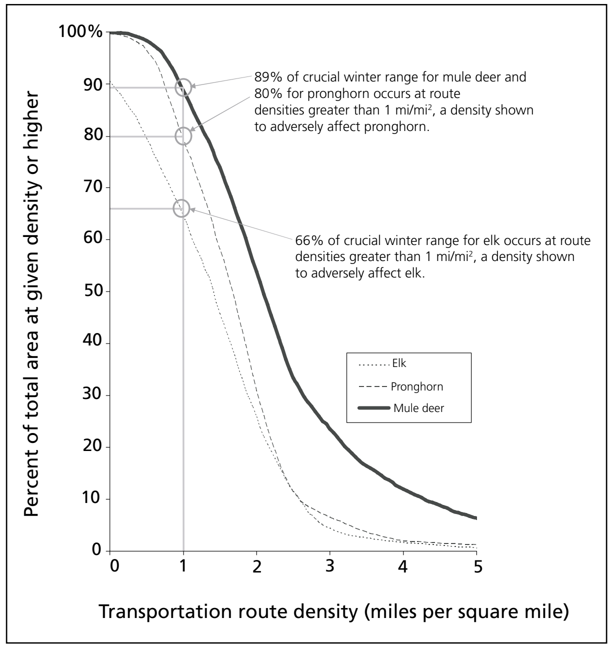


Figure 8. Transportation route densities for pronghorn, mule deer, and elk crucial winter ranges.

gas fields are summarized in Table 2. Route densities vary among the three fields. The Jonah Field, a fully developed gas field that is being considered for further "infill" drilling, has the highest route densities. Already, 95% of its area has route densities of more than 2 mi/mi². Route densities are lower in the Pinedale Anticline and proposed South Piney gas fields (Figure 9). The Pinedale Anticline is a recently permitted gas field (BLM 2000) where fewer than half the wells permitted have been drilled and half

Table 2. The development permit year and gas field size for the three gas fields where development is focused in the study area.

Gas field	Year permitted	Field size (acres)
Jonah	1998	47,000
Pinedale Anticline	2000	200,000
South Piney	pending	30,000

the new miles of road permitted have been bladed to date. The South Piney project is a proposed new gas field that to date has experienced only limited exploratory drilling. An EIS is currently being prepared to evaluate and potentially permit full field development. In both the Pinedale Anticline and South Piney fields, about 45% of the development area has route densities of more than 2 mi/mi².

Core area analysis and distance to route

The size of core areas—that is, wildlife habitat away from the disturbance of routes—varies substantially across the Pinedale RMA. State, private, and BLM lands are generally much closer to routes and have smaller core areas than USFS lands (Figures 10 and 11). About 63% of BLM land within the study area is less than ¼ mile from a route. Less than 20% of USFS land lies within this same proximity to

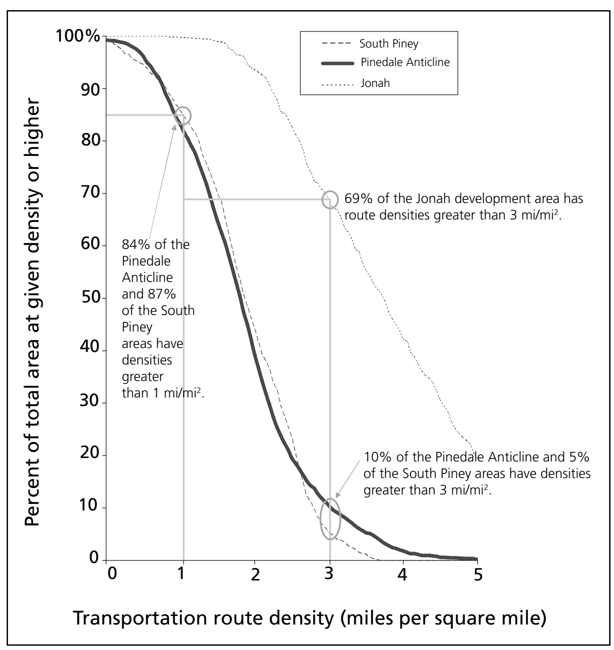


Figure 9. Transportation route densities in three gas fields.

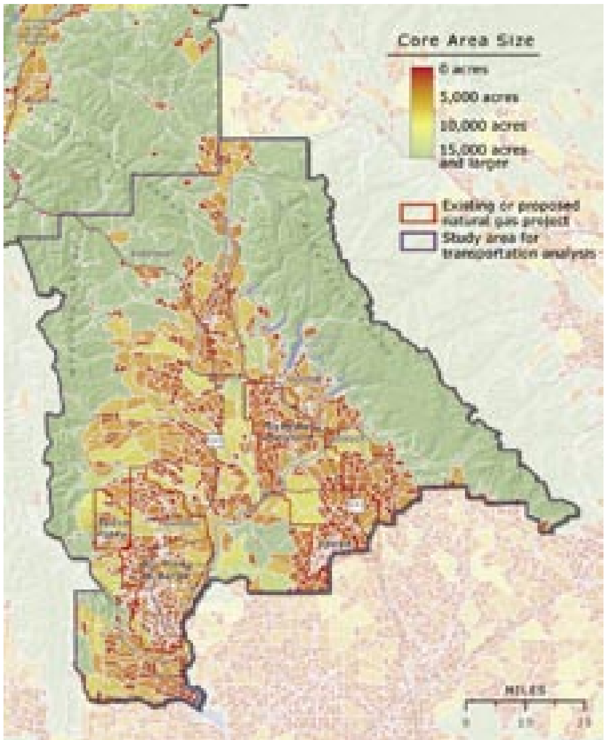


Figure 10. Core habitat areas outside the 500-foot transportation route effect zone. Considering an effect zone of 500 feet on either side of a route, the study area is fragmented into more than 2,021 "unroaded" core areas on BLM lands. These core areas have an average size of just over 300 acres.

a route. Notably, 87% of BLM land is within ½ mile of a route.

Statistics relating to core areas as defined by various route effect zone widths on BLM lands within the study area are shown in Table 3. For example, for effects on wildlife that extend 100 feet from a route, 90% of the landscape falls within the 2,596 core areas with a maximum patch size of 20,925 acres. For impacts on wildlife species that extend one mile from a route, only 2% of the landscape would fall within the 50 core areas with a maximum patch size of just 5,384 acres. A route effect zone of 500 feet is illustrated graphically in Figure 10, where BLM lands in the study area are fragmented into 2,021 core areas.

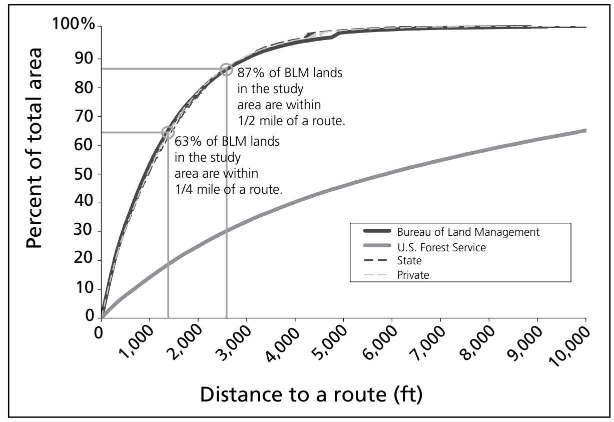


Figure 11. Cumulative distributions of distance to routes by land ownership type.

Core area habitat is limited in ungulate crucial winter range (Figure 12). For example, 90% of elk crucial winter range is within one mile of a route. Eighty-nine percent of pronghorn and 90% of mule deer crucial winter habitat is within ½ mile of a route. The study also shows little core area in the vicinity of sage grouse leks. Less than 30% of sage grouse leks falls within core areas farther than ¼ mile from a route, and only about 5% are farther than ½ mile from a route.

Core area habitat is most severely restricted within the study area's gas fields (Figure 13). The Jonah Field is most heavily affected by routes, with about 70% of its total area within 600 feet of a route and nearly all of the field within ½ mile of a route. In the Pinedale Anticline and South Piney fields, nearly 40% of the total area is within 600 feet of a route, and just under 90% is within ½ mile of a route.

Discussion

The nationally significant wildlife populations of the Upper Green River Valley are threatened by habitat loss and fragmentation from roads con-

Table 3. Characteristics of core areas as defined by different route effect zone widths.

	Route effect zone width				
Core areas	**100 ft**	**500 ft**	**¼ mi**	**½ mi**	**1 mi**
Number	2,596	2,021	1,105	430	50
Max acres	20,925	16,268	13,277	7,886	5,384
Min acres	<1	<1	<1	<1	<1
Mean acres	318	305	305	282	323
Total area in acres	826,172	616,685	336,526	121,380	16,163
Total area as percentage of study area	90%	67%	36%	13%	2%

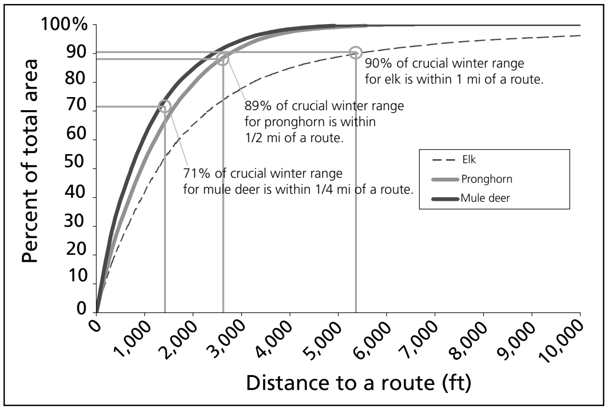


Figure 12. Cumulative distributions of distance to routes in pronghorn, mule deer, and elk crucial winter ranges.

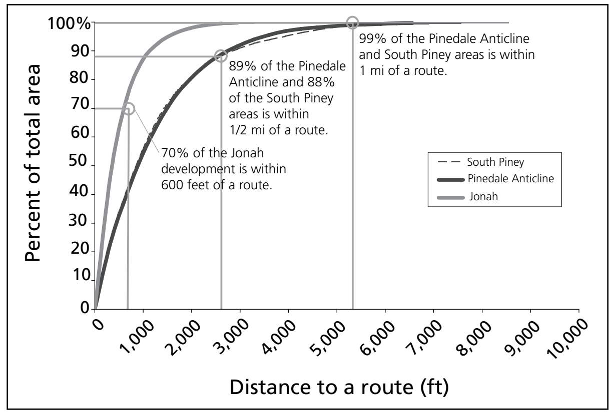


Figure 13. Cumulative distributions of distance to routes for three gas fields.

structed for energy development (WYG&F 2004). The BLM inventoried a substantial network of roads and other transportation routes, many directly associated with energy development, that fragment wildlife habitat in the Pinedale RMA.

Increasingly, scientists are assembling reviews of the effects of roads, other types of routes, and associated human activities on wildlife (Gucinski et al. 2001; Gaines et al. 2003). However, literature on this topic remains relatively scarce for rangeland landscapes. The Wyoming Game and Fish Department recently completed a report containing guidelines for wildlife protection in areas of energy development (WYG&F 2004). It includes a review of the literature on the impacts of roads, other infrastructure, and human activities associated with energy development on sagebrush and grassland habitats and their associated wildlife species in Wyoming.

Many studies have found that the effects of roads and other infrastructure extend well beyond the physical footprint of the feature (Lyon and Christensen 2002; Lutz et al. 2003; WYG&F 2004). The effects on terrestrial and aquatic wildlife include mortality from collisions, modifications of animal behavior (and effects on energetics), disruption of the physical environment, alteration of the chemical environment, fragmentation of connected habitats, spread of exotic species, and changes in human use of lands and water (Trombulak and Frissell 2000; Lutz et al. 2003).

More specifically addressing the infrastructure of energy development, the WYG&F report states: "As densities of wells, roads, and facilities increase, the effectiveness of adjacent habitats can decrease until most animals no longer use the habitat. Although vegetation and other natural features may remain unaltered within areas near oil and gas features, wildlife make proportionately less use of these areas than their availability. Animals attempting to forage inside the affected zones are also subjected to increased physiological stress. The avoidance/stress effect impairs the function by reducing the capability of wildlife to use the habitat effectively" (WYG&F 2004).

The Wyoming Game and Fish Department attributes six categories of effects specifically to oil and gas development: "1) direct loss of habitat, 2) physiological stress to wildlife, 3) disturbance and displacement of wildlife, 4) habitat fragmentation and isolation, 5) introduction of competitive and predatory organisms, and 6) secondary effects created by work force assimilation, growth of service industries, etc." (WYG&F 2004).

Implications of habitat fragmentation for wildlife species

In the present study, the highest route densities and lowest distance-to-route values (i.e., the smallest core areas) are found on the BLM, state, and private lands within the study area (Figures 7 and 11). In fact, route densities and distance-to-route values are very similar for these three land ownership classes. Route densities are lower and distance-to-route values higher on the USFS lands on the east, north, and west edges of the study area. Yet these less-fragmented lands cannot be expected to provide needed habitat for many of the wildlife species on BLM lands, because these lands are higher in elevation, provide substantially different vegetative habitat, and experience snow depths that prohibit use by many species during the winter months. The concentration of more-fragmented lands at the lower elevations critical for big game and sage grouse populations makes evaluating the impact of energy development and

managing for sustainable habitat exceedingly important.

While the degree of impact of roads on wildlife is not fully understood, our results indicate that route densities are high enough, and distance-to-route values low enough, in the BLM route inventory to adversely affect the four wildlife species studied. Comparison of wildlife habitat areas (Figures 2, 3, 4, and 5) with the route density map (Figure 6) and the core area map (Figure 10) illustrates graphically just how abundant routes are in ungulate winter range, birthing areas, and migratory corridors, as well as around sage grouse leks.

Mule deer

Energy development has the potential to directly and indirectly impact mule deer and their habitat, possibly leading to reductions in survival and reproductive capacity and potentially limiting the population's ability to sustain itself (Lutz et al. 2003). These effects can extend well beyond the area of the development and continue past the time period of the development (Lutz et al. 2003). Rost and Baley (1979) used mule deer pellet counts in north-central Colorado as an indication of winter habitat use, reporting lower densities of deer in open, mixed shrub, and forest habitat compared to sites with more forest cover. Their data showed that deer were three times more likely to occur 984–1,312 feet from a road than 328 feet from a road. Within our study area in the Pinedale RMA, 23% of BLM land and 29% of mule deer crucial winter range are closer than 328 feet to a route, and thus likely to show relatively reduced use by mule deer.

Another study of female mule deer in sagebrush winter range in north-central Colorado observed response distances to people on foot and on snowmobiles (Freddy et al. 1986). Mule deer were observed to alert to persons on foot and on snowmobiles at 1,096 feet and 1,542 feet, respectively, and to move away from these disturbances at distances of 436 feet and 627 feet. Measuring these response distances relative to routes in the Pinedale RMA reveals that mule deer could be affected by activities on roads in 35–77% of their crucial winter range habitat. This suggests human activity around drill pads in the winter could affect mule deer movements. The Wyoming Game and Fish Department used the alert distance of 1,542 feet to calculate that there is a 29-acre area of reduced habitat effectiveness around each drill pad (WYG&F 2004).

While data on mule deer response specifically to energy development are minimal (Lutz et al. 2003), mule deer have been shown to avoid human activity associated with roads and energy production facilities. A study in a North Dakota energy development area observed that active deer used habitat within 316 feet of a road less than its availability might suggest, while bedded deer avoided habitat within 158 feet of a road (Fox 1989).

An ongoing study by Sawyer et al. (2004) of Global Positioning System (GPS)-collared deer in the Pinedale Anticline Field found that deer utilized habitat progressively farther from roads and well pads over three years of increasing gas development and showed no evidence of acclimating to energy-related infrastructure. The effects of development were immediate, and areas of "high probability of use" before gas development were used substantially less after development, suggesting that deer may be displaced to less-preferred habitat (Sawyer et al. 2004). Lutz et al. (2003) agree that mule deer can be pressured into using less-preferred or lower-quality habitat, and that this could negatively affect an individual's energy balance "and ultimately decrease population productivity, especially on winter range." Sawyer et al. (2004) further suggest that direct loss of habitat from road and pad construction, combined with indirect loss from changes in habitat quality, may reduce winter range carrying capacity. To date, NEPA-based monitoring of the impacts of energy development on mule deer has not been sufficient to add to needed knowledge and has not been published in peer-reviewed literature (Sawyer and Lindzey 2004).

Pronghorn

Pronghorn are likely to be affected by the same types of human disturbance as mule deer, but are known to have a more sensitive flight response (WYG&F 2004). Based on preliminary results from on ongoing study by Berger and Beckmann (2004) in the Jonah and Pinedale Anticline fields, WYG&F (2004) concludes that migrating pronghorn avoid areas of dense energy development. BLM documents indicate that pronghorn are adversely affected at road densities of 1 mi/mi^2 (BLM 1999). Eighty percent of BLM lands and 80% of pronghorn crucial winter range in the study area have road densities of more than 1 mi/mi^2.

A study in central Arizona showed that pronghorn generally exhibited a weak avoidance of areas within 3,168 feet of a maintained road, as well as areas near non-maintained dirt roads and four-

wheel-drive trails (Ockenfels et al. 1994). Ninety-two percent of BLM lands and 94% of pronghorn crucial winter range in the study area fall closer than 3,168 feet to a route. Additionally, pronghorn may be more strongly affected by the noise and activity associated with a road than by the roadbed itself (Ockenfels et al. 1994), suggesting that temporal occupancy restrictions are particularly important. Also, an ongoing pronghorn study in the Pinedale area shows that the configuration and density of well pads and other surface disturbances further affect pronghorn use, and that there may be a threshold beyond which habitat utilization no longer occurs (Berger and Beckmann 2004).

Elk

In a major volume reviewing elk ecology and management, Lyon and Christensen (2002) stated, "Access—mainly that facilitated by roads—is perhaps the single most significant modifier of elk habitat and a factor that will remain central to elk management on public and private lands." Research by Lyon (1983) in forested habitat indicated that elk habitat effectiveness is reduced by 25% at road densities of 1 mi/mi^2, and by 50% at densities of 2 mi/mi^2. Eighty percent of the BLM lands in our study area have route densities of more than 1 mi/mi^2, and 36% have densities of more than 2 mi/mi^2. A study of elk habitat effectiveness in a forested area of north-central Wyoming found that few elk used areas with road densities of more than 0.5 mi/mi^2 (Sawyer et al. 1997). Ninety-five percent of BLM lands and 80% of elk crucial winter range in the study area of the Pinedale RMA have route densities of more than 0.5 mi/mi^2.

The above numbers are conservative, because the studies by Lyon (1983) and Sawyer et al. (1997) were conducted in forested landscapes, and road avoidance by wildlife is increased in open landscapes, such as in the study area, where one finds reduced habitat security (Perry and Overly 1976; Morgantini and Hudson 1979; Rost and Bailey 1979; Lyon 1979). A study in open habitat at Jack Morrow Hill in Wyoming observed that elk avoid areas within 1.2 miles of roads and active oil and gas wells in the summer and within 0.6 miles of these features in the winter (Powell 2003). It is possible that in areas with no cover, road densities of less than 1 mi/mi^2 may eliminate effective habitat (Lyon 1979). In our study area, 80% of BLM lands and 66% of elk crucial winter range have route densities of more than 1 mi/mi^2.

Additionally, Phillips and Aldredge (2000) observed that human disturbance during the calving season reduces elk calving success rates; they recommend maintaining "disturbance-free" areas during the calving season, based on work in alpine areas in Colorado. A radiotelemetry study by Edge and Marcum (1991) measured only a 5% probability of elk using lands within 0.6 mi of a road during calving season. In our study area, 82% of the 62,000 acres of elk birthing areas on BLM lands fall within 0.6 miles of a route.

Note that the role of elk winter feedgrounds is not addressed by the present study. State and federal agencies have made a substantial effort to protect ranchers' stored and feed hay from elk since the early 1900s (Dean et al. 2004). Since the 1970s, they have also endeavored to separate elk from cattle in order to minimize the spread of the ungulate disease brucellosis (Dean et al. 2004). These actions greatly complicate management strategies for elk. However, they do not negate the need to manage for high-quality elk winter range, birthing areas, and migration routes in the Upper Green River Valley.

Sage grouse

Research indicates that activities associated with gas field development—including road construction—can cause declines in nearby sage grouse populations (Braun 1998). Habitat used for wintering, lekking, nesting, and brood-rearing are of most concern in our study area. Because roads constructed for gas exploration and development result in permanent travel routes to previously inaccessible regions, the negative impacts on sage grouse are not limited to the initial development phase of an oil or gas field. Landscapes with less habitat fragmentation, better shrub structure, and a diverse understory of grasses and forbs are more secure for prey animals such as sage grouse (Braun 2002). The construction of fences, power lines, and other infrastructure, as well as the associated decreases in patch sizes and diversity, benefit sage grouse predators (Braun 2002).

Work by Lyon (2000) indicates that traffic disturbance has a long-term negative impact on breeding hens. The study, conducted in the region of the Pinedale Anticline Field, involved documenting nest-initiation and brood-rearing success rates of 48 hens from six leks in the area. The nest-initiation rate over a two-year period was 55% for hens from the three leks in close proximity to a road (average distance of 2,382 feet to a road). Hens from the three leks farther removed from roads (average distance of 7,742 feet) had a nest-initiation rate of 82% over the

same period. Following the same hens through early brood-rearing, Lyon determined that the hens that were most successful at raising chicks nested farther from roads (an average of 3,734 feet) than hens whose broods did not survive the first three weeks after hatching. Unsuccessful brood-rearing grounds averaged 879 feet from the nearest road. Forty-nine percent of BLM lands in the study area are within this distance of a route.

A recent field study by Holloran and Anderson (2004) measured the influence of natural gas development on sage grouse in the Pinedale Anticline and Jonah fields between 1998 and 2004. Results showed mean annual declines of 32% in the maximum number of males at leks within two miles of a drilling rig and declines of 19% within 1,640 feet of a road. The authors also stated, "Although lek attendance, male and female survival, and female demographics varied depending on lek-to-drilling-rig and nest-to-drilling-rig distances, the data suggest that the presence of a drilling rig within 5.5 kilometers [3.4 miles] directly and indirectly influenced sage grouse."

The Wyoming Game and Fish Department (2004) recommends that where sage grouse habitat has already been fragmented (as we have documented for this study area of the Pinedale RMA), future development "should completely avoid remaining habitats." The agency proposes a series of guidelines for development within two miles of a lek or nesting and rearing habitat, and recommends no roads or other infrastructure within 656 feet of identified winter habitat. To protect breeding areas, a number of authors (Braun 2002; Connelly et al. 2000; Braun et al. 1977) have suggested that areas within three miles of leks should be free of road disturbance during breeding and brood-rearing. All BLM lands within the study area are within three miles of a route. In fact, 98% of BLM lands are within one mile of a route. This suggests that most of the leks identified by WYG&F (Figure 5) may lie within habitat sufficiently fragmented and potentially open to disturbance during the breeding season as to have already reduced breeding functions.

Additional route impacts to wildlife

Beyond the fragmentation effects discussed above, transportation routes directly affect these wildlife species by blocking migration paths. Natural and human-made bottlenecks, or pinch points, in the 40–150-mile migration corridors for pronghorn and mule deer in the Pinedale RMA have been documented by Sawyer and Lindzey (2000; 2001) and Berger (2004a). Severing migration routes at these pinch points through additional road building for energy development or other purposes would threaten the fall and spring migrations, and thus maintenance of healthy populations, of these species (WETI 2003). According to WYG&F (2004), "long term displacement of wildlife from preferred habitats and disruption of migration routes could, in the extreme case, extirpate 'migration memory' that required several thousand years to evolve." Additionally, vehicle traffic and other human activities along roads can tax animals' limited energy reserves during the winter months. Increased stress and activity required to avoid roads (or other infrastructure) are likely associated with many roads in our study area within ungulate crucial winter range.

Limitations of this assessment and future research needs

Most importantly, additional monitoring is needed to understand the specific direct, indirect, and cumulative effects of roads, well pads, other energy infrastructure, and related human activities on wildlife species. Citations from the biological literature included in this report—while not exhaustive—are some of the best available, but fall short of what is needed. Nevertheless, our comparison of landscape measures of route density and distance-to-route values with scientific literature on the responses of wildlife to such infrastructure indicates that substantial caution is warranted in the permitting of additional energy roads and infrastructure.

Further, because the RMP currently in preparation will likely guide activities in the Pinedale RMA for 15–20 years, it is reasonable to expect an increase in proposed roads and infrastructure, and a corresponding increase in impacts to wildlife, over that time. Still, additional research is vital to understandinging the effects of this development. In particular, research is needed on species-specific impacts from different types, levels, and times (of day and season) of road use as well as activity levels and times of use on drill pads.

Our analysis is based on the best available GIS data for transportation routes and for the habitat boundaries of the targeted wildlife species. However, no GIS dataset is ever entirely complete and accurate, and many of the data layers used in this study will continue to be updated by various land-management and wildlife-management agencies. As stated earlier, the GIS route data available from the BLM at the time of our assessment did not include seasonal

restriction information; consequently, this information was not incorporated into our analysis.

There are several additional caveats. This study likely underestimates actual habitat fragmentation in the study area because it only addresses fragmentation resulting from transportation routes. That is, it does not account for other features that fragment the landscape such as other human infrastructure (e.g., pipelines, fences), natural topographic barriers, and natural vegetation breaks. In addition, the BLM route dataset did not capture all transportation routes. Nor does the study address habitat connectivity, variations in scale, differences in types of transportation features, or habituation to hunting regulations or other human activities. When these factors are considered, it may well be that even less optimal habitat remains than we have estimated here. With additional field research, a more comprehensive assessment of fragmentation metrics for each species or set of species could be generated.

Finally, the study does not address additional fragmentation and wildlife impacts from routes that have been permitted but not yet built. In the Pinedale Anticline Field, for example, many miles of roads, drill pads, and related infrastructure will be built in the coming years under the limits established in the 2000 EIS record of decision.

Recommendations and conclusions

This report demonstrates the feasibility of spatial analysis and its applicability to the decisions that will be made during the Pinedale RMP revision. Transportation routes and associated energy development infrastructure have a range of effects—direct, indirect, and cumulative—on the landscape. Informed decisionmaking requires state-of-the-art tools such as spatial analysis to provide critical information and gauge the potential negative effects of these routes on ecosystems.

As noted earlier, NEPA requires federal agencies to assess the direct, indirect, and cumulative environmental impacts of proposed actions, taking a "hard look" at environmental consequences and performing an analysis commensurate with the scale of the action at issue. In addition to field monitoring, spatial analysis is an appropriate way to take that hard look, particularly in relation to the impacts of roads and all energy development infrastructure on wildlife. We believe the BLM must apply these techniques to meet the requirements of NEPA.

The results of our spatial analysis suggest that the existing transportation route network in the Pinedale RMA is endangering wildlife populations through fragmentation and destruction of habitat. As noted above, the pressures on wildlife from development are likely to increase during the RMP's applicability over the next 15–20 years. Therefore, accurately assessing the effects of transportation routes on wildlife and taking action to ameliorate these impacts through RMP revision and other efforts is essential.

We recommend that the BLM employ the spatial analysis techniques used in this report to carefully evaluate the impacts of the existing transportation network on other species and natural and cultural resources in order to assess the need for closure and other limitations on the use of existing roads (and other routes), and to develop and thoroughly evaluate alternative transportation networks. We also recommend that the BLM continue to update data on the distribution and quality of wildlife habitat. Under the Data Quality Act, the BLM is required to use high-quality information that is objective, useful, and verifiable by others, and to use "sound statistical and research" methods (BLM 2002).

Especially in the absence of adequate data, science cannot always provide clear and certain answers to important questions about potential environmental impacts in a timely fashion. Lack of accurate boundaries for wildlife habitats and an incomplete understanding of the impacts of roads and other types of routes on wildlife are real problems that demand additional research.

However, such gaps in knowledge must not stop or delay decisions to protect wildlife resources by reducing the number and mileage of transportation routes across a landscape. Substantial numbers of published scientific studies suggest that roads and other transportation routes and their associated human activities can negatively affect wildlife at route-density and distance-to-route values like those measured in the present study. We recommend that management planning—using the best available data, techniques, and results such as those presented in this report—should proceed, with an emphasis on reductions in road densities and increases in the number and size of core habitat areas in ungulate wintering grounds and along migration corridors, and in sage grouse wintering, lekking, nesting, and rearing areas.

A key step in achieving these goals is implementing a consistent approach to identifying roads and other routes for closure and reclamation. We recommend that the BLM identify and schedule for

closure routes that do not have a specific ongoing use (i.e., those that are not associated with active energy development or do not provide access to a publicly recognized destination) and those providing redundant access, as suggested in the BLM's "Guidance for the Management of Sage Brush Plant Communities for Sage grouse Conservation" (BLM 2004).

In addition, we recommend that the BLM identify routes that impact wildlife habitat or increase the likelihood of non-compliance with existing conservation mandates, such as the Endangered Species Act, and then consider closing those routes or otherwise mitigating their identified impacts, including by rerouting, seasonal closures, or limitations on use. For those roads and routes that will be closed, the BLM should adopt obliteration and reclamation standards that will restore the area.

Our recommendations are in concert with the "precautionary principle" of conservation biology, which states that precautionary measures should be taken when a certain activity or inactivity threatens to harm human health or the environment, even when science has not fully established cause-and-effect relationships (Meffe and Carroll 1994; Noss and Cooperrider 1994). This principle is rooted in the recognition that scientific understanding of ecosystems is complicated by numerous factors, including dynamic ecosystem processes and the various effects of human activities. Put simply, it is easier to prevent harm to biodiversity than to attempt to repair it later. This prevention of harm is critical for ungulate winter range and migratory routes and for sage grouse wintering, lekking, nesting, and rearing areas in the Pinedale RMA.

Specific wildlife recommendations

Our analysis indicates that the existing transportation network identified by the BLM fragments wildlife habitat across the Pinedale RMA and is sufficiently likely to cause negative effects on all four of the wildlife species studied such that constraints on road use and energy development are warranted. We did not assess the potential impacts of the transportation network on other wildlife species in this analysis. However, the study area contains numerous additional species that would also be subject to the effects of transportation routes and their use. We recommend that the BLM take several actions to alleviate these effects:

(1) Ensure that plans are developed and implemented so that the scientifically derived standards listed below for reducing the impact of transportation routes on the four wildlife species addressed in this report are met. These standards should be met by closing and reclaiming routes not associated with active energy development or other specifically designated uses, routes providing redundant access, and routes excessively impacting habitat—and by mitigating the impacts of transportation routes through seasonal activity restrictions.

a. *Mule deer:* Increase the amount of core area to more than 1,542 feet (Freddy et al. 1986) from a road or other transportation route within mule deer crucial winter range and along migration routes. Allow no drilling or surface occupancy between November 15 and April 30 (WYG&F 2004) within crucial winter range.
b. *Pronghorn:* Increase the amount of core area to more than 3,168 feet (Ockenfels et al. 1994) from a road or other transportation route and reduce route densities to less than 1 mi/mi^2 (BLM 1999) within pronghorn crucial winter range and along migration routes. Allow no drilling or surface occupancy between November 15 and April 30 (WYG&F 2004) within crucial winter range.
c. *Elk:* Reduce road or other transportation route densities to less than 1 mi/mi^2 (Lyon 1979) within elk crucial winter range and along migration routes. Allow no drilling or surface occupancy between November 15 and April 30 (WYG&F 2004) within crucial winter range.
d. *Sage grouse:* Implement seasonal restrictions on traffic on all roads and other transportation routes within 656 feet (WYG&F 2004) of winter habitat (9:00 AM–5:30 PM, mid-November through March), within three miles of leks (Braun 2002; Connelly et al. 2000; Braun et al. 1977) or breeding and nesting areas (9:00 AM–5:30 PM, March through mid-May), and in brood-rearing areas (9:00 AM–5:30 PM, June through mid-July) (C. E. Braun, pers. comm.). Set a maximum speed limit of 30 miles per hour during restricted seasons during unrestricted hours (C. E. Braun, pers. comm.).

(2) Allow few exceptions to temporal occupancy restrictions. Temporal restrictions allow the BLM to fulfill its mandate to manage lands for multiple use and to prevent undue and unnecessary degradation of the land. Only short-term exceptions to temporal occupancy restrictions should be allowed, and only in limited cases as identified in the RMP.

Per the BLM's *Handbook on Planning for Fluid Minerals,* "[a]ll circumstances for granting a waiver, exception, or modification must be documented in the plan" (BLM 1990). BLM regulations also emphasize the importance of limiting exemptions from stipulations, stating: "[a] stipulation included in an oil and gas lease shall be subject to modification or waiver only if the authorized officer determines that the factors leading to its inclusion in the lease have changed sufficiently to make the protection provided by the stipulation no longer justified or if proposed operations would not cause unacceptable impacts" (43 CFR §3101.1–4). Also, a 30-day public review and comment period should be provided for modification or waiver of a stipulation prior to lease issuance if the stipulation involves an issue of major concern to the public and subsequent to lease issuance if the modification or waiver is deemed "substantial" (43 CFR §3101.1–4).

(3) Ensure directional drilling and cluster development. In its revision of the Pinedale RMP, the BLM should establish guidelines and requirements for operators to use directional drilling techniques and clustering of drill holes and other infrastructure on a single pad (UGRVC 2004). Such techniques can reduce the physical footprint of energy development and the impacts on wildlife (Molvar 2003; WYG&F 2004) and reflect best management practices endorsed by the BLM to mitigate the impacts of oil and gas development in Instruction Memorandum No. 2004-194, Integration of Best Management Practices into Application for Permit to Drill Approvals and Associated Rights-of-Way.

(4) Implement a plan for staged development for potential future energy development. The revision of the Pinedale RMP should lay out a staged leasing strategy in which some areas of the landscape are open for development while others are temporarily withdrawn. The staged leasing should be designed to ensure that critical winter range, birthing areas, and migration corridors for ungulates and winter habitat, breeding grounds, and nesting and rearing areas for sage grouse are not intensely developed all at once. This will not only disperse wildlife impacts over time and allow economic benefits to last longer, but also will allow time for the monitoring and evaluation of development impacts on wildlife.

(5) Restrict new roads and energy development. The revision of the Pinedale RMP should not allow any new energy development, expansion of existing development, or road construction within big game crucial winter range or at the pinch points of migration routes. Directional drilling should be required for any extraction of natural gas under these areas, with no surface disturbance or road construction allowed.

(6) Designate Areas of Critical Environmental Concern (ACEC). Designate the lands comprising winter range and/or migration route pinch points for multiple big game species as Areas of Critical Environmental Concern (ACEC), subject to management prescriptions that will protect their use for big game winter range and/or migration. The prescriptions should include: no creation of new routes, no expansion of existing routes, no new leasing (unless "no surface occupancy"), no new energy development, no cross-country travel, limitation of off-road vehicle use to designated routes, and closure of unnecessary routes. The new ACEC should include those nominated by various groups in a joint 2002 petition to the BLM during the RMP scoping period (Defenders of Wildlife et al. 2002) and addressed in the "Responsible Energy Development" proposal submitted to the BLM by the Upper Green River Valley Coalition (2004): the Trapper's Point Mule Deer and Pronghorn Migratory Bottleneck, Cora Butte Mule Deer and Pronghorn Transition Range, Fremont Lake Mule Deer Migratory Bottleneck, Green River Crossing Area, LaBarge Creek Native Elk Winter Range, and the Wind River Front area currently off-limits to leasing. We also recommend including ACEC designation for the Wyoming Range front proposed for no leasing or leasing with no surface occupancy by the Upper Green River Valley Coalition (2004). Sage grouse winter habitat is not yet fully documented. This habitat needs to be mapped, and at least 90% should be designated as ACEC, with the implementation of management strategies that would preserve cover and forage required for winter months (Braun 2002).

The above recommendations are based on the best available research about wildlife–road interactions and the distribution of habitat for the targeted species. As better data become available from agency and academic sources, the above recommendations can and should be adjusted and improved through an adaptive management process.

General recommendations for protection of wildlife

(1) Apply the analysis used to create this report, and the results generated, to inform the Pinedale RMP revision and to create a responsible travel management plan as part of the current planning

process. The BLM is legally required to designate areas and routes, avoid impairment of the public lands, and protect wildlife and other resources through its land use planning process. A spatial analysis of the impact of roads, other transportation routes, and other infrastructure on wildlife is also a key component of creating a comprehensive travel plan for the Pinedale RMA. In the Pinedale RMA, rapid expansion of roads to support gas exploration and development has been occurring and is projected to continue at a similar pace, heightening the adverse impacts on wildlife and, as a consequence, the corresponding importance of addressing these impacts through travel planning.

(2) Adopt an RMP that includes significant route decommissioning and restoration of the landscape's ecological health and integrity. Specific procedures, protocols, and priorities should be defined and implemented to close and reclaim roads and other transportation routes, including a schedule for closure and reclamation of specific roads and routes; requirements for immediate reclamation of unused areas and commencement of initial reclamation if no production activities have taken place for six months; requirements for submission and approval of reclamation plans with applications for permit to drill; requirements that reclamation plans include decompaction of soils, restoration of original contour and drainage, replanting of native vegetation, obliteration of visual evidence, and use of specified seed, fill, and other materials and methods as appropriate; monitoring of compliance with reclamation plans; and institution of scientifically based standards to assess when reclamation has been achieved (over and above simple re-seeding requirements).

(3) Use landscape fragmentation metrics to guide any and all management decisions regarding transportation routes. Calculate route density, core area, and distance-to-route (or route effect zone) metrics in accordance with scientific literature on wildlife species and evaluate the likely impacts of potential road networks on wildlife species and other resources the BLM is required to protect under relevant laws and policies. Goals should include reductions in road density and increases in core areas to provide greater habitat security.

(4) For all new roads that are built, follow the road construction guidelines of WYG&F (2004) to minimize the effect of routes on wildlife.

(5) Include clear enforcement mechanisms in the revision of the Pinedale RMP so that impacts of energy development on wildlife are minimized. These mechanisms should include a plan for enforcing permanent road closures, temporary/seasonal road closures, limits on off-road travel in designated areas or times of year, limits on road and well pad construction in critical habitats, and requirements for directional drilling and cluster development.

(6) Continue to evaluate the impacts of routes on wildlife (and other resources) as part of the travel management planning process and subsequent ongoing adaptive management. Ongoing NEPA-related monitoring of wildlife impacts from routes, well pads, and related human activities such as those described by Sawyer and Lindzey (2004) should be defined in the final RMP and implemented over the course of the development. The BLM must apply landscape fragmentation analysis to design a plan that meets its responsibility to protect all of the region's resources for multiple use and sustained yield, and give priority to designation and protection of ACEC.

(7) Promote additional wildlife research by the BLM, WYG&F, and other agencies and institutions. The BLM should encourage the collection of up-to-date, accurate digital data on the distribution of wildlife habitats and work to understand more thoroughly the ecological impacts of all types of transportation routes on wildlife species in the Pinedale RMA. In particular, research is needed on species-specific impacts from different types, levels, and times (of day and season) of road use, as well as impacts from different activity levels and times of use on drill pads.

Conclusions

Sagebrush ecosystems found in the Upper Green River Valley of western Wyoming contain crucial habitat for some of the largest migratory populations of ungulates in North America, and offer a chance for survival of healthy populations of sage grouse and other obligate sagebrush species. Yet fragmentation and declining quality of the valley's sagebrush and grassland ecosystems are the principal reasons why populations and distributions of dependent wildlife are declining (WYG&F 2004). Given the rapid recent development of new roads and infrastructure for oil and gas development in this area, the BLM is now at a critical juncture in deciding the long-term fate of key habitat for the nationally significant wildlife populations found here.

The BLM is responsible for adopting a protective RMP, including a travel management plan, that

improves the Pinedale RMA's long-term ecological health and integrity while providing for balanced public access and use of the landscape and its resources. The scientific literature documents direct, indirect, and cumulative impacts of transportation features on ecological processes, wildlife, plants, and archeological sites. In its upcoming RMP revision for the Pinedale RMA, the Pinedale BLM Field Office must make management decisions that recognize the best available science and proactively mitigate documented impacts to wildlife and other resources.

Good science, the law, and sound policy can guide the BLM as it develops an RMP and a travel management plan to preserve large core areas of habitat for the four species studied in this report. Those areas will have value far beyond the targeted species. Maintenance of unroaded core areas or minimally roaded areas in key habitat units as recommended in this report will provide an opportunity to balance the needs of the area's important wildlife populations with the area's growing energy development.

This paper offers science-based information and analysis for use in making critical management decisions. The Pinedale RMA, while heavily developed for oil and gas, hosts critical wildlife habitat for many species and has the potential to protect this habitat for generations to come. In its upcoming Pinedale RMP revision and in other analyses and plans, we encourage the BLM to reach sound, science-based management decisions that will close routes to restore and maintain critical habitat and habitat linkages.

Acknowledgments

We express our thanks to The Aspenwood Foundation for its generous support of our conservation science program in the Northern Rockies, as well as to The William and Flora Hewlett Foundation for its support of our BLM Action Center. Our appreciation goes to the Earth Friends Wildlife Foundation for its support of our work in the Upper Green River Valley. We thank the Environmental Systems Research Institute (ESRI) for its ongoing donation of GIS software. We thank biologists Bernie Holz of the Wyoming Game and Fish Department and Hall Sawyer of Western EcoSystems Technology, Inc., for their thoughtful reviews of earlier drafts of the report. Their participation as independent reviewers in no way implies agreement with or endorsement of the science, recommendations, or other content of this document.

References

Berger, J. 2003. Is it acceptable to let a species go extinct in a national park? *Conservation Biology* 17:1451–1454.

Berger, J. 2004a. The last mile: how to sustain long distance migration in mammals. *Conservation Biology* 18:320–329.

Berger, J. 2004b. Can we save the last of the great long-distance migrations? *Wild Earth* (Fall/Winter 2004–2005):22–25.

Berger, J., and J. P. Beckmann. 2004. Pronghorn survival and energy development in western Wyoming: assessing effects of human disturbance during winter. *Annual Report from the Wildlife Conservation Society*. New York: Wildlife Conservation Society.

Braun, C. E. 1998. Sage grouse declines in western North America: what are the problems? *In Proceedings of the Western Association of State Fish and Wildlife Agencies* 78:139–156.

Braun, C. E. 2002. A review of sage grouse habitat needs and sage grouse management issues for the revision of the BLM's Pinedale District Resource Management Plan. Tucson, Ariz.: Grouse Inc., for The Wilderness Society, the Wyoming Outdoor Council, and the Greater Yellowstone Coalition.

Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. *Wildlife Society Bulletin* 5(3):99–106.

Bureau of Land Management (BLM). 1990. *Handbook on planning for fluid minerals*. Washington, D.C.: Bureau of Land Management, H-1624 at IV.C.3.

Bureau of Land Management. 1998. Record of decision for the Jonah II natural gas development project environmental impact statement, Sublette County, WY. Pinedale, Wyo.: U.S. Department of the Interior, Bureau of Land Management, Rock Springs, Pinedale, and Green River Resource Areas.

Bureau of Land Management. 1999. Draft environmental impact statement for the Pinedale Anticline oil and gas exploration and development project, Sublette County, WY. Pinedale, Wyo.: U.S. Department of the Interior, Bureau of Land Management, Pinedale Field Office.

Bureau of Land Management. 2000. Record of decision and final environmental impact statement for the Pinedale Anticline oil and gas exploration and development project, Sublette County, WY. Pinedale, Wyo.: U.S. Department of the Interior, Bureau of Land Management, Pinedale Field Office.

Bureau of Land Management. 2002. Information quality guidelines. Washington, D.C.: Bureau of Land Management. <http://www.blm.gov/nhp/efoia/data_quality/guidelines.pdf>.

Bureau of Land Management. 2004. Guidance for the management of sagebrush plant communities for sage grouse conservation, national sage grouse habitat conservation strategy. Washington, D.C.:

Bureau of Land Management.

Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage grouse (*Centrocercus urophasianus*) populations in western North America. *Wildlife Biology* 3/4:123–128.

Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28(4):967–985.

Dean, R., M. Gocke, B. Holz, S. Kilpatrick, T. Kreeger, B. Scurlock, S. Smith, E. T. Thorne, and S. Werbelow. 2004. Elk feedgrounds in Wyoming. Cheyenne, Wyo.: Wyoming Game and Fish Department. <http://gf.state.wy.us/wildlife/ElkFeedgrounds/index.asp>.

Defenders of Wildlife, Greater Yellowstone Coalition, The Wilderness Society, Wyoming Outdoor Council, Upper Green River Valley Coalition, American Lands Alliance, and L. Dorsey. 2002. Critical condition: areas of critical environmental concern for big game in the upper Green River valley, Wyoming. A petition to the Wyoming BLM in accordance with the Pinedale RMP scoping process.

Edge, W. D., and C. L. Marcum. 1991. Topography ameliorates the effects of roads and human disturbance on elk. Pages 132–137 *in* A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps., *Proceedings of the elk vulnerability symposium*. Bozeman, Mont.: Montana State University.

Forman, R. T. 1999. Estimate of the area affected ecologically by the road system in the United States. *Conservation Biology* 14:31–35.

Fox, R. A. 1989. *Mule deer (*Odocoileus hemionus*) home range and habitat use in an energy-impacted area of the North Dakota badlands*. Master's thesis, University of North Dakota, Grand Forks, N.D.

Freddy, D. J., W. M. Bronaugh, and M. C. Fowler. 1986. Responses of mule deer to disturbance by persons afoot and snowmobiles. *Wildlife Society Bulletin* 14:63–68.

Gaines, W. L., P. H. Singleton, and R. C. Ross. 2003. Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. General Technical Report PNW-GTR-586. Portland, Ore.: U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Research Station.

Gucinski, H., M. J. Furniss, R. R. Ziemer, and M. H. Brookes. 2001. Forest roads: a synthesis of scientific information. General Technical Report PNW-GTR-509. Portland, Ore.: U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Research Station.

Holloran, M. J., and S. H. Anderson. 2004. Sage grouse response to natural gas field development in northwestern Wyoming. Abstract *in* 24th Meeting of the Western Agencies Sage and Columbian Sharp-Tailed Grouse Technical Committee, Wenatchee, Washington, June 28–July 1.

Knick, S. T., D. S. Dobkin, J. T. Rotenberry, M. A. Schroeder, W. M. Vander Haegen, and C. van Riper. 2003. Teetering on the edge or too late? Conservation and research issues of avifauna of sagebrush habitats. *The Condor* 105:611–634.

Lehmkuhl, J. F., and L. F. Ruggiero. 1991. Forest fragmentation in the Pacific Northwest and its potential effects on wildlife. Pages 35–46 *in* L. F. Ruggiero, K. B. Aubry, A. B. Carey, and M. H. Huff, tech. coords., *Wildlife and vegetation of unmanaged Douglas-fir forests*. General Technical Report PNW-GTR-285. Portland, Ore.: U.S. Department of Agriculture, U.S. Forest Service, Pacific Northwest Research Station.

Lutz, D. W., B. F. Wakeling, L. H. Carpenter, D. Stroud, M. Cox, D. McWhirter, S. Rosenstock, L. C. Bender, and A. F. Reeve. 2003. Impacts and changes to mule deer habitat. Pages 13–61 *in* J. C. de Vos, Jr., M.R. Conover, and N.E. Headrick, eds., *Mule deer conservation: issues and management strategies*. Logan, Utah: Jack H. Berryman Institute Press, Utah State University.

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. *Journal of Forestry* 77:658–660.

Lyon, L. J. 1983. Road density models describing habitat effectiveness for elk. *Journal of Forestry* 81:592–596.

Lyon, A. G. 2000. *The potential effects of natural gas development on sage grouse (*Centrocercus urophasianus*) near Pinedale, Wyoming.* Master's thesis, University of Wyoming, Laramie, Wyo.

Lyon, L. J., and A. G. Christensen. 2002. Elk and land management. Pages 557–581 *in* D. E. Toweill and J. W. Thomas, eds., *North American elk ecology and management*. Washington, D.C.: Smithsonian Institution Press.

Meffe, G. K., and C. R. Carroll. 1994. *Principles of conservation biology*. Sunderland, Mass.: Sinauer Associates, Inc..

Molvar, E. M. 2003. Drilling smarter: using minimum-footprint directional drilling to reduce oil and gas impacts in the intermountain West. Laramie, Wyo.: Biodiversity Conservation Alliance.

Morgantini, L. E., and R. J. Hudson. 1979. Human disturbance and habitat selection in elk. Pages 132–139 *in Symposium on elk ecology and management*, April 3–5, 1978, Laramie, Wyo.

Noss, R. F., and A. Y. Cooperrider. 1994. *Saving nature's legacy: protecting and restoring biodiversity*. Washington, D.C.: Island Press.

Ockenfels, R. A., A. Alexander, C. L. D. Ticer, and W. K. Carrel. 1994. Home range movement patterns and habitat selection of pronghorn in central Arizona. Technical Report 13. Phoenix, Ariz.: Arizona Game and Fish Department.

Phillips, G. E., and A. W. Alldredge. 2000. Reproductive success of elk following disturbance by humans

during calving season. *Journal of Wildlife Management* 64(2):512–530.

Powell, J. H. 2003. *Distribution, habitat use patterns, and elk response to human disturbance in the Jack Morrow Hills, Wyoming.* Master of Science thesis, University of Wyoming, Laramie.

Rost, G. R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. *Journal of Wildlife Management* 43(3):634–641.

Sawyer, H. H., and F. G. Lindzey. 2000. Jackson Hole pronghorn study. Laramie, Wyo.: Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming, prepared for Ultra Petroleum, Wyoming Game and Fish Department, U.S. Fish and Wildlife Service, USDA Forest Service, Bureau of Land Management, and Teton Science School.

Sawyer, H. H., and F. G. Lindzey. 2001. Sublette mule deer study. Laramie, Wyo.: Wyoming Cooperative Fish and Wildlife Research Unit, University of Wyoming.

Sawyer, H. H., and F. G. Lindzey. 2004. Assessing impacts of oil and gas development on mule deer. *Transactions of the 69th North American Wildlife and Natural Resources Conference*, Spokane, Washington. Washington, D.C.: Wildlife Management Institute.

Sawyer, H. H., F. G. Lindzey, and B. A. Jellison. 1997. Applying GIS technology to test an elk habitat effectiveness model in north-central Wyoming. Pages 176–183 *in* J. de Vos, ed., *Proceedings of the 1997 Deer/Elk Workshop*, Rio Rico, Arizona. Phoenix, Ariz.: Arizona Game and Fish Department.

Sawyer, H. H., R. Nielson, L. McDonald, and D. Strickland. 2004. Sublette mule deer study (phase II): long-term monitoring plan to assess potential impacts of energy development on mule deer in the Pinedale Anticline project area. Cheyenne, Wyo.: Western EcoSystems Technology, Inc., prepared for Questar Exploration and Production Company, TRC Mariah Associates, Inc., Bureau of Land Management, and Wyoming Game and Fish Department.

Trombulak, S. C., and C. A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology* 14:18–30.

Upper Green River Valley Coalition (UGRVC). 2004. A responsible energy development alternative for consideration in the Bureau of Land Management Pinedale Resource Area resource management plan revision. Pinedale, Wyo.: Upper Green River Valley Coalition.

Weller, C., J. L. Thomson, P. Morton, and G. H. Aplet. 2002. *Fragmenting our lands: the ecological footprint from oil and gas development.* Washington, D.C.: The Wilderness Society.

Western EcoSystems Technology, Inc. (WETI). 2003. An evaluation of the 1988 BLM Pinedale resource management plan, 2000 BLM Pinedale Anticline final environmental impact statement and recommendation for the current revision of the Pinedale resource management plan. Cheyenne, Wyo.: Western EcoSystems Technology, Inc., prepared for The Wilderness Society, Wyoming Outdoor Council and Greater Yellowstone Coalition (January 22).

Wyoming Game and Fish Department (WYG&F). 2004. Minimum recommendations for development of oil and gas resources within crucial and important wildlife habitats on BLM lands. Cheyenne, Wyo.: Wyoming Game and Fish Department.

Fire in the Yellowstone Landscape: Surprises and Lessons

Monica G. Turner

Department of Zoology, University of Wisconsin, Madison, WI 53706 (608-262-2592, turnermg@wisc.edu)

William H. Romme

Department of Forest Sciences, Colorado State University, Fort Collins, CO 80523
(970-491-2870, romme@cnr.colostate.edu)

Morning Keynote, October 18, 2005 (Dr. Turner)

Monica G. Turner grew up in New York, and first visited Yellowstone (and the western U.S.) in 1978, when she worked at Old Faithful as a ranger-naturalist through the Student Conservation Association. That formative summer confirmed her decision to become an ecologist. After completing a BS in Biology from Fordham University, she earned a PhD in Ecology from the University of Georgia. As a graduate student, she worked as a summer intern with the NPS in Washington, D.C.; she conducted her doctoral research in Virgin Islands National Park and Cumberland Island National Seashore. Currently a professor at the University of Wisconsin, she has studied fire, vegetation, and ecosystem processes in Yellowstone since 1988, and is also studying elk movement and habitat use. She was a member of the National Research Council committee that evaluated ungulate management in Yellowstone (*Ungulate Dynamics on Yellowstone's Northern Range,* 2002, National Academy Press). Currently, she is co-editor-in-chief of *Ecosystems,* an editorial board member for *BioScience,* and a member of the Rapid Response Team of the Ecological Society of America. She has received awards for distinguished scholarship, and was elected to membership in the National Academy of Sciences in 2004.

Introduction

The size and severity of the fires that burned through Yellowstone National Park (YNP) and surrounding lands during the summer of 1988 surprised scientists, park managers, and the general public. These fires burned under conditions of severe drought and high winds (Renkin and Despain 1992), ultimately affecting nearly 40% of the park. Although clearly not unprecedented within the ecosystem, the fires were the largest observed since the park was created in 1872, and they challenged contemporary understanding of fire dynamics and policy. Many people initially thought the fires had destroyed America's crown jewel, based on media reports that summer (Smith 1996). That perception was largely corrected as recovery of the burned areas through natural processes became increasingly evident. Stand-replacing fires have occurred in YNP at 100-to-500-year intervals throughout the past 10,000 years (Romme 1982; Romme and Despain 1989; Millspaugh et al. 2000; 2004). The 1988 fires were most certainly not an ecological catastrophe, but rather a natural event to which the plants and animals that inhabit the Yellowstone landscape are well adapted (Turner et al. 2003a; Romme and Turner 2004).

Natural disturbances are key sources of heterogeneity in many ecosystems, yet the causes and consequences of disturbances that are large, severe, and infrequent are not well understood. Many northern conifer forests, including those in Yellowstone, are characterized by a natural fire regime of infrequent, stand-replacing fires driven largely by climate (Turner and Romme 1994; Johnson 1992). The 1988 Yellowstone fires provided scientists with a valuable opportunity for ecological study of a large, infrequent disturbance in a system minimally influenced by humans. Such studies can provide important insights into how ecological systems respond to extreme events. We have studied vegetation and ecosystem processes in response to the 1988 fires, and here we highlight several of the surprises and lessons that emerged from our research. Our studies have addressed the effects of fire in the conifer forests that dominate the central plateau, and we focus on four major areas: (1) landscape heterogeneity, (2) patterns of succession, (3) ecosystem function, and (4) long-term trajectories.

Landscape heterogeneity

Disturbances both respond to and create heterogeneity in landscapes. During the period of natu-

ral fire management in Yellowstone (1972–1987), naturally ignited fires burned primarily in the oldest forests, where there was abundant and well-connected (both vertically and horizontally) live fuel. During that time, the summer of 1981 had the largest area burned, with 3,300 ha affected by 28 fires (Renkin and Despain 1992). During less severe drought years, when conditions were suitable for burning but not extreme, fire spread was constrained by the amount and spatial distribution of old-growth (>250-yr) forests. Fire behavior during the early summer of 1988 was similar to that which had been observed previously—fires burned through old forest and stopped when they encountered young forests. However, as the drought of 1988 worsened and conditions of high wind developed, the fires no longer responded to heterogeneity across the landscape. Forests of all ages burned, and natural firebreaks such as the Grand Canyon of the Yellowstone River did not stop fire spread. Analyses of the spatial patterns of burning conducted after the fire season quantified these differences in fire patterns between the early and late summer periods of 1988 (Turner et al. 1994). As in other landscapes with a natural fire regime of severe, stand-replacing fire, pre-fire heterogeneity of the landscape is important under moderate burning conditions, but not when fire weather is extreme. This is consistent with results reported for many areas in which few fire events (or years) result in most of the area burned (Johnson 1992; Bessie and Johnson 1995; Flannigan and Wotton 2001).

The 1988 fires were large and severe, but importantly, they did not homogenize the landscape. Rather, they produced a complex mosaic of patches of varying size, shape, and burn severity (Christensen et al. 1989, Turner et al. 1994). Photographs of the post-fire landscape patterns provided striking visual evidence of this spatial heterogeneity (see Christensen et al. 1989 and Turner et al. 2003a). Within the burned area, 50% of the areas of crown fire was within 50 m of green forest, and 75% was within 200 m of a green edge (Turner et al. 1994). Thus, the fires increased landscape diversity within the burn perimeter. In addition, the complex burn mosaic motivated our initial field studies to explore the influence of this post-fire landscape heterogeneity on succession.

Patterns of succession

Plant re-establishment following the 1988 fires was rapid. The fires did not burn deeply into the soil, averaging 14 mm in areas of stand-replacing burn (Turner et al. 1999). The "biotic legacies" that remained after the fires dominated post-fire recovery and generated plant communities similar to those present before the fires. Native perennial plants resprouted from surviving roots and rhizomes in 1989 and flowered abundantly in 1990, resulting in a large pulse of seedling recruitment of numerous wild flowers, grasses, and sedges within the burned area (Turner et al. 1997). Local dispersal from surviving individuals, rather than long-distance dispersal from unburned forest, appeared to be the most important process. Non-native invasive plant species largely did not expand into the burned areas, counter to our initial expectations (Turner et al. 1997).

Seedlings of the dominant tree, lodgepole pine (*Pinus contorta* var. *latifolia*), established abundantly in 1989 and 1990 (Anderson and Romme 1991; Turner et al. 1997; 1999). The spatial variability in the density of lodgepole pine seedlings was particularly noteworthy. Some burned forests had few if any tree seedlings, whereas others had >500,000 seedlings per hectare. We determined that this wide variability in post-fire tree density resulted from two primary causes. First, there exists in Yellowstone considerable spatial variation in the proportion of lodgepole pine trees that bear serotinous cones—an adaptation to fire in which closed cones that are sealed with a resin are retained on the tree for many years, releasing their seeds when heated, as by fire. Lodgepole pine is well known to be a serotinous species, but the variation in this trait across the landscape was surprising (Tinker et al. 1994). Lodgepole pine seedlings were most abundant in locations where pre-fire serotiny was high, and least abundant where pre-fire serotiny was low (Anderson and Romme 1991; Turner et al. 1997; 1999). In turn, the occurrence of serotiny in Yellowstone's lodgepole pine stands varied with elevation, which is correlated with fire return interval. Schoennagel et al. (2003) found a low proportion of trees bearing serotinous cones at high elevations (>2,300 m), where fire return intervals average nearly 300 years. At lower elevations (<2,300 m), where fire return intervals average 170 years, however, the proportion of trees bearing serotinous cones was quite high for stands >70 yrs old.

The second factor influencing post-fire lodgepole pine seedling density was burn severity. Post-fire seedling densities were highest in areas of severe surface fire, where the trees were killed but the needles and cones not consumed by the fire (Turner et al. 1997; 1999). Thus, the landscape mosaic of burn severities had a direct influence on the initial

pattern of stand density after the fire. Collectively, the variation in topography, serotiny, and fire severity resulted in a spatially complex pattern of stand densities initiated by the fires (Turner et al. 2004) that was established soon after the fires. As of 1999, post-fire stand densities of lodgepole pine averaged 29,380 stems ha^{-1} (median of 3,100 stems ha^{-1}). Densities exceeded 20,000 stems ha^{-1} over 20% of the burned landscape; densities were <5,000 stems ha^{-1} over 55% of the landscape. Clearly, the spatial variation in stand structures produced by the fires was substantial. By 2003, many of the trees were highly productive and already producing abundant cones, with cone densities ranging from 4,000 to 4,000,000 cones ha^{-1}. Thus, post-fire tree recruitment was both abundant and rapid.

Trembling aspen (*Populus tremuloides*) is a tree species of concern in YNP and throughout the Intermountain West. Aspen produces clonal stands that may persist for centuries or more, but many authors have noted a decline in the number, extent, and vigor of aspen stands throughout the West (Romme et al. 1995). In 1989, the year after the fires, there was widespread and locally abundant establishment of seedling aspen only in burned forests and well beyond the pre-fire distribution of aspen (Romme et al. 1997; Turner et al. 2003b). This appeared to be an infrequent seedling recruitment event in a long-lived species, and genetic diversity in the seedling populations increased relative to mature aspen stands in Yellowstone (Tuskan et al. 1996; Stevens et al. 1999). As of 2000, the seedling aspen were persisting in many locations, but most stems were not very tall (averaging 30 cm) because of sub-optimal environmental conditions and browsing by native ungulates, primarily elk (*Cervus elaphus*) (Romme et al. 2005).

In sum, vegetation recovery in YNP occurred rapidly and through natural processes. Reproduction by surviving grasses, forbs, and shrubs within the burned area was more important than long-distance dispersal from unburned forests, and exotic invasive species did not establish. Post-fire lodgepole pine establishment was also rapid and abundant, and the spatial patterns of stand density developed early and have persisted thus far. Variation in the occurrence of serotinous cones and burn severity were important controls on post-fire tree recruitment. Establishment of seedling aspen may not be so unusual after all, but recruitment of tree-sized aspen may be rare under current conditions.

Ecosystem function

What are the implications of the spatial variation in post-fire vegetation for ecosystem function? We have addressed several functional indicators in the YNP landscape, including aboveground net primary production (ANPP), leaf area index (LAI), the accumulation of coarse wood (fallen dead trees) after the fires, and rates of decomposition, nitrogen cycling, and microbial activity. We were surprised by the high rates of ANPP that we observed only 10 years after the fires (Turner et al. 2004). ANPP averaged 2.8 Mg ha^{-1} yr^{-1} in 1998, increased with increasing lodgepole pine density, and was as high as 15 Mg ha^{-1} yr^{-1} in some stands. When extrapolated to the entire burned landscape, ANPP exceeded 2 Mg ha^{-1} yr^{-1} across 33% of the area burned, and exceeded 4 Mg ha^{-1} yr^{-1} in 10% of the burned area (Turner et al. 2004). Thus, rates of primary production are being restored rapidly across the landscape.

Although loss of nitrogen (N) following disturbances has been observed in many forested ecosystems (cf. Chapin et al. 2002), changes in N cycling associated with severe, stand-replacing fires have received surprisingly little study (Smithwick et al. 2005a). Studies in YNP have not documented elevated nitrate concentrations in stream water after the fires of 1988 or 1996 (Minshall et al. 2004; Romme and Turner 2004). We observed higher rates of nitrification in soils two years after the 1996 Pelican fire compared to stands that were 10, 120, or >300 years post fire, but rates were still relatively low (Romme and Turner 2004). None of our results to date suggest extensive losses of N following fires in Yellowstone, but ongoing studies will provide much greater insight into these processes.

The trees killed by the 1988 fires began falling noticeably in the mid-1990s, and 74% of the fire-killed trees had fallen by 2003 (unpublished data). There was considerable spatial variability in tree-fall rates, however, with 90% of the trees down in some locations and none in others. Trees were more likely to still be standing at higher elevations and to have fallen down at lower elevations. The fallen trees provide physical structure within the developing forest stands and, as they decay, serve as long-term sources of carbon and nutrients to the soil. However, the downed wood also influences ecosystem processes both within stands and across the landscape. For example, decomposition rates were lower under newly fallen logs that were elevated above the ground and more rapid when associated with "legacy logs" (dead

wood that was present before the fires) (Remsburg and Turner in press). Only 8% of the dead wood that was in the forests prior to the 1988 fires was consumed in the fires (Tinker and Knight 2000), so legacy logs remain an important component of post-fire ecosystems. The recently fallen elevated logs appear to create more spatial variability in microclimates within a stand, resulting in dry soils directly under the elevated logs but moister conditions where the water is channeled down. Microbial communities and the expression of extracellular enzymes also varied with position relative to coarse wood or pine saplings (unpublished data).

The abundant coarse wood and dense pine saplings within the forests burned in 1988 appear to be influencing habitat use patterns of Yellowstone's native elk populations. During summer, elk are preferentially using the burned forests, especially if they are within proximity to non-forest habitats (e.g., meadows) that provide a source of food (Forester 2005, Mao et al. 2005). The dense, young forests may provide cover for the elk and protection from wolf (*Canis lupus*) predation, and they may also make it more difficult for wolves to effectively make a kill. This also suggests that despite what several authors have suggested (e.g., Ripple and Larsen 2001; Turner et al. 2003), the abundant, coarse wood may not protect aspen seedling from browsing if elk preferentially use these sites (Forester 2005). Nonetheless, there may be an important indirect effect of the fires on higher trophic levels.

In summary, ecosystem function in the Yellowstone landscape seems quite resilient to the effects of the 1988 fires. The fires clearly had a significant and quantifiable effect on many ecosystem processes, but ANPP and LAI recovered rapidly, with increasing vegetative cover throughout the burned areas. Our ongoing studies focus on both characterizing and explaining the variability in ecosystem processes through time and across the landscape following stand-replacing fires in YNP.

Long-term trajectories

What happens to post-fire stand structure and function as succession proceeds through time? For how long is the imprint of the 1988 fires likely to persist in the landscape? By studying a chronosequence of 62 lodgepole pine stands across the YNP landscape, Kashian et al. (2005a; 2005b) documented declines in mean stand density and the spatial variability in stand density with increasing stand age. The stands that regenerated following the 1988 fires are of higher mean density and much more spatially variable than older stands, but considerable variation remains in stands that are 125–175 yrs old (mean density ca. 3,000 stems ha^{-1} with coefficient of variation among stands ca. 80%). By 200 years, however, stand density and growth rates converge, and variability declines (mean stand density ca. 1,200 stems ha^{-1} with coefficient of variation among stands ca. 30%). The variability in numerous other functional attributes also changes with stand age. For instance, variation in total soil N and the ratio of fungi:bacteria in the soil have higher variability among stands in younger age classes (Smithwick et al. 2005b). Collectively, these results suggest that fires are a source of significant functional heterogeneity at landscape scales, and that the spatial variation in stand structure and function produced by the 1988 fires may be detectable in this ecosystem for as many as 175 years.

Conclusions

Infrequent but severe stand-replacing fires have long been part of the Yellowstone landscape. The 1988 fires offered an unusual opportunity for scientists to study a rare event, to observe natural processes of recovery at work, and to unravel at least some of the complex mechanisms that underpin the system's resilience. Studies to date indicate that Yellowstone's biota are well adapted to such disturbances. The YNP landscape has demonstrated striking resilience following the 1988 fires. Clearly **not** catastrophes in any ecological sense, the fires were an important source of landscape heterogeneity, producing tremendous spatial variation in forest structure and function throughout the burned areas. The lessons learned from the 1988 fires should provide valuable data for land managers in the Greater Yellowstone Ecosystem, and may also apply to other forests characterized by natural, stand-replacing fire regimes. "Natural laboratories" like YNP are invaluable systems in which to study for such research, providing a baseline of understanding of disturbance and recovery that may help interpret the effects of large, infrequent disturbances in other locations. As succession continues on its course, subsequent studies of the patterns and processes associated with the 1988 fires are likely to continue producing new insights into the structure and function of this dynamic landscape.

Acknowledgements

Dr. Turner thanks the organizers of the 2005 science conference in Yellowstone National Park

for the opportunity to present a keynote address and contribute this paper. We are indebted to the many individuals who have worked as part of our field crews during the past 17 years and to the very capable collaborators, graduate students, and post-docs with whom we have been so fortunate to work. In particular, we thank Bob Gardner, Dennis Knight, Mike Ryan, Dan Tinker, Jerry Tuskan, Don Despain, Linda Wallace, Tania Schoennagel, Dan Kashian, Creighton Litton, Erica Smithwick, Kris Metzger, Michael Stevens, James Forester, and Alysa Remsburg. The YNP staff have always been very helpful, and we appreciate their consideration and support. We are extremely grateful to the following agencies for funding our research on fire, vegetation, and ecosystem processes in the Yellowstone landscape: National Science Foundation (Ecology and Ecosystem Studies Programs); USDA NRIGCP Forest/Crop/Range/Aquatic Ecosystems Program; Joint Fire Sciences Program; National Geographic Society; University of Wyoming–National Park Service Research Center's Small Grants Program; and the Andrew W. Mellon Foundation.

References

Anderson, J. E., and W. H. Romme. 1991. Initial floristics in lodgepole pine (*Pinus contorta*) forests following the 1988 Yellowstone fires. *International Journal of Wildland Fire* 1:119–124.

Bessie, W. C., and E. A. Johnson. 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. *Ecology* 76:747–762.

Chapin, F. S. III, P. A. Matson, and H. A. Mooney. 2002. *Principles of terrestrial ecosystem ecology.* New York: Springer-Verlag.

Christensen, N. L., J. K. Agee, P. F. Brussard, J. Hughes, D. H. Knight, G. W. Minshall, J. M. Peek, S. J. Pyne, F. J. Swanson, J. W. Thomas, S. Wells, S. E. Williams, and H. A. Wright. 1989. Interpreting the Yellowstone fires of 1988. *BioScience* 39:678–685.

Flannigan, M. D., and B. M. Wotton. 2001. Climate, weather and area burned. Pages 351–373 *in* E. A. Johnson and K Miyanishi, eds. *Forest fires*. New York: Academic Press.

Forester, J. D. 2005. Multi-scale resource selection in heterogeneous landscapes: effects of forage, predation and disturbance on habitat use by elk in Yellowstone National Park, USA. Ph.D. dissertation, University of Wisconsin–Madison.

Johnson, E. A. 1992. *Fire and vegetation dynamics*. Cambridge University Press, New York.

Kashian, D. M., M. G. Turner, and W. H. Romme. 2005a. Changes in leaf area and stemwood increment with stand development in Yellowstone National Park: relationships between forest stand structure and function. *Ecosystems* 8:48–61.

Kashian, D. M., M. G. Turner, W. H. Romme, and C. J. Lorimer. 2005b. Variability and convergence in stand structure with forest development on a fire-dominated landscape. *Ecology* 86:643–654.

Mao, J. S., M. S. Boyce, E. H. Merrill, D. W. Smith, F. J. Singer, D. J. Vales, J. M. Vore, and E. H. Merrill. 2005. Habitat selection by elk before and after wolf reintroduction in Yellowstone National Park. *Journal of Wildlife Management* 69(4):1691–1707.

Millspaugh, S. H., C. Whitlock, and P. J. Bartlein. 2000. Variations in fire frequency and climate over the past 17,000 years in central Yellowstone National Park. *Geology* 28:211–214.

Millspaugh, S. H., C. Whitlock, and P. J. Bartlein. 2004. Postglacial fire, vegetation and climate history of the Yellowstone–Lamar and Central Plateau Provinces, Yellowstone National Park. Pages 10–28 *in* L. L. Wallace, ed., *After the fires: the ecology of change in Yellowstone National Park*. New Haven: Yale University Press.

Minshall, G. W., T. V. Royer, and C. T. Robinson. 2004. Stream ecosystem response to fire: the first ten years. Pages 165–188 *in* L. L. Wallace, ed., *After the fires: the ecology of change in Yellowstone National Park*. New Haven: Yale University Press.

Remsburg, A. J., and M. G. Turner. In press. Amount, position and age of coarse wood influence litter decomposition within and among young post-fire *Pinus contorta* stands. *Canadian Journal of Forest Research*.

Renkin, R. A., and D. G. Despain. 1992. Fuel moisture, forest type and lightning-caused fire in Yellowstone National Park. *Canadian Journal of Forest Research* 22:37–45.

Ripple, W. J., and E. J. Larsen. 2001. The role of postfire coarse woody debris in aspen regeneration. *Western Journal of Applied Forestry* 16:61–64.

Romme, W. H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. *Ecological Monographs* 52:199–221.

Romme, W. H., and D. G. Despain. 1989. Historical perspective on the Yellowstone fires of 1988. *BioScience* 39:695–699.

Romme W. H., and M. G. Turner. 2004. Ten years after the 1988 Yellowstone fires: is restoration needed? Pages 318–361 *in* L. L. Wallace, ed., *After the fires: the ecology of change in Yellowstone National Park.* New Haven: Yale University Press.

Romme, W. H., M. G. Turner, R. H. Gardner, W. W. Hargrove, G. A. Tuskan, D. G. Despain, and R. A. Renkin. 1997. A rare episode of sexual reproduction in aspen (*Populus tremuloides*) following the 1988 Yellowstone fires. *Natural Areas Journal* 17:17–25.

Romme, W. H., M. G. Turner, G. A. Tuskan, and R. A. Reed. 2005. Establishment, persistence and growth of aspen (*Populus tremuloides*) seedlings in Yellow-

stone National Park. *Ecology* 86:404–418.

Romme, W. H., M. G. Turner, L. L. Wallace, and J. Walker. 1995. Aspen, elk and fire in northern Yellowstone National Park. *Ecology* 76:2097–2106.

Schoennagel, T., M. G. Turner, and W. H. Romme. 2003. The influence of fire interval and serotiny on postfire lodgepole pine density in Yellowstone National Park. *Ecology* 84:1967–1978.

Smith, C. 1996. Media coverage of fire ecology in Yellowstone after 1988. Pages 25–34 *in* J. Greenlee, ed., *The ecological implications of fire in Greater Yellowstone*. Proceedings of the Second Biennial Scientific Conference on the Greater Yellowstone Ecosystem. Fairfield, Wash.: International Association of Wildland Fire.

Smithwick, E. A. H., M. G. Turner, M. C. Mack, and F. S. Chapin, III. 2005a. Post-fire soil N cycling in northern conifer forests affected by severe, stand-replacing wildfires. *Ecosystems* 8:163–181.

Smithwick, E. A. H., M. G. Turner, K. L. Metzger, and T. C. Balser. 2005b. Variation in NH_4^+ mineralization and microbial communities with stand age in lodgepole pine (*Pinus contorta*) forests, Yellowstone National Park (USA). *Soil Biology and Biogeochemistry* 37:1546–1559.

Stevens, M. T., M. G. Turner, G. A. Tuskan, W. H. Romme, and D. M. Waller. 1999. Genetic variation in postfire aspen seedlings in Yellowstone National Park. *Molecular Ecology* 8:1769–1780.

Tinker, D. B., and D. H. Knight. 2000. Coarse woody debris following fire and logging in Wyoming lodgepole pine forests. *Ecosystems* 3:472–483.

Tinker, D. B., W. H. Romme, W. W. Hargrove, R. H. Gardner, and M. G. Turner. 1994. Landscape-scale heterogeneity in lodgepole pine serotiny. *Canadian Journal of Forest Research* 24:897–903.

Turner, M. G., and W. H. Romme. 1994. Landscape dynamics in crown fire ecosystems. *Landscape Ecology* 9:59–77.

Turner, M. G., W. H. Hargrove, R. H. Gardner, and W. H. Romme. 1994. Effects of fire on landscape heterogeneity in Yellowstone National Park, Wyoming. *Journal of Vegetation Science* 5:731–742.

Turner, M. G., W. H. Romme, and R. H. Gardner. 1999. Prefire heterogeneity, fire severity and plant reestablishment in subalpine forests of Yellowstone National Park, Wyoming. *International Journal of Wildland Fire* 9:21–36.

Turner, M. G., W. H. Romme, R. H. Gardner, and W. W. Hargrove. 1997. Effects of fire size and pattern on early succession in Yellowstone National Park. *Ecological Monographs* 67:411–433.

Turner, M. G., W. H. Romme, R. A. Reed, and G. A. Tuskan. 2003b. Postfire aspen seedling recruitment across the Yellowstone (USA) landscape. *Landscape Ecology* 18:127–140.

Turner, M. G., W. H. Romme, and D. B. Tinker. 2003a. Surprises and lessons from the 1988 Yellowstone fires. *Frontiers in Ecology and the Environment* 1:351–358.

Turner, M. G., D. B. Tinker, W. H. Romme, D. M. Kashian, and C. M. Litton. 2004. Landscape patterns of sapling density, leaf area, and aboveground net primary production in postfire lodgepole pine forests, Yellowstone National Park (USA). *Ecosystems* 7:751–775.

Tuskan, G. A., K. E. Francis, S. L. Russ, W. H. Romme, and M. G. Turner. 1996. RAPDs demonstrates genetic diversity within and among aspen populations in Yellowstone National Park, USA. *Canadian Journal of Forest Research* 26:2088–2098.

Well-behaved Scientists Seldom Make History

Karen Wade

Former Intermountain Region Director, National Park Service

Morning Keynote, October 17, 2005

Karen Wade retired in 2003 as director of the Intermountain Region, National Park Service, and currently resides near Glacier National Park, Montana. Her NPS career began in 1960, as a radio dispatcher at Mesa Verde National Park, and eventually led to assignments as superintendent of Fort McHenry National Monument and Historic Shrine, Guadalupe Mountains National Park, Wrangell-St. Elias National Park and Preserve, and Great Smoky Mountains National Park. Karen currently serves on the board of the Sonoran Institute, and is one of the founders of Earth Care Connection, USA, a mentoring organization for women in conservation. Throughout her career, Karen has emphasized the importance of developing and nurturing professional relationships across the full conservation community, and involving local communities in park management dialogue. She was a member of the team that developed the Natural Resource Challenge for the National Park Service.

Note: The text that follows is an edited transcription of Ms. Wade's remarks at the conference.

Good morning. I haven't been the center of attention for two years! When the planning team asked me to come to speak with you today, I was very, very pleased to have that opportunity. I was pleased to have the opportunity to speak anywhere, to tell you the truth. It's an interesting transition to go from being the center of the vortex to being spun outside the vortex and to spending a whole lot of time with yourself—time that you haven't had for a long time—I think. When Paul [Schullery] called to ask me to speak, I thought maybe the word just hadn't gotten up to Yellowstone yet that I'd retired. It's been a really special treat, too, to sit here and listen to some of my modern-day heroes speak and inspire, do a little bit of coaching and sharing, because basically I think that's what a conference ought to be about: the interchange that occurs between the participants. And I hope you've had as great a time as I've had. I've certainly enjoyed it. It's been something that all of the organizers here can be very proud of. Congratulations.

And I also couldn't help but reflect, as I sat here, about the efforts that you've made during this conference to honor the [U.S.] Forest Service. I started out working on a really tough project, the Appalachian Trail project in the East. Our responsibility was to protect the Appalachian Trail from Maine to Georgia. And if it had not been for my forest service colleagues who worked right alongside me in some of the toughest places in Virginia and Pennsylvania, I would never have been successful in providing the right of way for the trail across some of the really tough valley crossings in Virginia. So I have great experience with forest service colleagues and I think it's wonderful that you've chosen this time to honor some of the leaders of the forest service and have them here. And I know they're engaged every day in work that you do.

I also was struck by the words of [National Elk Refuge Manager] Barry Reiswig, and I love these words: he said there is something special about this place. It's truly magnificent, truly awesome. And that's why I chose, after being a vagabond for 40 years, moving around the country and the world, to make my home in Montana. . . . I'm very, very happy to have found the last best place to settle down. In doing that, I also feel like I have a responsibility, and that responsibility is to continue to assure that it remains the last best place. So it's been my pleasure to engage in Montana and to be a part of trying to find the solutions to many of the opportunities and issues that we have here.

I also wanted to provide you with a little bit of perspective that I gained along the way, particularly in the Great Smoky Mountains National Park. I know this ecosystem is a bit different, but just picture a summer day in 1995, in Great Smoky Mountains National Park. I'm the superintendent, but on this particular day I happen to be with a group of park employees and a number of volunteers from Trout Unlimited. We're in a remote part of the park, doing a very important project of fish restoration. On this particular day we're taking tanks on our backs, hiking

up to the very high waters in one of the valleys there, and catching fingerlings—putting them in the tanks and hauling them to another section of the park. As some of you may know, the brook trout in Great Smoky Mountains National Park are sandwiched at high elevations between the encroaching brown trout and rainbow trout at the lower elevations, and the pollution that's descending from the higher elevations. Their range is beginning to dwindle and decline. So the challenge is to take these fish and begin to put them at locations where they have a chance of populating new streams. Where are those streams? Well, they are streams that in the early 1900s, before the creation of the park, were destroyed—where all life was destroyed by the logging activities that took place there. So the logging had removed all life from these streams, and our job now was to take these little fingerlings, these little brook trout, and put them in those streams and begin to restore brook trout into the Great Smoky Mountains National Park on a level that had never been tried before.

Much of the fisheries work that gets done in the Great Smokies is done by volunteers—by Trout Unlimited. On that particular day we spent a very long, hard day doing this task. And at the very end of it, as we were hiking up the last grade, beside me was this wonderful man who spent the whole day carrying this tank of little fish. I said to him, "You know, you really look exhausted. Why don't you let me carry that tank for just a little bit? Just let me give you a little break, or we can sit down here and rest a little bit." And he looked at me with tears in his eyes, and he said to me, "You know, Karen, I can't rest until this job is done." He said, "My grandfather was a logger here in Great Smoky Mountains, and he was a contributing factor to what happened to the decline of the native brook trout in this area and the decline of this place." And he said, "It's my responsibility today to be a part of this effort and to make sure that these fish get to their new home. It's my responsibility to make sure that these fish are a part of the future of Great Smoky Mountains National Park, and not only that I remember that, but that my children remember that."

So I kind of flashed back on a story that I had used just a few days earlier in a speech. In that speech, I had spent some time talking about Aldo Leopold's clock repair story. Do you all know that story? Leopold wrote that if you're going to take a clock apart, the first rule of intelligent tinkering is to save all the parts. Makes sense, doesn't it? Leopold used his clock repair story, as you probably know, as a way to get others to envision the ecological complexities of the landscapes within which we live. Without understanding, and with[out] all the pieces, we cannot ever expect to fix that which is broken.

As I left our fish restoration project that day, I couldn't help but think what a privilege it was to share time with a citizen who not only understood the task we were involved with, but also the bigger idea. He clearly knew that if we lost the native brook trout in this system, we would have very little chance to fix and to maintain the systems that sustain all life—and quality of life and experience—for humans in that ecosystem. Importantly, he not only appreciated it, but also was willing to devote his time and energy to that project.

We'll fast forward maybe just a year, to another experience in the Smokies that kept my thinking going. I was hiking up Greenbrier in the park not very far from my home, one of the prettiest spots on Earth, I must say, in the spring. Wildflowers all over the place. Just kind of poking along trying to restore my soul and say, "oh yeah, you know, being a superintendent isn't too bad, especially on days when I can get out of that office." And I'm poking along and there's an older gentleman along the trail, kind of sitting there on a log. And I say hi and just pass some pleasantries with him, and then I continue on up the trail a ways and spend probably another hour or so just poking around. And then I come back down and he's still there. And being the service person I am, I thought, well, you know, he doesn't know I have anything to do with the park service, but I really have a responsibility to just check on him and see if he's okay, because he was quite an elderly gentleman.

So I said, "How are you doing; are you enjoying the day? Beautiful, isn't it? You want to walk on back down the trail with me?"

"Oh, no, I got a job to do."

I thought well, gee, that's interesting.

"What kind of a job do you have to do here?" I asked.

"Well, I'll tell you about it because it looks to me like you're mighty interested in these flowers along here."

"Yeah, I am mighty interested in these flowers along here; they sure are beautiful, aren't they?"

"Yeah, they're beautiful, and they're also precious." Well, that's right—I can identify with that. They are precious.

"What do you do?" he said.

"Well, I work for the park, and I think they're precious, too. I really enjoy sharing this day with you

and being up here; isn't this the prettiest spot on the earth?"

He allowed as how it was, and then said, "Well, I want to tell you something. If you work for the park, I want to just share something with you. Now, this is a secret."

"I like secrets, so go ahead—what did you want to tell me about?"

"Well, I've been keeping an eye on a plant here for about 20 years. It's a really special plant. The park doesn't even know it's here; those park people, they don't know very much, you know. But I know it's here. Do you want to see it?"

"I sure would like to see it."

So he moved over a few feet from where he was sitting and kind of brushed the leaves out of the way, and here's this beautiful little wildflower, an anemone of some kind. And he pulled out of his pocket this little packet of papers, and I could see there was writing, little teeny-tiny writing, on these sheets of paper.

And he said, "It bloomed 10 years ago on (this day); first time it bloomed was 10 years ago. The first time, the earliest it bloomed was 10 years ago and on (this day). And last year it bloomed on (this day)." And he went on and showed the annotations that he had made over the course of many, many years about this one plant. "I've done a lot of research on it. It doesn't exist anywhere else in the Great Smokies."

"Well that's very interesting, very fascinating."

That conversation stuck with me. I went back to the office, back to the botanist, and I said, "Tell me about this flower."

"Oh, it doesn't exist in the Smokies."

"Well, let me tell you, I don't know if I can find it again, and it's covered up with leaves, but I know it's here. I know it's here."

So when I was asked to speak at this conference, I reflected on the conference theme, "Greater Yellowstone Public Lands: A Century of Discovery, Hard Lessons, and Bright Prospects," and what that means for science and scientists. I thought of my own involvement, since 1978, as a land manager, and I again thought about the Smokies, and I thought about brook trout restoration, elk reintroduction, all the things we had going on there, and all the things that I've been exposed to in this region that are associated with saving all the parts, and keeping all the pieces. And I thought about citizen stewardship and this man who devoted his life to protecting this flower in Greenbrier. I hope he's still alive—and if he's not, I hope he's passed along his responsibility to somebody else. And I thought about the lasting consequences of some of the things we learn as we go along.

We had an opportunity in the Great Smokies, at one point in time, to take advantage of the fact that we had citizen involvement and commitment and dedication, and we had an ecosystem where the parts and pieces were going to remain parts and pieces until they were lost if we didn't do some major efforts. And so in 1999, we began the first-ever all-taxa biodiversity inventory [ATBI], conducted under a nonprofit we formed called Discover Life in America. Some of you have probably heard of this. The idea—a pretty broad idea—was to inventory all of the more than 100,000 species of life in Great Smoky Mountains National Park. The framework of Discover Life wasn't just the collection of data, which would be done by scientists, our staff, volunteers—whoever we could mobilize to do that under protocols established for the purpose of doing it comprehensively—but also the education associated with what we were learning. That education would be done by instructors that we would bring in, [with] their students. However we could get a curriculum set up and going, we would be doing that. The goal was to excite, engage, and involve everyone possible—anyone who wanted to—in a voyage of discovery. A scientific inquiry with a depth of understanding not previously known about any place on the planet. Think about that. That is a grand adventure, wouldn't you say? A new frontier. Learning things in depth. We've already known the broad picture of things. But how much do we know in depth? And as we inventoried and looked at every single thing we found, we would then begin to study the inner relationships of those things that live in one place on the planet.

To date, because of the all-taxa biodiversity inventory in Great Smoky Mountains (if you go to the website <www.dlinamerica.org>, you'll learn what's happened since 1999), 565 species new to science have been discovered in the Smokies. [To repeat,] 565 species **new to science** have been discovered in the Smokies, largely through volunteer efforts. Three thousand five hundred sixty-seven—it's probably more today than it was yesterday, when I found these figures—3,567 species previously not known to inhabit the park were located. And I'll never forget the day that one of my staff people walked in with this worm that was about (this long, and big around,) and said, "Guess what, we have a new species not known to science." But it was known to the maintenance people who'd worked in the park for years. They

didn't know the name of it, but it was "that worm." Sixty-seven species of algae not previously known to science have been discovered.

The Smokies project also spun off the education components that we were able to get funded later under a National Park [Service] initiative called the Natural Resource Challenge. So the education component (and I wish I could quote such precise statistics about the success of that) has really prospered and grown, and is an amazing thing in the Smokies. But it's also been spun off into other areas of the system. The Smokies project of inventorying has now spun off into the Adirondacks. The Tennessee state parks are doing comprehensive inventory surveys utilizing volunteers; Point Reyes, in the [National] Park System; Rock Creek Parkway; Boston Harbor Islands. And I have to say—I know very well [that] here [in Yellowstone], you're not going to say you spun anything off the Smokies—but I know [that] here, [former Yellowstone Center for Resources chief] John Varley and [current chief] Tom Olliff and perhaps many of you have done the greatest microbe inventories ever done—something to be extremely proud of—and probably a lot of other things I don't know anything about.

Now one might ask here today, why put all this time and energy into such an ambitious project at a time when resources are hard to get and there's already more work [to do] than you can ever possibly imagine? Your staff's overloaded. Do they need another thing to do? I don't think so. [So] why do something so ambitious? And I think—to get back to the reason you asked me to come here—the reason relates to the "hard lessons and bright prospects" part of our discussions here this week, and our responsibility as individual scientists, conservationists, public land managers, educators—whatever we are here today. As others have noted during this conference, we know the Yellowstone region has experienced at least a 62% increase in population between 1970 and 2000. And that the amount of developed land in rural areas has grown by 365%. I don't know who did that calculation [but s]omewhere around 365% is a lot of conversion, I would say. If we forecast the rate of development at its fastest-growing scenario, nearly all unprotected lands on private lands would experience some development in the next four years. Whew! Think on that. I live up near Kalispell. Have any of you been up there recently? Some of you live up near there, probably. I don't know. I bought land up there in 1999 to vacation on, and of course it hooked me. I'm up near the Canadian border, a ways away from that, but I have to drive through Kalispell on a regular basis. I have never seen anything like the conversion of land there. It is incredible. And it's not slowing down one iota. The question is not whether we'll have growth in Montana or in the Yellowstone region, but how. [Again, i]t's not whether, it's how. And how it experiences that growth will very much determine the fate of the life sustained on our public lands.

So back to the question: why would we do an ATBI in the Smokies at a time when we're flat broke, the region's growth was clearly overwhelming and choking the life out of the park, and we couldn't even begin to get all the existing workload done? Well, I went back to my friend who's the coach and the connecter, the staff person in the Smokies responsible for the direction of the ATBI. His name is Keith Langdon; some of you know him. I said, "You answer that question—why would we do that?" He said, "At the time I thought you were nuts. I thought you were out of your mind." And I'm not sure I yet have the words, although [Keith], like John Varley, is becoming very articulate and eloquent about why we're doing what we're doing. [But essentially] he said, using citizens, park staff, scientists, and educators in activities together, [we've discovered] . . . undescribed, rare, beautiful, newly arrived exotic organisms. All of that's true, all those wonderful things. But together we've [also] created new ideas. The synergy of studying these things together, finding them, discovering them, being together in this project of discovery, has created pride of ownership and newly won respect for this park by its citizens. The reason, then, [is] the new frontier—the great adventure of it, respect for resources, citizen engagement and commitment in things that matter, things that have to do with the home place, the place that we cherish, the place we have a passion for.

And what's the end result in the Smokies? What do you know the Smokies for? The most heavily visited national park in the system? I'll tell you what it is today. There are lots of words for it, but "one of the most precious life reservoirs on the planet—" how does that sound? And it's not just that to me; it's that to a lot of people. Quite a contrast between those two definitions.

In a nifty little book that I pick up from time to time called *The Pleasure of Finding Things Out*, physicist Richard Feynman talks about both the value and the meaning of science. According to Feynman, scientific knowledge enables us to do and make all kinds of things. It's an enabling power. [At] the

other extreme, it can be a destructive power. But we know it is an enabling power. It gives us access to the fun of intellectual enjoyment. Why do you think people with the great minds do this stuff? Why do you think John Varley's dedicated his whole life to this? Why do you think Karen Wade dedicated her whole life to this? It's the fun! It's the great adventure! As Feynman says, with more knowledge comes deeper, more wonderful mystery, luring us to penetrate deeper and deeper, never concerned that the answer may prove disappointing. With pleasure and confidence we turn over each new stone (or leaf, as it may be) to find unimagined strangeness leading on to more wonderful questions and mysteries. Certainly a grand adventure, as Feynman says. I've read few books, seen few photographs or paintings, and heard no poems that explicitly talk about that grand adventure. And within a government agency, and in scientific forums such as this, even those of us who've had such grand adventures don't talk about them in such language.

So what about the value of science from the standpoint of the grand adventure—the journey to the understanding of big ideas, such as those of my friends in Trout Unlimited? Those of you who have children, and those of you who have a child inside of you, know of what I speak. It's the catching onto the ideas that makes a scientist, a poet, an artist, a conservationist, a photographer, a public servant. Do we presume here that someone else will create the next generation of scientists and conservationists? I hope not. It gets us to the question of what our responsibilities are. And what you study is critically important to share. Maybe that is the most important responsibility you have. You accumulate knowledge and understanding of how the physical world behaves. It's a complex place, right? And man, if you listen to the talks this week, the degree to which we can analyze and look at things, dissect them, penetrate them, get to the depths of them, is tremendous these days. We have tremendous capacity. The other night we were talking about what a pleasure it is to go to one of these [conferences] and watch the computers transform our presentations—in our early days, before overheads, we had filmstrips! Some of you in this room, I know, have seen filmstrips, and then we went to overheads, and man, those were painful things to sit through, let me tell you! And now we're getting to the point where the degree of sophistication we have [is] amazing. You can build a tree out of this data and make it look pretty exciting, I must say. The context in which you are making this contribution is hugely important for people to understand as we march inexorably forward into the future. How do we communicate that knowledge and understanding? How do we do it in ways that people can understand? They do deserve to understand it, don't they? Don't you want them to take this grand adventure, too? Don't you want them to get hooked on the highs of what you do?

Well, what are the key messages, the grand messages that come out of this conference this week? Have you written some of them down? Did they just kind of hit you, like, "wow, that is really neat"? And do you have amongst you someone sitting here that can go to that newspaper tomorrow and talk about something besides fire? Right? So is there sitting amongst us here someone who can take that grand mystery, that grand journey that we're on, and put that into language that can reach everyone who reads the newspaper, or everybody who sees the television? Distill the message. Simplify it. Make it relevant. Relate it to the big picture. Study the fine art of public speaking. (And public swimming!)

One of the great units in the Intermountain Region of the National Park Service is in Santa Fe. The unit is called the submerged resources unit. They're divers and scientists, and these people go around the world diving into the waters, finding the treasures, the mystery, the stories, and speaking of them into cameras that are broadcast with the stories across the country into classrooms, [and] wherever [else] the stories can be captured and told. Now I don't think those people, when I first went to Intermountain Region, had any idea that their job was to look into that camera, [or to] point at this thing [or that] later on, in a voice over, describing what it is and what its value is and why we need to know more about it. They never saw themselves as TV personalities, I can tell you, but they're getting mighty good at it, and if you catch one of them one day on public television, you're going to be very impressed.

In the Smokies we believed that it is the duty of every individual there to begin to tell the stories of the kinds of things that are going on. Every program there is open to volunteer effort and citizen involvement, and the ATBI is only one part of the many things like that in the Smokies. I just choose the Smokies as an example; when you become a regional director, you're not supposed to speak eloquently about other people's programs or take any credit for them. And I'm not going to take any credit for what goes on here in this ecosystem. But I can take credit for the fact that I learned some mighty lessons from

my experience.

A friend of mine, a very dear friend of mine, my primary mentor who died just a few years ago, always used to answer the question, "what's the value of parks?" (and he could have been saying "public lands") by saying [that they] are the university system of the planet. I've only just begun to fully appreciate what he meant when he said that. I can say with confidence, before you here today, that if you were asked, "what is the value of Yellowstone's public lands?" you would agree—we would all agree—that [they're] part of that great university system of the planet. And you here in Yellowstone have a platform for that that is greater than [that of] any [other] park in the system, greater than any unit amongst the agencies that are part of this ecosystem. Even more important, these lands are the incubators of great ideas and great adventures. People become more fervent and impassioned when they engage in the exploration of new frontiers and new ideas. It's not just the experience of seeing an elk, or seeing a bison; it's the experience of understanding the being of an elk or a bison and the relationship of life in this ecosystem.

I don't really think I need to remind you that our interests in these public lands for their relevance to science and education are not the interests shared by others, or by everyone. Never in my lifetime have public lands been so up for grabs for purposes that are the antithesis to their preservation for the purposes of knowledge and understanding. This is a political fight that most of you cannot engage in. What you can do, however, is consider a message on one of my favorite t-shirts. And I brought my favorite t-shirt. There is a quotation on here. And if you remember, [earlier in the conference, former Yellowstone superintendent] Bob Barbee said something about "adventuresomeness in bureaucracies may not be appreciated—" something like that. Well, I sort of disagree, and he's not here so he can't defend himself, and I can say anything I please! So I'm not so sure that we want to stay too tied to that historical perspective. I think adventuresomeness, as long as we treat it as a contagious disease, is a good thing. My favorite t-shirt quotation is (some of you would already guess, I think. I wear this up at the ranch all the time. It just really shakes up my neighbors): "Well-behaved women seldom make history." Some of you are wondering, "what the heck has that to do with me?" But I would adapt it to this audience, and if I could have found a place that had these letters en route here, I would have had another one made up, and it would say, "Well-behaved scientists seldom make history."

So with that in mind, get to work. Find a way to take people on a grand adventure, engage them in ideas, at times kind of inoculate them with adventure and ideas. Share the mystery and the wonder of what you do, and do it in ways that can engage them, involve them in your projects, in your fieldwork, whatever you're doing. Let them become involved. If you're successful, I can guarantee that how the Yellowstone region grows will be dramatically different in the future than how it has grown in the past.

The other day I got a news clip in an envelope from Great Smoky Mountains National Park. Gatlinburg [Tennessee] (if you've never been there, you should go—once, anyway) and the park have jointly funded a wildlife biologist to work full-time on bear issues associated with the community of Gatlinburg. Never would I have believed that. In fact, I almost fainted when [Gatlinburg] passed a proclamation requiring that people take care of their garbage—a garbage ordinance of some kind. But that's the kind of thing that can happen: citizen commitment. Concern that extends well beyond the kind of concerns that we have as stewards.

In conclusion, people do care about the quality of their lives. People do care what happens to their home places. People from the Smokies to Yellowstone to Point Reyes are looking for a better future, one with healthy landscapes full of mystery, vibrant economies, and livable communities. As scientists, resource managers, educators, citizens, we must work together to find the necessary hooks that provide the opportunities for people to fully engage in our passion for this place. I don't believe there's anything you can do that's more important or more necessary at this time in our nation's history. And what's the worst that can happen? You might be known as the scientist who is not well-behaved.

Thank you.

Spatial Distribution of Snow Properties to Enhance Our Understanding of Snow–Elk Relationships, Northern Elk Winter Range, Yellowstone National Park

Mark Williams

University of Colorado, Institute of Arctic and Alpine Research (INSTAAR), Campus Box 450, 1560 30th Street, University of Colorado, Boulder, CO 80309 (303-492-8830, markw@snobear.colorado.edu)

Craig Anderson

INSTAAR, University of Colorado, CB 450, Boulder, CO 80309 (cranders@colorado.edu)

Robert Crabtree

Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59718 (406-556-1414, crabtree@yellowstoneresearch.org)

Abstract

Winter severity is the primary control on elk mortality in the northern elk winter range of Yellowstone National Park (YNP). Our ability to measure and model snow parameters that control elk mortality has not kept pace with recent improvements in measuring elk movements at high spatial and temporal resolution, such as collared tags with GPS units. Here, we evaluate the development of a spatially-distributed snow model based on parsimonious data requirements to improve our understanding of snow–elk interactions on the northern range. We spatially distributed the 1-d SNTHERM point model in the Crystal Creek drainage of YNP by classifying the study area into 30 discrete regions using a combination of elevation, aspect, and landcover type (based on 1,200 snow depth measurements), with elevation having the largest effect on snow water equivalent (R^2 = 0.45). A regression analysis shows that modeled estimates of snow depth, density, and water equivalent were highly correlated with results from monthly snow pits in each region (R^2 ranged from 0.91–0.94, all slopes near 1). A comparison of our daily snow water equivalent measurements from SNTHERM to SNOTEL sites at Canyon and the Northeast Entrance showed an R^2 of about 0.95 for both SNOTEL sites, suggesting that we may be able to estimate the spatial distribution of snow properties over the northern elk winter range domain from historical records of point measurements at SNOTEL sites. These results show that we can obtain detailed information on snow properties at hourly to daily resolutions on the spatial scale of tens of meters.

Note: The text that follows is an edited transcription of Dr. Williams's remarks at the conference.

We're going to chat some more about snow. This is work done by my co-authors, Craig Anderson, who did this for a Master's thesis, and Bob Crabtree from YERC [the Yellowstone Ecological Research Center]. . . . [W]e know . . . that snow is a major control on elk, so the amount of snow, the duration of snow, the extent of snow, [all have] a big effect on elk populations. In fact, if you look at the elk literature, the main control on elk mortality is winter severity. Right? And everybody knows what winter severity is, correct? So let me give you the definition of winter severity right now, because I chat with a lot of people, and everybody I talk to [has] sort of a different impression. So how many of you know what pornography is? You can't really define it, but you know it when you see it, right? Winter severity is sort of that way. And we're trying to get a little bit more detail of what it means when we say that there's a "severe winter" and there's high elk mortality because of it.

The snowpack is composed of a lot of different properties. The depth . . . [and] . . . density [of the snowpack] . . . have different effects on elk locomotion and energetics. The stratigraphy is particularly important to snow–elk interactions. How many of you have gone skiing or snowboarding or snowshoeing? [Depth, density, and stratigraphy] all affect

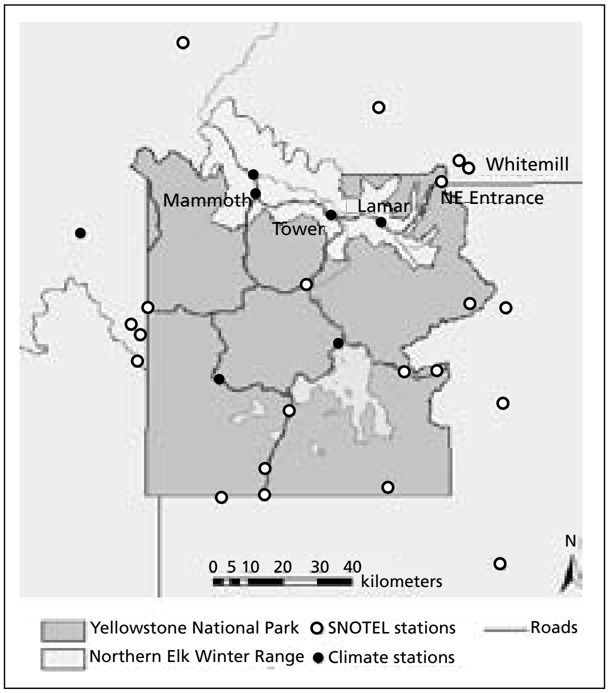


Figure 1. Study area: northern elk winter range, Yellowstone National Park.

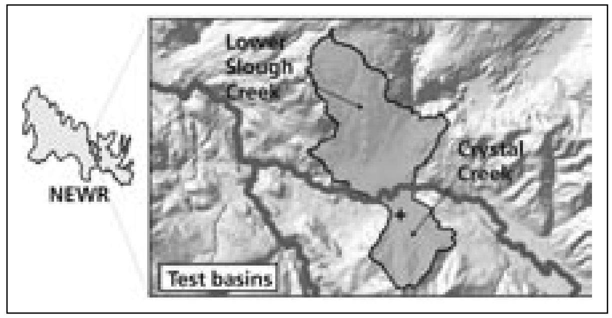


Figure 2. Test basins.

your ability to move around in the snow, don't they? And they affect elk. If you have a crust layer on the snowpack that can support the weight of a wolf but not that of an elk, an elk's going to sink and flounder, but a wolf's going to be able to move really easily and the kill ratio goes up quite highly. It's really hard to get that information, and so we're trying to come up with some techniques to allow us to model things like snow depth, density, stratigraphy, and snow water equivalent (SWE), which is the amount of water you get if you melt the snow—the depth of water—to figure out what the elk would be doing [under certain conditions], what would happen to them.

Why do we need the model? [Because physical sampling of snowpack characteristics is logistically impossible, models are needed to effectively characterize snowpack properties over large spatial domains.] It sounds like we take a lot of snow measurements, right? We've got the SNOTEL site, [which is] really comprehensive. In Colorado, we measure snow with one measurement site every 893 square kilometers; that's essentially an 8 × 4 sheet of plywood about every 1,000 square kilometers. That's not very high density. But the elk see a lot finer resolution than that. So what we're going to try [to do] is take this very low resolution data and provide a high spatial resolution model.

This is our domain right here (Figure 1). The northern elk range is [represented by the light color] on the top. . . . [T]he dots are SNOTEL sites [and climate stations]; there are no SNOTEL sites in the winter elk range. So even though we know snow and winter mortality is a main control on elk, there are no SNOTEL sites [in their winter range]. So that makes life a little difficult. So . . . we [came] up with research in two test basins (Figure 2). The main one is Crystal Creek, up on the road . . . to Lamar River. The Crystal Creek basin is where the [park] did the initial wolf release, and it's pretty representative of the type of habitat [on] the northern elk range. We [also] include a part of Slough Creek, so we have some southern exposures, as well.

[When we collected our] field data, one thing we did was [to take] very high-resolution measurements of snow depth. On one survey we took 1,200 measurements of snow depth in five square kilometers, and we registered each point with a GPS unit—pretty high spatial resolution. So we have very good measurements of what the snow depth was at that time, and that's part of this modeling technique that I'll explain. We took monthly snow-pit [measurements] at 30 different sites. . . . At each of those snow pits, we measured depth, density, stratigraphy, snow water equivalent, temperature, grain size, etc., and that's a lot of work. That's what graduate students are for. So Craig did all that!

Then we still needed higher-resolution meteorological data, because that's what drives the model that I'm going to talk about. And so we had to put up our own climate station, because Yellowstone National Park doesn't collect that type of information. So that went up at Crystal Creek, and I want to thank the park service for facilitating the permitting process to allow us to put up that climate station.

The winters [when we took our measurements], 2003 and 2004, [were] warmer than usual, and particularly in the later parts of the winter, there was less snow than usual. So we're talking about two winters that were a little warmer than usual and had earlier snow melt. We used a one-dimensional model called

SNTHERM, which was developed by the U.S. Army to figure out where kinks have been in cold regions. It's a very good model, and it gives us all the snow properties that we want: density, stratigraphy, grain size, etc. To drive it, you need a lot of climate information, and because the snow changes diurnally—it's cold at night, the sun comes out during the day—snow properties change radically; you have to collect the information at hourly intervals. So we're collecting all this climate data at hourly intervals, and running our model at hourly intervals.

So what do the models show us? Measured in orange, modeled in blue, Figure 3 shows the information from our index site where the climate station is. We ran [the model] for 80 days. With all that input, we're usually much better than 10% in snow depth, and that was the case here. Snow depth estimates were accurate within 1–16%; density, within 7–11%; SWE, 3–8%. So the model does well.

Figure 4 shows stratigraphy. [W]e had some sun crusts, [visible in the photo on the left], and the model actually captured those crusts. So we can, with this model, actually get information on ice lenses and sun crusts and things of that nature within the snowpack; this is information you don't get from a SNOTEL site.

And then we wanted to spatially distribute it over our domain. To do that, we developed a landscape classification scheme. We took those 1,200 snow depth measurements, and then the DEM [digital elevation model] information that we got from the park to see what explained those snow depth deformations. [E]levation [proved to be] the major component, so we used two elevations (high and low); . . . aspect; and . . . vegetation cover, which was coniferous forest, deciduous forest, and non-forested, as our parameters.

We ended up with 30 combinations, so we divided our domain of five square kilometers or so into these 30 discrete regions. . . . The snowpack properties differed among the regions, but within each of these landscape types they were the same; they were treated as homogeneous units.

[Because] we ran our snow model in each one of these 30 units separately, we had to spatially extrapolate all our climate drivers at an hourly time-step over 30 regions and run the model. The thing that's most important is getting the solar radiation right. [W]e ran [the model] every hour over the entire domain for 80-something days. Figure 5 is a snapshot of one day. At the bottom is a north-facing aspect, at the top a south-facing [aspect]. You can see that solar

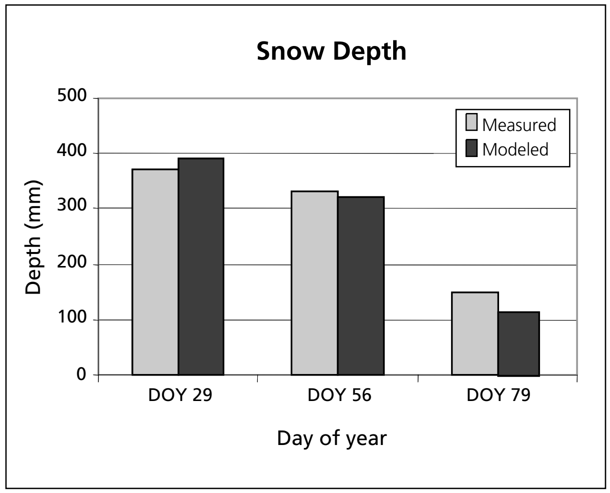


Figure 3. 1-D SNTHERM vs. field data, Crystal Creek index snowpit, winter 2004.

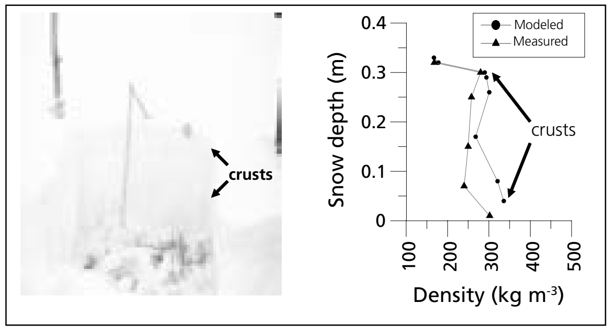


Figure 4. Snowpack stratigraphy, Crystal Creek index snowpit, February 25, 2004.

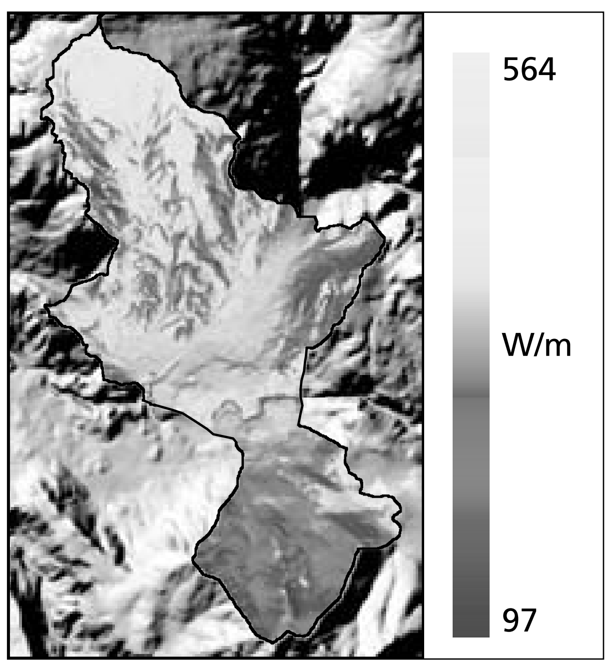


Figure 5. Solar radiation distribution. Modeled incident solar radiation, March 10, 2004. Hourly time-step for sunny and cloudy conditions.

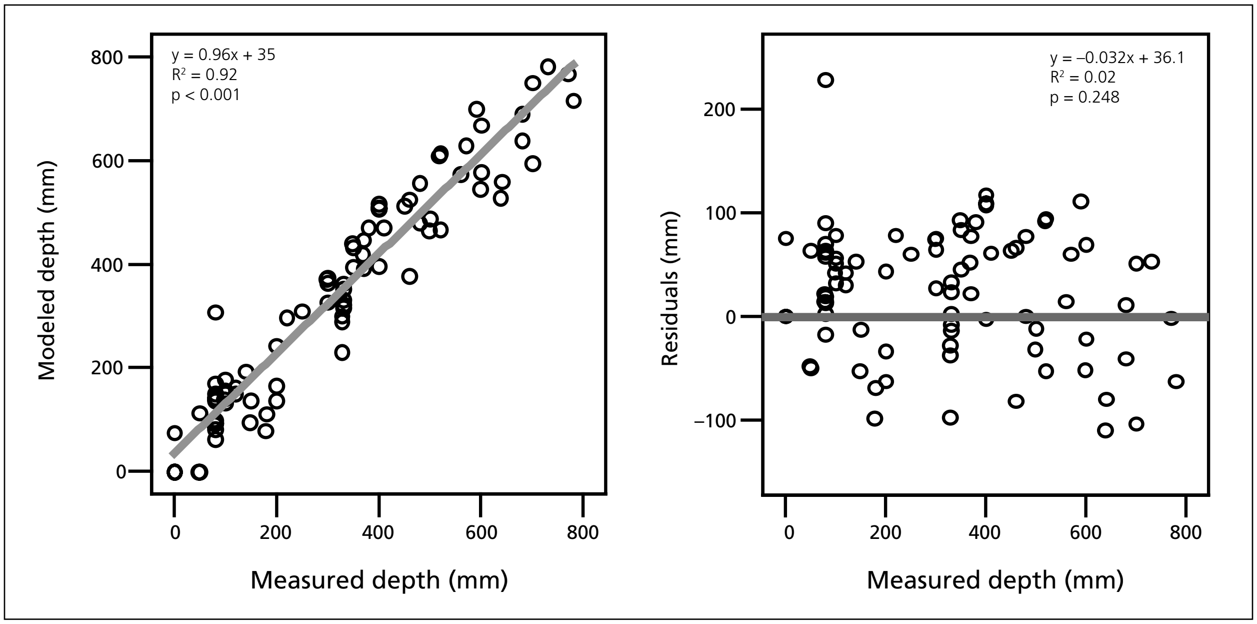


Figure 6. Distributed SNTHERM vs. field data, NEWR test basins, winter 2004.

radiation ranges by a factor of five from north-facing slopes to south-facing slopes. The snowpack conditions respond to that, and the elk and wolves are sensitive to those changes in snowpack properties.

So here's what the results look like (Figure 6). We compared our SNTHERM distributed results with the field measurements from 30 pits and got an R^2 of 0.96. That's just incredibly good. R-squareds range from zero to one, with one being perfect, and so . . . it was much better than I expected. I think it has a lot to do with the special sort of terrain that's in Yellowstone. We [also] can test how well we did by a different way, which is to look at the residuals, the error. It's not correlated, so we're doing a pretty good job there.

We also got the stratigraphy right, in general. [In Figure 7,] the red is where we got the stratigraphy wrong. On the rest of it we got the stratigraphy right, so we can actually spatially distribute ice lenses and things that either help or hinder elk and wolf movement reasonably well.

There's another model out there, developed by CSU [Colorado State University], called the NREL model, and we compared [this model to] that model just to see if we're doing as well as they did. Their R^2 is quite a bit less; that's because they're using those SNOTEL sites to drive the model, and it's static (Figure 8). There's no daily meteorological data. So I think our model is a big improvement over that.

[W]e can spatially distribute the data reasonably well with the current year's data. Now the question is, can we spatially distribute past years? [To] do that, we take our 2004 data and correlate it against SNOTEL sites, and then take that SNOTEL data and run it through the model and compare it against field measurements in 2003. If that works, then we can spatially distribute those point measurements from SNOTEL back 25 years, or with Dave [McGinnis]'s data, back to 1948.

So this is how we do it. Figure 9 shows our data from Canyon. The R^2 is 0.97, so we're doing really well, our data at this index site is well correlated with the SNOTEL data. And that was for 2004, so in 2003 what we did is just take that SNOTEL data, spatially extrapolate it based on the model, with no other

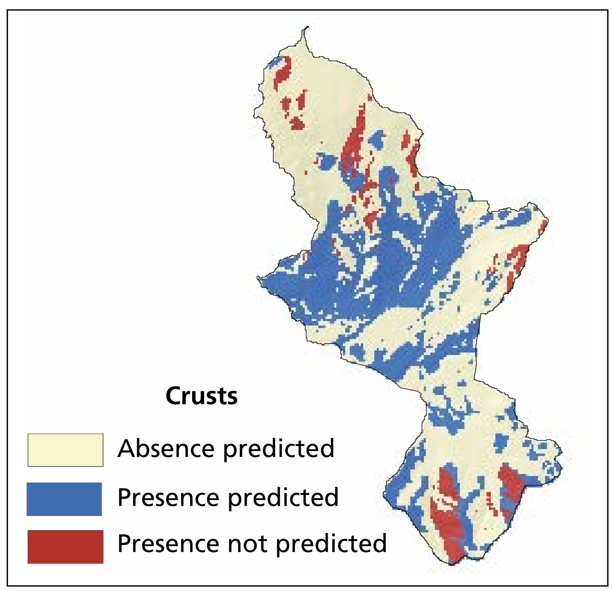


Figure 7. Distributed SNTHERM stratigraphy.

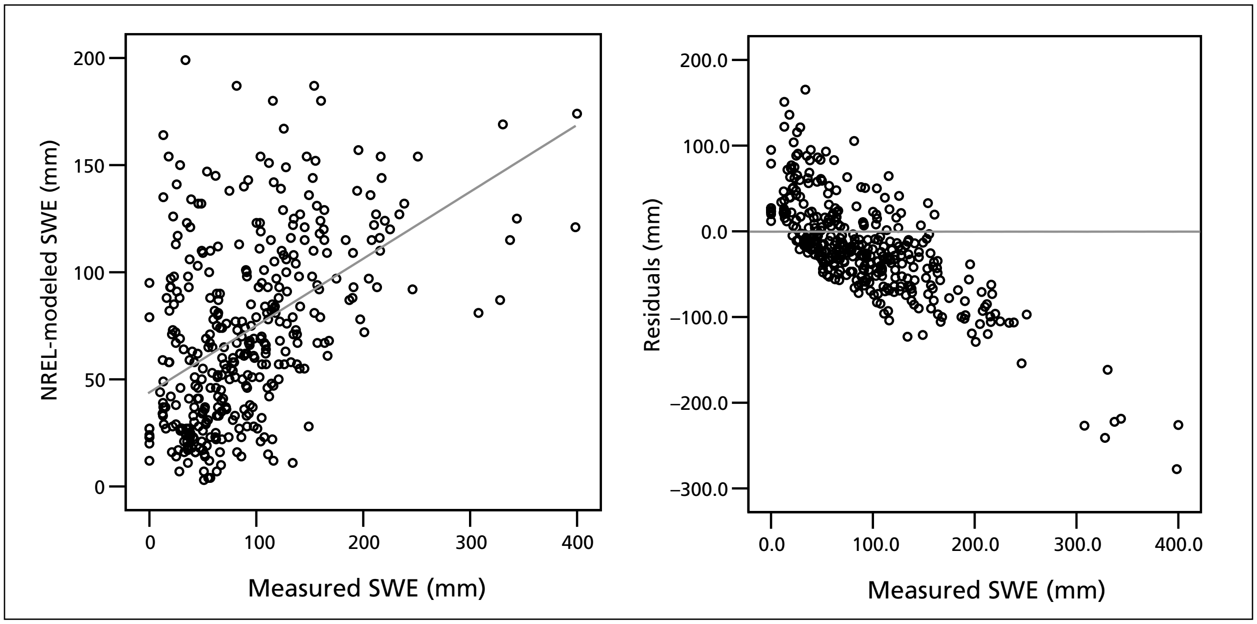


Figure 8. NREL snow model vs. field data, winters 2003 and 2004.

measurements, and then compare it to the field data we had. And the R^2 is pretty good: 0.64. And it's actually a little better than that, because . . . the two black dots . . . are outliers; without those, the R^2 is up around 0.9. [That's] because of wind redistribution. So that's one thing that's not in the model, and that we didn't capture well. [Including] that would improve the model.

So essentially, [our model] worked well, [meaning that] we can actually spatially distribute point measurements of snow properties. We can do it at a scale that the elk actually see. [This work], . . . I think, [is really going to] help the elk researchers and the wolf researchers. We [also] can go back in time. We can take existing data back as far as 1948 and spatially extrapolate those point measurements, and use that to understand elk dynamics and winter severity.

The bad [news is] that Yellowstone National Park, at this point, does not collect sufficient information to drive these models. And that's something that I think we need to think about, and that YNP, in particular, needs to think about. And it's not just our

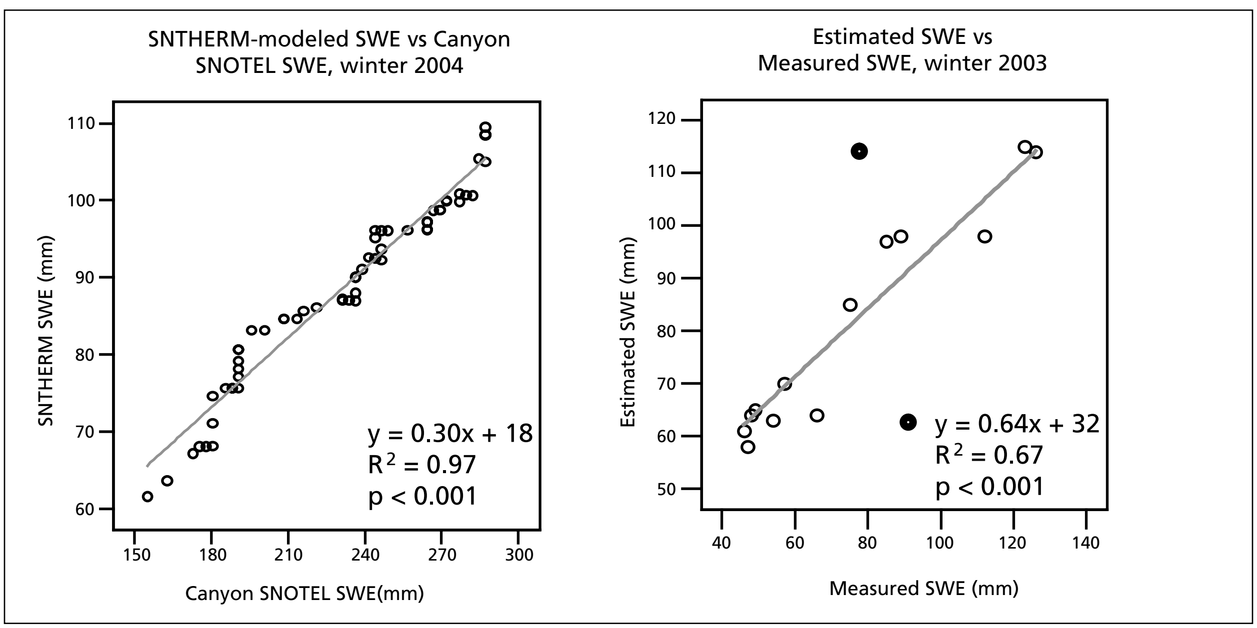


Figure 9. Retrospective SWE estimates. *Left,* SNTHERM-modeled SWE vs. Canyon SNOTEL SWE, winter 2004. *Right,* estimated SWE vs. measured SWE, winter 2003.

model; a lot of the good ecology models now run on this hourly time-step, and they need those meteorological drivers.

Future directions: We've actually expanded the domain all the way up to the Gallatin River. We took those measurements last year; we're working those up now. It would be great to include other physical and biological parameters for which we don't have funding, but which we understand would help—in particular, wind redistribution. And last, we need to work closer with the elk [researchers], because right now we actually have distributed snow measurements at better precision than the elk [researchers] have elk measurements. The elk data is not nearly as precise as you think it is, and at this point we've leapt ahead of the elk [researchers].

Thanks a lot.

Additional Conference Abstracts

Bruzgul, Judsen. Ph.D. candidate, Stanford University, 334 Serra Mall, Stanford, CA 94305 (bruzgul@stanford.edu, 650-498-4995)
Elizabeth Hadly, Assistant Professor, Stanford University. Same address as above (hadly@stanford.edu)
Regional Effects on the Yellowstone Mammalian Species Pool

Understanding the processes creating patterns of biodiversity is fundamental to ecology. We used the assembly of the biota of Yellowstone National Park over the past 10,000 years as a natural experiment for investigating the processes that generated the modern species pool. Our approach enabled us to investigate the myriad processes working at a variety of spatial and temporal scales. We applied null models to generate the local species pool, and used a vector-based approach to determine biogeographic affinity of species. Our results indicate that the Yellowstone fauna is composed of a non-random subset of mammals from different body size categories and with different biogeographic affinities. We found a general bias towards species that demonstrate affinity to the northern Rocky Mountain region. This result is counter to the more general pattern of south-to-north colonization following glacial retreat of continental ice in Canada. The bias is driven by an overrepresentation of Carnivora from the north. We also found significantly fewer Rodentia with biogeographic affinity to the Great Basin region than expected from random assembly from all regions. Using a spatially explicit approach, our results demonstrate that the Yellowstone biota is differentially affected by physical and biological factors, and our approach holds promise for alternative methods of predicting ecosystem response to future environmental changes.

Copeland, Holly. Director of GIS, The Nature Conservancy, 258 Main Street, Suite 200, Lander, WY 82520 (hcopeland@tnc.org, 307-335-2129)
Joni Ward, Director of Science, The Nature Conservancy. Same address as above (jward@tnc.org)
Joseph Kiesecker, Senior Ecologist, The Nature Conservancy. Same address as above (jkiesecker@tnc.org)
Prioritization of Conservation Areas in the Greater Yellowstone Ecosystem

With the greatest concentration of large mammals in the lower 48 states and a full complement of native carnivores, the Greater Yellowstone Ecosystem (GYE) is one of the few temperate ecosystems where ecological processes such as predator–prey interactions are still in place. With headwaters of three great river systems, at 27 million acres the GYE is also home to the longest overland migration in the lower 48 states. Despite its size and biological significance, increased human populations combined with proposed energy development, and increasing outdoor recreation all warrant the refinement of conservation priorities in the GYE. The prioritization of conservation areas for the GYE conducted in this report grew out of two previous conservation planning efforts (Noss et al. 2001: *A Biological Conservation Assessment for the Utah–Wyoming Rocky Mountains Ecoregion* and NatureServe's *2004: A Rapid Assessment Using Coarse- and Regional-Scale Conservation Targets in the Greater Yellowstone Ecosystem*). In this analysis, we prioritize areas for wide-ranging species and coarse and regional scale ecological systems, improved with recent data on migratory corridors, fire regimes, road density, and invasive species.

Crabtree, Robert. Chief Scientist, Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59718 (crabtree@yellowstoneresearch.org, 406-556-1414)
Jennifer Sheldon, Research Biologist. Same address as above.
Ecological Drivers and the Importance of Pristine Ecosystems

Ecology is traditionally defined as the study of living organisms and their interactions with the environment. The environment includes both abiotic factors (climate and geology) and the biotic components of the system (other living elements or organisms). Yet, this set of definitions presents a static picture of a highly dynamic set of processes, patterns, and interactions. After all, ecologists attempt to assign the variability in spatial and temporal patterns to parameters—or succinctly put—to answer the question, "why is what where when?" Recently, ecologists have cast about for tools and models to describe and quantify the dynamic nature of ecosystems in an attempt to assess the causal nature of ecosystem patterns and processes. The notion of "drivers" (major elements of ecosystem process that are causal in nature) is emerging as important in ecology, because these are the elements that may cause departure from existing conditions. But how can we assess the impacts of these drivers without a standard or control? We argue that such standards can best be provided by conducting research in pristine systems like that in Yellowstone, which provides the best standard of comparison related to the historic range of variability. We examine a variety of data sets collected from northern Yellowstone that suggest some of the major drivers may be causing a significant departure from Holocene variability. Examples of drivers that we consider are drought, fire, invasive colonization, species restorations, and human activities such as development and

ungulate harvest. We also diverge from classic species management and focus on ungulate migration as an endangered process worthy of further consideration.

Darin, Tom. Public Lands Director, Jackson Hole Conservation Alliance, P.O. Box 2728, Jackson, WY 83001 (tom@jhalliance.org, 307-733-9417)

The Death of Environmentalism and Shift Toward Community-Created Conservation

Advocacy groups across the West are approaching conservation from the wrong perspective. The paper, "Death of Environmentalism," and the *High Country News* story about the same and Libby, Montana, should be a wake up call to us all, instead of the many defensive reactions from my colleagues. We are out of touch with core community values. The paper calls for a major shift in advocacy and that conservation groups start with conservation by creating the call for it at the community level. The paper explains how to achieve this model and identifies problems with "mainstream" groups and being out of touch with shared values, how funding can negatively affect groups and the issues they work on, and the evolution of paid staffers and credibility. "NIMBYism" (Not In My Back Yard) is also touched upon as a concept that we need to embrace. I view this paper as somewhat controversial and setting me apart from many of my colleagues.

Despain, Don G. Ecologist, USGS Northern Rocky Mountain Science Center, 8490 Lookfar Way, Bozeman, MT 59715 (don_despain@usgs.gov, 406-994-7257)

An Alternative Explanation for Willow Height Increase Following Wolf Reintroduction

Willows are well-adapted to the cool, moist sites that constitute their habitats. These sites also produce high amounts of the plant biomass that is significant to most of the herbivores using the same areas. Two opposing forces have influenced physiological adaptation in willows. Height growth is needed to compete with neighbors for light—but that growth must be defended against herbivores. Willow growth depends on plant hormones (auxins) and availability of carbohydrates, but the production and transport of auxins to growth sites are sensitive to temperature. Auxins are also influenced by day length. The long days of spring and early summer allow for maximum auxin production. Shorter days of late summer and fall cause a decrease in auxin availability and thus, growth, as the plants begin the cold acclimation process for winter survival. Production of defensive chemicals also depends on carbohydrate availability, but is second to growth in competition for carbohydrates. Willows throughout Yellowstone National Park's northern winter range switched from producing annual growth of 20–30 cm to 60–120 cm about 1997. On the northern range, the number of days with minimum temperatures >0°C for the months of May–October increased by an average of 25.4 days (29%) for the period 1997–2004, compared to 1985–1996. For May–July, the increase was 11.8 days (23%) and for August–October, 13.6 days (37%). This change in climate could explain the increased summer growth throughout the winter range, and the appearance of tall willows in some locations.

Haroldson, Mark. Wildlife Biologist, U.S. Geological Survey, Interagency Grizzly Bear Study Team, Forestry Science Lab, Montana State University, Bozeman, MT 59717 (mark_haroldson@usgs.gov, 406-994-5042)

Charles C. Schwartz, USGS, Interagency Grizzly Bear Study Team, Forestry Sciences Lab, Montana State University, Bozeman, MT 59717 (chuck_schwartz@usgs.gov, 406-994-5043)

Gary C. White, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523 (gwhite@cnr.colostate.edu, 970-491-6678)

Richard B. Harris, Wildlife Biology Program, College of Forestry and Conservation, University of Montana, Missoula, MT 59812 (rharris@montana.com, 406-542-6399)

Steve Cherry, Department of Mathematical Sciences, Montana State University, Bozeman, MT 59717 (cherry@math.montana.edu, 406-994-5367)

Kim A. Keating, USGS, Northern Rocky Mountain Science Center, Forestry Sciences Lab, Montana State University, Bozeman, MT 59717 (kkeating@usgs.gov, 406-994-7333)

Dave Moody, Trophy Game Section, Wyoming Game and Fish Department, 260 Buena Vista, Lander, WY 82520 (Dave.Moody@wgf.state.wy.us, 307-332-7723)

Christopher Servheen, U.S. Fish and Wildlife Service, University of Montana, Missoula, MT 59812 (griz@umontana.edu, 406-243-4903)

Temporal, Spatial, and Environmental Influences on the Demographics of Grizzly Bears in the Greater Yellowstone Ecosystem

During the past two decades, the grizzly bear (*Ursus arctos*) population in the Greater Yellowstone Ecosystem (GYE) has increased in numbers and expanded in range. Understanding temporal, environmental, and spatial variables responsible for this change is useful in evaluating what likely influenced grizzly bear demographics in the GYE, and where future management efforts might benefit conservation and management. We used data from bears radiomarked during 1983–2002 to explore the influence of an array of individual, temporal, and spatial covariates on estimated vital rates (fecundity and survival). We found that indices of where bears lived relative to Yellowstone National Park (YNP) and the U.S. Fish and Wildlife Service Recovery Zone (RZ), together with whitebark pine (*Pinus albicaulis*) cone production, were consistently important

covariates. Estimated vital rates used to model demographic vigor (lambda [λ]) suggest mean λ for the population was ≥1.04. Population trajectory was most sensitive to changes in survival of independent females. The appropriate mortality target for independent female bears depends on the risk of a population decline (i.e., $\lambda < 1$) that managers and the public are willing to accept. For the chance of a population decline to be ≤5% under conditions applying during 1983–2002, annual mortality of independent females would have to be ≤10%. A source–sink dynamic is also indicated, with $\lambda \geq 1$ inside YNP and the RZ, but $\lambda \leq 1$ outside the RZ. This dynamic requires new discussions about population management, mortality thresholds, and elimination of anthropogenic foods on the edge of the ecosystem.

Hektner, Mary. Vegetation Section Lead, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (mary_hektner@nps.gov, 307-344-2151)
Lynn Burton, Rangeland Management Specialist, Gallatin National Forest, 3710 Fallon Street, Suite C, Bozeman, MT 59718 (lburton@fs.fed.us, 406-522-2540)
Monica Pokorny, Restoration Program Coordinator, Center for Invasive Plant Management, Montana State University, 334 Leon Johnson Hall, Bozeman, MT 59717-3120 (mpokorny@montana.edu, 406-994-6599)
Roy Renkin, Vegetation Management Specialist, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (roy_renkin@nps.gov, 307-344-2161)
P. J. White, Ungulate Biologist, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (pjwhite@nps.gov, 307-344-2442)

Restoring Native Vegetation on Ungulate Winter Range in and near Yellowstone National Park

Lands within the Yellowstone River valley immediately north of Yellowstone National Park, known as the Gardiner Basin, were deemed essential for elk and pronghorn winter range and acquired by the park in the 1920s and 1930s. The U.S. Forest Service (Gallatin National Forest) acquired adjacent lands in the Gardiner Basin during the 1990s, also for wildlife habitat. Due to previous agricultural land use, semi-arid conditions, altered hydrologic regimes and soil conditions, and increased exotic weeds, these acquired lands support relatively low amounts and quality of forage for wildlife. Recent unsuccessful attempts at restoration demonstrated that additional expertise representing diverse disciplines was needed to effectively restore 1,200 acres of atypical ecosystem to native vegetation and provide higher-quality habitat for wintering ungulates. We convened a workshop in April 2005 with state, federal, academic, and practicing restoration and reclamation specialists to develop feasible, ecologically-based restoration and management strategies for these old agricultural lands. The goals of the workshop were (1) to formulate a directional, coordinated plan for the restoration and long-term management of the federally-owned portions of the Gardiner Basin; and (2) to develop an action plan to implement ecologically-based and sustainable practices for restoration of disturbed lands in a multi-use, semi-desert ecosystem with high levels of use by native ungulates. With the assistance of restoration experts, we developed methods for restoring landscape-scale, degraded lands to native vegetation by addressing ecosystem processes.

Inman, Robert. Director, Greater Yellowstone Wolverine Program, Wildlife Conservation Society, 4 Trail Creek, Ennis, MT 59729 (binman@wcs.org, 406-682-3437)
Kristine H. Inman, Wildlife Conservation Society, 2023 Stadium Drive Suite 1A, Bozeman, MT 59715

Establishing a Spatial Framework and Determining an Effective Geographic Scale for Wolverine Conservation in Greater Yellowstone

Principal foundations for effective wolverine conservation in the Greater Yellowstone Area (GYA) include establishing a spatial framework and determining an appropriate geographic scale for effective management. We captured and monitored 26 wolverines at two study sites in the GYA between 2001–2005. We estimated first-order (landscape scale) habitat selection with compositional analysis of 1,494 telemetry locations of 17 wolverines (9 females, 8 males) within 1,000-ft. elevation bands. Annual wolverine use of the 9,000–9,999-ft. elevation band was five times greater than availability, and different than all other bands ($P<0.02$). Mean annual (March 1–February 29) 95% fixed kernel home range size was 645 km^2 for adult females ($n = 7$ wolverine years) and 1,204 km^2 for adult males ($n = 7$ wolverine years). Home ranges (100% minimum convex polygon) of same-sex adults from a non-harvested population did not overlap. We located dispersing aged individuals a maximum of 168 km (male) and 80 km (female) from the mother's center of activity, and estimated population density at 13 (95% CI-- 12–22) wolverines/3,071 km^2 of wolverine habitat (1 wolverine/140–256 km^2). We located these 26 wolverines within a minimum of 21 distinct political jurisdictions including three states, two national parks, ten districts of four national forests, and on U.S. Fish & Wildlife Service, Agricultural Research Service, Bureau of Land Management, State, Tribal, and private lands. Our data suggest that wolverine populations in the GYA likely function at the regional scale across multiple political jurisdictions, and that persistence of wolverine populations would benefit from and may depend on multi-jurisdictional,

collaborative planning at the landscape level.

Korb, Nathan. Southwest Montana Land Steward, The Nature Conservancy, P.O. Box 212, Lima, MT 59739 (nkorb@tnc.org, 406-925-1144)
William H. Romme, Professor, Colorado State University, 970-491-2870

Using Historical Fire Regimes and Forest Structure to Guide Management of Douglas-fir Forests in the Centennial Valley of Southwest Montana

Douglas-fir (*Pseudotsuga menziesii* var. glauca) dominates most of the lower elevation forests in the Greater Yellowstone Ecosystem (GYE). Human activities including timber management, residential development, and fire suppression have been concentrated in Douglas-fir forests due to their accessibility, ownership patterns, and nominal protection. Information about the historical range of variability for fire regimes and forest structures provides a valuable guide for managing forests. Several previous studies have reconstructed chronologies of low-severity fires in the Douglas-fir forests in the northern GYE; however, the complex mixed-severity fire regimes that these forests supported have not been adequately researched. In the Centennial Valley of southwest Montana, one of The Nature Conservancy's high-priority landscapes in the GYE, we reconstructed the historical fire regimes and forest structure for xeric and mesic sites. The xeric forests generally supported low-severity fires that maintained open forest structures, while the mesic forests supported a more complex fire regime with patches of high-severity fires and a wide range of forest structure and composition. Compared to historical mixed-severity fires, the 2003 Winslow fire burned through the mesic site with higher severity and less fine-scale spatial heterogeneity within severe patches. Recent wildfires and widespread tree mortality resulting from drought and insects have placed forest management at the forefront of social and ecological concerns. The purpose of this presentation is to briefly outline the results of our research and to describe how the information is being used to guide forest and fire management of Douglas-fir forests across various land ownerships in the Centennial Valley.

McFarland, Malcolm. Prescribed Fire and Fuels Specialist, Grand Teton National Park, P.O. Box 170, Moose, WY 83012 (mack_mcfarland@nps.gov, 307-739-3313)
Diane Abendroth, Grand Teton National Park, 307-739-3665
Eric Miller, Yellowstone National Park, 307-344-2360

Linking the Fire Environment to Long-Term Fire Effects

Perhaps the most common quantifiable data collected during wildland fire and prescribed fire events concerns the conditions in fire environment. During fire incidents, this data aids in predicting short-term fire behavior and weather during the event. This methodology utilizes fire environment conditions (temperature, relative humidity, fine fuel moisture, and winds) collected during fire events to link those environmental conditions to fire effects (severity, regeneration, species composition, etc.) Similarly, this methodology may be used to graphically display prescription parameters described in prescribed burn plans compared to actual conditions during the event to determine the effectiveness of prescriptions in meeting project objectives. Data groupings of environmental conditions from historical fires may be produced and compared to fire effects that have been observed since the event. These groupings are then used to benchmark environmental conditions on prescribed fires against those conditions on wildland fire. This comparison links long-term fire effects with environmental conditions experienced. The link is applied to other events of prescribed or wildland fire to more accurately predict the long-term fire effects that would be expected to develop following the fire. Managers use this link to refine prescriptions, determine trigger points, and better understand the potential for system changes in vegetative communities in response to fire. This methodology is also useful in public education/information forums for displaying current and expected fire site conditions, especially in relation to benchmark fire events.

McGinnis, David. Research Professor, Montana State University–Billings, 3233 Turnberry Circle, Billings, MT 59101 (dmcginnis@msubillings.edu, 406-254-1795)
David Bennett, University of Iowa
Duncan Patten, Montana State University
Mark Williams, University of Colorado–Boulder
William Travis, University of Colorado–Boulder

***Panel*: Biocomplexity on Yellowstone's Northern Range: Human Impacts and Natural Ecosystems**

Yellowstone National Park provides a unique opportunity to study the biocomplexity of coupled natural–human systems. Yellowstone is often regarded as a pristine ecological island, but is it? Various ecosystem elements routinely cross the park boundary into lands managed for other purposes. The Yellowstone ecosystem is, therefore, a complex mosaic of different management practices, land use patterns, and ecological relationships, all moderated by human decisions and tightly coupled to the surrounding, human-dominated landscape. This panel presents findings from a National Science Foundation project, "Biocomplexity in the Environment—Coupled Natural and Human Systems," that uses elk and riparian habitat as a "currency" to understand the complex interactions that exist among climate variability, elk population dynamics, prey–predator relationships (wolves and human

hunters), demographic and land use/land cover change, and policy decisions within the study area. The project is focused on the Yellowstone northern elk herd winter range, a highly contested environment where stakeholder groups strive to produce a landscape that reflects a particular vision that often fails to consider the full complexity of the system. This research results in agent-based models that can simulate alternative system states in a way that will prove useful in conflict resolution and future policy planning. Panelists have expertise in climate, snowpack, riparian ecology, land use and demographic change, and agent-based modeling. We will present our findings from multiple perspectives and demonstrate how holistic research involving physical and social scientists can merge such that the sum of the parts creates a larger whole.

McIntire, Eliot. Post-doctoral Fellow, University of Montana, 32 Campus Dr., Missoula, MT 59812 (emcintire@forestry.umt.edu, 406-243-5239)
Elizabeth E. Crone, Assistant Professor, Department of Ecosystem and Conservation Sciences, University of Montana, Missoula, MT 59812

Predicting Whitebark Pine Cone Production for Grizzly Bear Management

The seeds from whitebark pine trees provide a major food source for grizzly bears in the Greater Yellowstone Area (GYA). In years with low seed production, grizzly bears must forage on alternate food sources. This tends to create more intense conflict with humans, because the alternate food sources are in the valleys where most humans concentrate. Because cone production usually varies over 20-fold on a given tree between years and does not follow a regular cycle, it has been challenging to successfully predict cone production, and therefore mitigate human–grizzly bear conflict. More than 24 years ago, grizzly bear managers set up whitebark pine cone transects where they have estimated yearly cone production throughout the park on up to 171 trees. In this project, we fit these time series using physiological models that incorporate resource storage within a hierarchical Bayesian framework. We used the two climate variables thought to be most important for whitebark pine: growing degree days in the current and previous summer, and the number of hard frost days during the growing season. In contrast to a multiple regression approach that was unsuccessful at blind predictions, our modeling approach made successful blind predictions, for instance, the 2004 cone production failure across the GYA (actual median: 1 cone per tree; predicted 95% credible interval: 1 to 3 cones per tree). With these successful predictions and tight credible intervals, grizzly bear management within the GYA can take action in advance of a given cone failure.

Pierce, Kenneth L.,[1] Don G. Despain,[1] Lisa A. Morgan,[2] and John M. Good[3]
[1]USGS, NRMSC, Bozeman, MT, 59757, kpierce@usgs.gov, don_despain.usgs.gov
[2]USGS, MS 966, P.O. Box 25046, Federal Center, Denver, CO 80225, lmorgan@usgs.gov
[3]PO Box 4743, Jackson, WY 83001, jmgood@vcmails.com

The Geologic Basis of Management Agency Diversity in the Greater Yellowstone Ecosystem

The role of geologic processes should not be overlooked in attempting to understand the social and ecological paradigms of the Greater Yellowstone region. Three ongoing geologic processes associated with the Yellowstone hotspot have created many aspects of Greater Yellowstone landscapes. These processes and their characteristics are:

- Uplift has created the Yellowstone crescent of high terrain and its associated cold, snowy climate. From this central highland, streams flow outward toward lower areas. Stream incision and slope erosion in response to this uplift have created rugged, high-relief terrain in much of the Greater Yellowstone Ecosystem.
- Volcanism has created the lodgepole forests of the Yellowstone Plateau, and hotspot volcanism has left in its wake the lowland of the eastern Snake River Plain, which serves as a conduit for moisture-laden storms rising to the Yellowstone uplands.
- Active faulting in part of the Greater Yellowstone Ecosystem has created basin–ranges, with their contrasting landscapes and ecology. Alluvial flats with drier, non-forested basins flank high, steep, eroding ranges with winter snows.

This unity has been recognized by modern designation as the Greater Yellowstone Ecosystem. But political subdivision of this landscape has fragmented its management. Largely because of its high landscapes and cold, snowy winters, development along the western frontier came slower to Yellowstone, so the area was largely unoccupied, permitting establishment of the world's first National Park in 1872. Two national parks, six national forests and two forest service regions, two national wildlife refuges, three states, and about 22 counties make up the Greater Yellowstone Ecosystem. More than 20 drainages and associated drainage divides radiate outward from the Yellowstone crescent of high terrain. Because Greater Yellowstone was a nearly unpopulated area on generally unusable land, political fragmentation easily occurred at the onset. For example, had the area been a lowland rather than an upland, more political unity might have occurred. But now we have to deal with political fragmentation of an area that modern ecological concepts have led us to recognize as the Greater Yellowstone Ecosystem: a terrain that has an underlying geologic unity created by the processes of volcanism, faulting, and particularly, uplift associated with the Yellowstone hotspot.

Rasker, Ray. Director, SocioEconomics Program, Sonoran Institute, 201 S. Wallace Ave., Bozeman, MT 59715 (ray@sonoran.org, 406-587-7331)

The Role of Conservation in Economic Development

This study covers the results of a West-wide empirical test to verify whether protected public lands in the West play a positive or negative role in the development of the economy of nearby communities. Long-term regional economic and demographic trends in the Greater Yellowstone region are highlighted as an example. We discovered that wilderness, national parks, national monuments, and other protected public lands, set aside for their wildland characteristics, can and do play an important role in stimulating economic growth—and the more protected the better. We also found that there are many other important pieces of the economic development puzzle, and that not all communities benefit equally from protected lands. Access to metropolitan areas, via road and air travel, is also extremely important, yet some rural communities are remote and isolated. The education of the workforce, in-migration of newcomers, and a number of other factors allow some areas to flourish and take advantage of protected lands as part of an economic development strategy. Communities without these economic assets, in spite of being surrounded by spectacular scenery, tend to struggle to keep people and businesses from leaving. This study is therefore an attempt to lay out the factors that are needed for economic success in the West, and to describe the role of public lands in that context.

Renkin, Roy. Vegetation Management Specialist, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (roy_renkin@nps.gov, 307-344-2161)

John S. Klaptosky, Biological Science Technician, P.O. Box 168, Yellowstone National Park, WY 82190

Eric J. Larsen, Assistant Professor of Geography, University of Wisconsin–Stevens Point, Stevens Point, WI 54481

Don G. Despain, Ecologist, USGS Northern Rocky Mountain Science Center, Montana State University, Bozeman, MT 59717

William J. Ripple, Director, Environmental Remote Sensing Applications Laboratory, Department of Forest Resources, Oregon State University, Corvallis, OR 97331

What Did They Eat?: Browse History of Aspen in Northern Yellowstone

Historic photographs have been used to infer the lack of browsing on small aspen saplings, which further facilitated understory recruitment into the overstory. Such inferences formed the basis for arguing the presence and/or relative size of the elk population preceding and during the period of Euro-American settlement in northern Yellowstone, and the role of browsing in the subsequent decline of aspen over the past century. We adopted field methods that assess plant architecture in relation to browsing, and interpreted these architectural signals preserved in the pith trace of aspen trees. We used aspen trees (1) with a known browse history; (2) that over time had died and fallen within 112 aspen clones that have been monitored for growth since 1999; and (3) that had recently (2003 and 2004) died and uprooted to assess browse frequency and relative browse intensity on trees that successfully grew through the browse zone. We further collected cross-sections from sample trees for aging to determine the influence of browse frequency on growth rate, years required to achieve breast height, temporal distribution of browse occurrence, and evidence of mechanical bole scarring. These data obscure the popular interpretation of historically unbrowsed aspen across northern Yellowstone, and shed light on theoretical or observed aspen growth under emerging hypotheses of trophic cascades interactions involving wolves and elk.

Romme, William H. Professor of Fire Ecology, Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship, Fort Collins, CO 80523 (romme@cnr.colostate.edu, 970-491-2870)

Dan Tinker, Professor, University of Wyoming, Department of Botany, Laramie, WY 82071

Don Despain, Ecologist, USGS Northern Rocky Mountain Science Center, Montana State University, Bozeman, MT 59717

Key Issues in Fire Ecology and Fire Management in the Greater Yellowstone Ecosystem

Fire is a key ecological process that transcends political or administrative boundaries in the Greater Yellowstone Ecosystem (GYE). Effective fire management, including wildland fire use, must couple our understanding of the science of fire behavior and fire effects with the expectations and priorities of management agencies and the public. Wildland fire in the GYE differs importantly from fire in other ecosystems, such as southwestern ponderosa pine, and we cannot simply transfer scientific or management paradigms developed in other regions and other kinds of ecosystems to the GYE. For example, historical GYE fire regimes were dominated by infrequent, stand-replacing fires; thus, simply thinning dense forest canopies or conducting low-intensity prescribed burns—effective tools for restoration and fire hazard mitigation in many southwestern ponderosa pine forests—would not represent restoration in much of the GYE, and might be unachievable or have limited effectiveness in preventing wildfire damage. Recent large fires in the GYE generally have not differed greatly in behavior or ecological effects from historical fires. However, climate changes during the next half-century may push fire frequency and severity outside the historical range of variability,

and post-fire invasion by non-native plant species may compromise recovery of native plant communities. One of the biggest constraints managers face in allowing fire to operate as a natural ecological process in the GYE is the proliferation of vulnerable homes and other structures within fire-prone vegetation. There is an urgent need to develop and implement effective and ecologically sound fire mitigation techniques in areas of exurban development.

Schat, Marjolein. Graduate student, Montana State University (mschat@montana.edu)
Sharlene Sing, U.S. Forest Service, Rocky Mountain Research Station, 406-994-7931
David Weaver, Montana State University, 406-994-6099
Bob Peterson, Montana State University, 406-994-7927
Pat Hoppe, Gallatin National Forest, 406-848-7375
Craig McClure, Yellowstone National Park, 307-344-2168

Biological Control of Dalmatian Toadflax: A Sustainable Weed Control Option for the Greater Yellowstone Area?

Dalmatian toadflax, *Linaria dalmatica,* a short-lived Eurasian perennial, was introduced to North America in 1894. Since then, it has spread across the country, and is now listed as a noxious or restricted weed in 12 western states, including Montana, Idaho, and Wyoming. Dalmatian toadflax invades forest and range lands, reducing species diversity and stock carrying capacity. It is well-adapted to dry conditions, and readily invades after fire. Herbicides can be effective, but are impractical and cost-prohibitive on large-scale infestations. Biological control has been suggested as a cost-effective alternative or complement to herbicide application, but little is known about the ability of the main control agent, *Mecinus janthinus* (stem-boring weevils), to establish and control toadflax in the habitat and terrain surrounding Yellowstone National Park. With the lengthening drought and the threat of ever-more-severe fire seasons, it is vital that an effective plan is in place to reduce the population of toadflax in the Greater Yellowstone Area, and to learn how the control agent and weed populations respond to burned areas. A cooperative effort between Montana State University, the U.S. Forest Service, and the U.S. Animal and Plant Health Inspection Service has been made in direct response to a well-identified community need to make as many *Mecinus* releases as possible in the Greater Yellowstone Area. Along with making releases, permanent plots and transects have been established near Gardiner, Montana, to document the impact of the weevils on toadflax. Releases were made in 2002 and 2004, and yearly sampling has been done to characterize the weed, control agent, and community interactions over time.

Seneker, Brian. Research Scientist, HyPerspectives, Inc., 2048 Analysis Drive, Suite C, Bozeman, MT 59718 (seneker@hyperspectives.net, 406-556-9880)
Kerry Q. Halligan, Todd D. Lushin, and Robert L. Crabtree, Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59718

The Ability of Airborne LiDAR to Measure Tree Characteristics Across Large Spatial Scales

LiDAR (Laser Ranging and Detection) has the capability to provide precise information on vegetation structure given its high resolution (1 meter) and vertical accuracy (20 cm). We evaluated the ability of a scanning LiDAR sensor to measure tree heights and derive biomass of forested regions in Yellowstone. LiDAR data were collected over the northern Yellowstone region on August 1, 2003, as part of a multi-agency and multi-sensor research project termed YOGI (Yellowstone Optical and SAR Ground Imaging). It produced first-return and second-return Digital Elevation Models (DEM) and intensity data (1.064 nm reflectance). Extensive ground-truth data was collected in the Fisher Creek drainage north of Cooke City, Montana, during the summer of 2003, and in the Soda Butte and Lamar River valleys in the summer of 2004. The key requirements of the field survey were to measure trees from (1) all available height classes, (2) all available tree species, (3) trees growing on varying slope angles, (4) trees growing on different aspects, and (5) trees growing across the spatial scale of the LiDAR footprint. Trees were measured in the field using a centimeter accuracy "total station" GPS/laser-coupled survey system. More than 1,000 trees were measured and precisely co-registered with the LiDAR data. A YERC-developed software program called ELF created a precise bare-earth model (BEM) from the first-return and intensity data. The first-return LiDAR was subtracted from the BEM to generate individual tree heights. Statistical analysis revealed strong relationships between ground-truth and LiDAR- derived height and biomass (e.g., $r^2 = 0.92$ for height). Regression analysis explored the variability of species, slope, and aspect.

Smith, Douglas W. Wolf Project Leader, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (doug_smith@nps.gov, 307-344-2242)
Daniel R. Stahler, Debra S. Guernsey, Dennis Murray, Edward E. Bangs, Michael Jimenez, Carter Niemeyer, Joseph Fontaine

Wolf Survival and Public Land: Do Wolves Have a Chance Outside of Reserves?

An analysis of 716 radio collared wolves from 1982–2004 throughout Idaho, Montana, and Wyoming indicates that wolf survival and land use are related. Average survival of wolves in reserves (wilderness or na-

tional park) averaged >80%, while survival on lands not in reserves was <60%. Annual survival rates of <60% are not sustainable, nor do they permit movement of wolves between recovery areas (dispersal/genetic exchange). Wolf recovery in the northern Rocky Mountains depended on public land being a core protected area where wolves would have high survival and robust populations. This vision was successful in Idaho and in the Greater Yellowstone Area with the central Idaho wilderness and Yellowstone National Park (YNP) providing the needed protection, but Glacier National Park and the Bob Marshall Wilderness have not functioned as core wolf reserves. The high elevation in these areas does not allow for year-round ungulate populations; therefore, the area harbors only a few packs of wolves. The northwest Montana population of wolves is the oldest (established 1979), but has the lowest number of wolves and lowest survival. In the Greater Yellowstone Area, wolf survival was >80% in and out of YNP until 2002, but has been declining outside of YNP to <60%, whereas survival rates remain >80% in YNP. For wolf recovery to achieve its stated objectives of a metapopulation structure with connectivity between the three recovery areas, management attention needs to be directed toward increasing wolf survival on public land outside reserves and in habitat corridors, thereby linking the three recovery areas.

Tinker, Dan. University of Wyoming, Department of Botany, Laramie, WY 82071 (tinker@uwyo.edu, 307-766-4967)
Randy Walsh (see abstract)
William H. Romme (see abstract)
Nathan Korb (see abstract)
***Panel*: Fire in the Greater Yellowstone Ecosystem: Coupling Social Expectations with Ecological Realities**

Fire is an ecological process that transcends political or administrative boundaries, and its management thus requires effective communication and cooperation among federal, state, and county agencies, as well as non-governmental organizations, private landowners, and other stakeholders. Effective fire management also must be grounded in a good understanding of the science of fire behavior and fire effects. Wildland fire in the Greater Yellowstone Ecosystem (GYE) differs importantly from fire in other ecosystems, such as southwestern ponderosa pine, and we cannot simply transfer paradigms developed in other regions and other kinds of ecosystems to the GYE. For example, simply thinning dense forest canopies—an effective tool for restoration and fire hazard mitigation in many southwestern ponderosa pine forests—is unlikely to be effective in many forests of the GYE, because of fundamental ecological differences. Therefore, the purpose of this session is to (1) identify the key issues related to wildland fire management in the GYE, including both ecological and social/political issues; (2) to present the current state of scientific knowledge about these issues; and (3) to initiate a dialogue on how to best couple societal expectations about wildland fire with ecological realities in the GYE.

Varley, Nathan. Ph.D. candidate, University of Alberta, Box 490, Gardiner, MT 59030 (nathan@wolftracker.com, 406-223-2152)
M. S. Boyce, E. H. Merrill, and **H. L. Beyer,** Department of Biological Sciences, University of Alberta, Edmonton, Alberta
R. L. Crabtree, Yellowstone Ecological Research Center, Bozeman, Montana
Mechanisms for a Trophic Cascade: Hypothesis Testing in Yellowstone's Wolf–Elk–Willow Food Chain

The trophic cascade concept is popular in ecological research, and studies suggest wolves, as top predators, have strong structuring effects in many food webs. In the wolf–elk–willow food chain in Yellowstone National Park, Wyoming, an effect has been readily hypothesized but not yet well-supported. Since wolf recovery in the mid-1990s, willow species may have been subjected to either a trait-mediated (prey behavior) or a density-mediated (predation) indirect effect of wolves. Empirical evidence for a growth event for two willow species on elk winter range, along with observable willow release at some sites, has generated several hypotheses for top-down (wolf–elk-caused) and bottom-up (climate) mechanisms. These alternative hypotheses were evaluated using information-theoretic criteria to select among models in which explanatory variables were fit to spatial variation in elk browse rates. Browse rates at 19 (2004) and 23 (2005) winter range plots were estimated from willow biomass measurements. Elk consumed 40–70% of available willow biomass, still relatively high, suggesting release from browse suppression at many willow sites is questionable under current browse rates. A wolf-related response, if present, may be found in the spatial variation of the browse pressure, rather than a mean increase in overall willow biomass. Competing models that included variables for elk use, wolf use, elk mortality risk, site characteristics, and weather were fit to the data for an indication of relative support for each hypothesis. Information-theoretic approaches were used to interpret observed willow growth with existing weather and landscape data and observations of wolf and elk behavior. Mechanisms for landscape-altering effects of wolves were discussed.

Walsh, J. Randall. Colorado State University, Dept. of Forest, Rangeland & Watershed Stewardship, Fort Collins, Colorado 80523 and National Park Service, Biological Resources Management Division, Fort Collins, Colorado 80525; current address: ENSR, 1601 Prospect Parkway, Fort Collins, CO 80525 (jwalsh@ensr.aecom.com)

Fire Ecology of Whitebark Pine Forests in the Greater Yellowstone Ecosystem

Editor's note: This abstract has been expanded from its original form to include more information recently provided by the author.

Whitebark pine (*Pinus albicaulis*) is a keystone tree species of upper subalpine ecosystems, and is especially important in the high-elevation forest ecosystems of the northern and central Rocky Mountains. Whitebark pine is a vital landscape component of the Greater Yellowstone Ecosystem (GYE), as its seeds are an important food source for many wildlife species, including the threatened grizzly bear. Whitebark pine is also highly valued for its effects on subalpine hydrology, and recognized for its outstanding aesthetic and recreation values. Over the past century, whitebark pine has severely declined throughout much of its range as a result of an introduced fungus, white pine blister rust (*Cronartium ribicola*), and outbreaks of mountain pine beetle (*Dendroctonus ponderosae*). In the northern Rockies, whitebark pine decline has also been linked to successional replacement by more shade-tolerant conifers, primarily subalpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmanii*). Fire disturbance is considered important to the regeneration and survival of whitebark pine on sites where it is seral, and it is believed that modern fire exclusion efforts have facilitated this successional replacement by reducing the frequency of fires in these areas. Restoration efforts, including the use of prescribed fire and silvicultural treatments, have recently been initiated in an attempt to counteract whitebark pine decline in western Montana and Idaho. But knowledge of disturbance regimes derived from research in one particular area may not necessarily apply to other regions. This presentation reports on a recent study examining the fire history and stand dynamics of whitebark pine specific to the GYE.

I investigated fire history and stand dynamics of seven whitebark pine forests across the broad expanse of the GYE, representing some of the natural variability in this forest type. Stands dominated by whitebark pine were used to characterize the variation in age structure, fire history, fuel loadings, and successional dynamics at these upper-subalpine sites. Results indicate a wide variability in both fire history and structure in the sampled stands. It appears that whitebark pine forests of the GYE have been shaped, in part, by historical fires of various frequencies and intensities, as well as different environments. The natural disturbance regime of whitebark pine includes multiple factors, including native insects, native pathogens, abiotic factors, and fire. A consequence of these disturbances is whitebark pine communities that exhibit a range of stand compositions and structures. This research indicates that the role of fire in whitebark pine forests of the GYE is complex, and that the spatial and temporal variability of historical fires that helped shape present-day communities should not be minimized. Some communities in the GYE are the result of large stand-replacing events, while others appear to have been maintained by periodic (though also infrequent) non-lethal surface fires—perhaps as part of mixed fire complexes.

Finally, results do not suggest that twentieth-century fire suppression efforts have caused a significant decline in fire frequency or caused abnormal stand development in any of the stands sampled. Intervals between fires of any kind were on the order of many decades or centuries. As such, attempts to actively restore community structure or function through the use of management-ignited fires should be critically evaluated, as no empirical evidence to support such action is provided by this research. Whitebark pine stand structures generally appear to be well within the historic range of variability; thus, extensive mechanical thinning to reduce the competitive stress on whitebark pine imposed by spruce and fir is also cautioned. More sampling is needed for broad generalization concerning fire history and successional dynamics of whitebark pine in the GYE. At this time, it is recommended that site-specific data be collected and analyzed prior to any restoration treatment designed for whitebark pine stands in the GYE, in order to adequately address historic disturbance patterns and successional status of stands.

Yochim, Michael. Outdoor Recreation Planner, Office of Planning and Compliance, P.O. Box 168, Yellowstone National Park, WY 82190 (mike_yochim@nps.gov, 307-344-2703)

Yellowstone, the Winter Wonderland: Contested Landscape, Conflicting Meanings

Yellowstone National Park's snowmobile policy has been the subject of increasing controversy in the last decade. Concerns over snowmobile air and noise pollution, wildlife impacts, crowding, and the appropriateness of such recreational vehicles in national parks contribute to a controversy that has become the most visible national park dilemma in America. Why does this issue continue to fester? Examining its history and the positions of involved stakeholders reveals that underlying the controversy are contesting American values and ideas of national park purpose. Originally allowed to satisfy pressure from local communities to accommodate winter use, snowmobile use by the 1980s was well-established, serving as the foundation and identity of local winter economies. Recent efforts to curtail snowmobile use threaten the family values behind locally-owned businesses, along with towns' identities. Snowmobilers, moreover, have come to see their machines as icons of freedom, and thus view attempts to restrict park access as infringements of basic American freedoms. Meanwhile, environmentalists have long viewed parks as sacred nature temples, and therefore, believe snowmobiles derogate the national park ideal of pristine nature. Additionally, park managers find their efforts to base policies on sound science thwarted by conflicting conclusions from the scientists

investigating snowmobile impacts on park wildlife. Finally, Yellowstone's primacy as the first national park further elevates the debate, as does intense political interest—from both sides of the aisle—in the policy. Such conflicts and confusion suggest that the issue is likely to occupy managers' time for years to come.

Poster Session Abstracts

Aho, Ken. Ph.D. candidate (Ecology), Montana State University, 523 W. Arthur, Bozeman, MT 59715 (kaho@montana.edu, 406-582-8546)
Tad Weaver, Montana State University, (406-994-4563, tweaver@montana.edu

Alpine Plant Communities of the Northern Rocky Mountain Volcanics

The alpine vegetation of the Absaroka volcanics of Yellowstone National Park was investigated to identify and characterize native communities, compare them to other North American alpine communities, and describe their distribution with regard to important environmental variables. Cover of all plant species, and environmental data were recorded for 110 plots on nine different mountains. NMDS ordination and agglomerative classification techniques found fifteen communities within four major environmental types: (1) ridgetops/turf, (2) ledge/cliff-base, (3) late-snowmelt sites, and (4) talus. Communities were compared with respect to species composition, diversity, cover of families and functional groups (i.e., cushion plants, graminoids, and forbs), and positions along environmental gradients. Ordination and classification solutions were in agreement with respect to interpretation of vegetation patterns. When used as a categorical variable, the 15 communities explained 87% percent of the variance in a projection of the most important NMDS dimensions. The relative importance of environmental variables was determined by vector fitting techniques and fuzzy set ordination (FSO). The best environmental predictors of vegetation composition were soil accumulation/development and elevation. While unmeasured, the importance of soil moisture and soil temperature could also be inferred from the importance of soil pH (which is negatively correlated with soil moisture), and incident solar radiation. While similarities to other alpine areas within the region exist, the Absaroka vegetation is unique in the absence of several species including *Dryas octopetala*, *Eritrichium nanum*, and *Bupleurum americanum*. In this respect it resembles vegetation of andesitic–alpine areas in Colorado and New Mexico.

Boss, Stephen. Director, Environmental Dynamics Program, University of Arkansas, 113 Ozark Hall, Fayetteville, AR 72701 (sboss@uark.edu; 479-575-7134)
John C. Dennis, Environmental Dynamics Program, 113 Ozark Hall, University of Arkansas, Fayetteville, AR 72701 (jdennis@uark.edu)

Impacts of Roadway Engineering on the Shore Zone of Yellowstone Lake

Within Yellowstone National Park, the ecotone represented by the Yellowstone Lake shore represents one of the most dramatic/dynamic environmental transitions within the Greater Yellowstone Ecosystem. Along the western, northern, and northeastern shores of the Yellowstone lakeshore ecotone, a primary road often defines the boundary of terrestrial/lacustrine environments. The objective of this research is to elucidate impacts of roadway engineering on the evolution of lakeshore morphology through comparison of non-engineered and engineered segments of the Yellowstone Lake shore. Photographs and precision laser profiles of non-engineered versus engineered lakeshore segments suggest morphological differences indicative of enhanced erosion/shore degradation at engineered shore sites. These morphological features include narrowing of dry beach width, coarsening of beach texture, variations of shore profiles, and complete loss of dry beach at low to normal lake levels. Integrating data from historical documents, precision laser surveys, and repeat surveys to determine rates of annual change of non-engineered versus engineered lakeshore will provide insights into differential responses of non-engineered/engineered lakeshore to shore zone physical processes. These insights will help inform long-term park planning, management, and resource conservation in order to preserve the quality of the lakeshore environment and the quality of visitor experiences at the lakeshore.

Cherry, Steve. Associate Professor of Statistics, Department of Mathematical Sciences, Montana State University, Bozeman, Montana, 59717-2400 (cherry@math.montana.edu, 406-994-5367)
Charles Schwartz, U.S. Geological Survey–Biological Resources Discipline, Interagency Grizzly Bear Study Team
Gregg DeNitto, Liz Davy, and Melissa Jenkins, U.S. Forest Service
Erin Shanahan, Dan Reinhart, Rob Bennetts, and **Mary Maj,** National Park Service

Monitoring Whitebark Pine in the Greater Yellowstone Ecosystem

Whitebark pine is a keystone species throughout the Greater Yellowstone Ecosystem (GYE). Its cones serve as a major food source for grizzly bears and other wildlife species. Whitebark pine (WbP) stands have been decimated in areas of the northern Rocky Mountains due to an exotic fungus, white pine blister rust, and from infestation by endemic mountain pine beetles. Given the ecological importance of whitebark pine in the ecosystem and that 98% of WbP occurs on public lands, the conservation of this species depends heavily on the collaboration of all public land management units in the GYE. Established in 1998, the Greater Yellowstone Whitebark Pine Committee, comprised of resource managers from eight federal land management units, has been working together to ensure the

viability and function of WbP throughout the region. A smaller group of the committee, with representatives from the U.S. Forest Service, National Park Service, US. Geological Survey, and Montana State University, focused on development of a unified monitoring program for the Greater Yellowstone area in 2003–2004. Monitoring objectives are as follows: (1) To estimate the proportion of individual WbP trees (>1.4 m high) infected with white pine blister rust, and to determine the rate at which infection is changing over time, (2) To determine the relative severity of infection within infected sample transects, and (3) To estimate survival of individual WbP trees (>1.4 m high) related to the effects of infection and severity of white pine blister rust, and infestation by mountain pine beetle, dwarf mistletoe, and fire. Additional objectives aimed at assessing recruitment and the effects of forest succession are being planned. Starting in 2004, 51 transects were surveyed in 45 stands of WbP randomly located across two national parks and six national forests of the Greater Yellowstone. A second year of monitoring will be conducted, with some modifications to the sampling regime, along new and additional transects in 2005. This project is being designed and implemented to serve as a long-term regional monitoring strategy. The proposed poster will present additional information on monitoring objectives, methods, preliminary results and discussion.

Crabtree, Robert. Chief Scientist, Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59718 (crabtree@yellowstoneresearch.org, 406-556-1414)
Kerry Q. Halligan(a), W. Andrew Marcus(b), Mustafa Mirik(c), Jack E. Norland(c), Charles R. Peterson(d), Jeremy P. Shive(a), and **Alan Swanson(a)**
(a) Yellowstone Ecological Research Center, 7500 Jarmen Circle, Suite 2, Bozeman, MT 59715
(b) Department of Geography, University of Oregon, Eugene, OR 97403-1251
(c) Animal and Range Sciences, North Dakota State University Hultz Hall, Fargo, ND 58105
(d) Department of Biological Sciences, Idaho State University, Pocatello, ID

High Resolution Remote Measurement of Ecological Variables: Evaluation and Applications

The majority of today's major environmental issues are large-area in nature. Decisionmaking with regard to invasive species, catastrophic events (e.g., fires and floods), climate change, declining populations, disease, and water pollution requires accurate, detailed measurement of ecological variables over large spatial areas. The need for high resolution data over large areas requires new and improved tools such as current remote sensing technologies. Until recently, remote sensing as a tool provided large-area coverage but limited ability to accurately measure numerous ecological variables because of its coarse spatial and spectral resolution. A new generation of airborne and satellite based sensors that have significant increases in spatial resolution, spectral resolution, and spectral coverage have been developed yet little evaluation of ecological applications have been conducted. Using high-resolution data from hyperspectral and active (LiDAR, IFSAR, and POLSAR) sensors flown over the northeast region of Yellowstone, we evaluate these and other factors with respect to a wide range of ecological variables of current interest to end-users. Ten variables were measured and evaluated according to five data types: (1) categorical (in-stream habitat type and vegetation type), (2) continuous (stream depth and ungulate forage (plant) biomass), (3) single-target detection-common (woody debris and conifer disease), (4) single-target detection-rare (Canada thistle and amphibian breeding sites), and (5) 3-dimensional (vegetation height and biomass). High statistical accuracies (e.g., percent correctly classified and r^2 values) and significant ecological results were achieved for all ten variable types. With a priori knowledge of the spectral and spatial properties of the ecological variable of interest, high resolution remote sensing data can be a powerful and affordable tool for a wide range of ecological applications.

Farnes, Phillip. Principal Hydrologist, Snowcap Hydrology, P.O. Box 691, Bozeman, MT 59771-0691 (farnes@montana.net) 406-587-8393)

Climate Change at Mammoth Over the Past Century

Climate affects all flora and fauna, runoff from watersheds and thermal areas, and human activities in Yellowstone National Park. Any discussion of historic relationships observed within the park need to consider the variability and change in the climate over time. Climate records have been kept at Mammoth Hot Springs for more than 110 years. Daily observations have been made on maximum and minimum air temperatures, precipitation, snowfall, and depth of snow on the ground since 1894. Records from 1894 through 1905 were kept by the U.S. Army. In 1904, the National Weather Service made Mammoth an official station named Yellowstone Park. Continuous monthly observations of temperature are available since 1988, and for precipitation since 1890. Continuous daily data taken by the National Park Service is available from the 1905 water year to the present. These records have been analyzed to determine trends for annual, winter (October–March), spring (April–June), and summer (July–September) precipitation and average temperature. Start of snow accumulation, day of the calculated maximum snow water equivalent and maximum snow depth, day of end of seasonal snowpack, estimated day when grasses and trees break dormancy, day when accumulated growing degree-days for grasses reaches 750, day when minimum fall temperature drops to –50°C, and total accumulated growing degree-days for the season

have been tabulated. Average air temperatures have increased over the past 100 years with increases in the winter months being greater than for spring and summer months. Winter precipitation has decreased for the winter period and increased for the summer months. Long-term trends for other variables will be discussed.

Hager, Stacey. Candid Researcher, Yellowstone Ecological Research Center, Cascade Volcano Observatory, 2507 Turkey Red Lane, Bozeman, MT 59715 (sahager16@yahoo.com, 406-582-8893)

Kenneth McGee, Cascade Volcano Observatory, 1300 SE Cardinal Court, Building 10, Suite 100, Vancouver, Washington, 98683-9589 (kenmcgee@usgs.gov, 360-993-8900)

Monitoring Gases at Hotspot Volcanoes

Monitoring emissions at actively degassing volcanoes may provide scientists with early indications of serious volcanic unrest. Monitoring strategies have been developed at Kilauea Volcano, Hawaii, to collect and establish baseline gas emission data to which future data may be compared. Two methods that have met success at Kilauea have been ground-based remote sensing of the gas plume and deployment of continuously-monitoring gas sensors to high emission locations around the volcano. Aspects of these models are currently being adapted and utilized at Yellowstone to determine background degassing levels. CO_2 is the best indicator of magma migration through the Yellowstone reservoir system because it exsolves from magma deep under the surface and at high pressures, and because the gas is sparingly soluble in water. Most of the CO_2 will migrate through water layers or hydrothermal systems without being scrubbed by hydrolysis reactions, a process that greatly affects the surface expression of other volcanic gas species such as SO_2. To quantify CO_2 emissions at Yellowstone, airborne measurements have been collected by orbiting particular features of interest such as single fumaroles or a whole geyser basin. By passing through the gas plume at different elevations we can construct concentration cross-sections and, knowing wind speed, calculate emission rates. A primary difficulty of this technique is sorting out gas contributions from the multitude of degassing sources in Yellowstone. In the future, deploying continuously-monitoring sensors, such as those used at Kilauea, may provide further insights about magma supply in association with the deformation observed at Yellowstone.

Johnson, Kimberly. GIS/Mapping Coordinator, Fremont County Wyoming Weed & Pest Control District, 1446 Cowboy Ln., Riverton, WY 82501 (fcwpmap@direcpc.com; 307-856-2192)

Crossing Boundaries with Invasive Plant Species Mapping

The Greater Yellowstone Coordinating Committee Noxious Weed Subcommittee is successfully compiling mapping data for invasive plant species from numerous local, state, and federal agencies in Idaho, Montana, and Wyoming. The data are put into a large coverage that consists of an area of approximately 28 million acres. There are currently 24 different agencies contributing their mapped invasive plant species data, including the U.S. Forest Service, Bureau of Land Management (BLM), Yellowstone National Park, Grand Teton National Park, local weed and pest control districts, rangeland groups, and weed management areas. Files submitted by some agencies contain invasive plant species data for several other agencies that have contracted with them to treat or map infestations. For example, in the file submitted by Fremont County Wyoming Weed & Pest Control District, there are data on land managed by the Shoshone National Forest, BLM, Bureau of Reclamation, Wind River Indian Reservation, State of Wyoming lands, Sinks Canyon State Park, Boysen State Park, Wyoming Game and Fish, and private land owners. As of December 31, 2004, there were approximately 160,000 records of invasive plant infestations in this coverage. The data are invaluable in interpreting the spread of invasive species, where those species have not been found to occur before and by what means/trends/paths the infestations are spreading. Because different agencies collect data in different ways with varying amounts of accuracy and with different species priorities, it should be understood that this coverage is only a representation of the infestations. If more detailed information is needed, then the agency that submitted the data is contacted.

McClure, Craig. P.O. Box 168, Yellowstone National Park, WY 82190 (craig_mcclure@nps.gov. 307-344-2168)

Kent Houston, Soil Scientist, Shoshone National Forest

Lars Baker, Weed and Pest Supervisor, Fremont County, Wyoming

Mary Maj, Executive Coordinator, Greater Yellowstone Coordinating Committee

Steve Dewey, Utah Weed Extension Specialist

Weeds Without Boundaries

The invasion of exotic plants (noxious weeds) poses one of the most serious threats to native ecosystems in the world, and the Greater Yellowstone Ecosystem (GYE) is no exception. For the past 20 years, more than 100 land managers in the GYE at the private, county, state, and federal levels have been collaborating to protect our native plant and animal communities from this threat. With support from the Greater Yellowstone Coordinating Committee, managers have focused efforts on four areas, including educating agency staff and the public regarding the threat weeds pose to public and private lands, cooperative inventorying and mapping of weed invasions in the GYE, supporting the development and operation of eleven cooperative weed management areas (CWMAs), and promoting implementa-

tion of effective weed prevention programs. Even with all of these cooperative efforts, the future of weed management in the GYE is tenuous. Over the years, prior to aggressive cooperative management, many of the weeds in the GYE have become well established and, with the exception of the use of biological control agents, treatment costs have become prohibitive for many species. Therefore, the hope and focus of most weed managers today is implementing an effective prevention effort followed by persistent early detection and management of new invaders. Without this approach, program costs will continue to increase, eradication or containment efforts will fail, and the integrity of our backcountry wildlands will be lost. Noxious weeds are a very serious issue, because once lands become infested the situation is irreversible, and the use of that land changes forever.

McEneaney, Terry. Ornithologist, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, Wyoming 82190 (terry_mceneaney@nps.gov, 307-344-2222)

A Cautionary Note on the Pitfalls and Shortcomings of Conducting Songbird Research on the Northern Range (Yellowstone National Park and Vicinity)

The northern range is one of the most complex and dynamic ecological areas found in and near Yellowstone National Park. It also happens to be a focal point of continuous controversy and scientific debate. Generally speaking, this 247,000-acre (100,000-ha) study area is found in the south end of the Paradise and Gardiner valleys in Montana, and the northern third of the park, which is bordered on the west by the crest of the Gallatin Mountains, to the south by Mount Washburn, and to the east by the Absaroka Mountains. The area is characteristically defined as lying below the 7,005-foot (2,135-meter) elevation mark, and is easily identified by its open preponderance of grasslands interspersed with varying amounts of Douglas-fir, Engelmann spruce, Rocky Mountain juniper, limber pine, cottonwood, willow, and aspen, and having traditionally low levels of snow accumulation. The northern range is also a major wintering area and minor summering area for six species of ungulates, including a full complement of associated predators and scavengers. However, assessment of the condition of the vegetation has always been a major source of contention and discourse. The northern range has also experienced a full kaleidoscope of management practices, much in part due to some of these research findings and attitudes at the time. Very little songbird research has been conducted on the northern range to date, but increased interest appears to be surfacing. This paper will examine the history of songbird research on the northern range and examine the strengths and weaknesses of the existing science and data. Primarily it will point out the pitfalls and shortcomings of conducting songbird research on the northern range, and offer suggestions and insights as to how songbird research may be best accomplished. All this will be based on a review of the published literature in addition to personal extensive experience censusing Yellowstone birds.

Moorcroft, Paul. Professor, Harvard University, 22 Divinty Ave., Cambridge, MA 02138 (paul_moorcroft@harvard.edu, 617-496-6744)
Mark A. Lewis, Department of Mathematical and Statistical Sciences, and Department of Biological Sciences, University of Alberta, 6-32 Central Academic Building, Edmonton AB T6G 2G1 Canada (mlewis@math.ualberta.ca, 780-492-0197)
Robert L. Crabtree and **J. W. Sheldon,** Yellowstone Ecological Research Center 2048 Analysis Drive, Suite B, Bozeman MT 59715 (crabtree@yellowstoneresearch.org, 406-556-1414)

The Determinants of Home Range Movement Patterns: A Mechanistic Analysis Example Using Coyote Data from Yellowstone

Understanding the determinants of movement for large vertebrates is critically important to management concerns in the Greater Yellowstone region. Since its introduction in the 1950s, radio telemetry has become a mainstream technique used in studies of large vertebrates to describe a diverse array of patterns of space-use. However, until recently, the models used to analyze telemetry data have had no mechanistic basis underlying their descriptions of space-use, and as a result, the analysis of animal home ranges has been an entirely descriptive endeavor. In this paper, we use data from coyote (*Canis latrans*) home range movement studies in Yellowstone National Park to illustrate the mechanistic approach. Using partial differential equations for expected space use, we derive an underlying mechanistic description of individual movement behavior. The results provide direct empirical support for a mechanistic home range model in which the observed patterns of space-use prior to wolf re-introduction were arising from individuals responding to the spatial distribution of resources and the presence of neighboring groups. We then show how the model fits can be used to predict changes in home range patterns in response to environmental or demographic perturbation.

Olenicki, Thomas. GIS Project Manager, Craighead Environmental Research Institute, 201 South Wallace Ave., Bozeman, MT 59715 (GIS@grizzlybear.org, 406-585-8705)
Mark A. Haroldson, U.S. Geological Survey, Northern Rocky Mountain Science Center, Interagency Grizzly Bear Study Team, Forestry Sciences Lab, Montana State University, Bozeman, MT 59717 (mark_haroldson@usgs.gov)
Lance Craighead, Craighead Environmental

Research Institute, 201 South Wallace Avenue, Bozeman MT 59715 (lance@grizzlybear.org)

Evaluation and Application of Grizzly Bear Habitat Models for the Greater Yellowstone Ecosystem

Models of both habitat quality (or capability) and effectiveness (or suitability) for grizzly bears (*Ursus arctos*) are tools that can help understand the relative effects of human developments on bear distribution and movement, and can identify areas where grizzlies are likely to survive. Models guide conservation planning for wildlife core and movement habitat. To determine whether current habitat models accurately predicted grizzly bear locations, and to compare relative accuracy of various models, we evaluated habitat models from four sources (Carroll et al. (2001), Merrill and Mattson (2003), the Yellowstone Grizzly Bear Cumulative Effects Model (2002), and Walker and Craighead (1999)) by comparing model results with known locations from GPS-satellite collars. We conducted a statistical analysis considering all locations as independent samples at two different spatial scales of selection, employing receiver operators characteristic (ROC) curves. A simple, expert opinion-based habitat suitability model with two components (CERI model) performed as well, or better, than the other, resource selection function-based, models evaluated at the finer scale. The basic CERI habitat effectiveness model was then refined, and put into an ESRI ArcGIS Modelbuilder format. The results of ROC curve model comparisons for a first iteration over a larger study area indicated that none of the models performed as well at the broader scale. Both the rsf-based and expert opinion-based models examined were similar in identifying habitat quality. Improvements in accuracy resulted with more accurate landcover data. Our results indicate that there is a wide disparity among the models in regard to identifying habitat effectiveness.

Papineau, Diane. Graduate Teaching Assistant, Montana State University, 426½ South Fifth Street, Livingston, MT 59047 (dmpapineau@montana.edu, 406-222-6273)

Transforming Canyon Junction: Managing Cultural Landscape Change in Yellowstone National Park

The cultural landscape at Canyon Junction in Yellowstone National Park dramatically changed between 1940 and 1970. During that era, the entire development was relocated to the north, away from the canyon rim, and an older, rustic-style architectural landscape was replaced by a new modern built environment. At the new Canyon location, new government and visitor service facilities were built with Mission 66 dollars. The presence of the new Canyon Village enabled park management to remove the entire formerly developed area, which had been built too close to the Grand Canyon of the Yellowstone River. What remains of the earlier development are the day use facilities (trails, overlooks, and their access roads), comfort stations, and a few artifacts scattered on the ground. Canyon's cultural landscape evolution is similar to other visitor landscapes in Yellowstone and other western national parks. The area was originally developed because it was near a valued natural feature (the Grand Canyon), and it grew in response to visitor demands and available monies. But, unlike other visitor locations in Yellowstone, the older Canyon cultural landscape was slated for change quite early—and it changed dramatically. This paper chronicles the story of that cultural landscape change at Canyon Junction. This reconstruction sheds light on broader management shifts that were transforming the National Park Service between 1940 and 1970. It suggests that changes at Canyon presaged similar adjustments in Yellowstone and elsewhere in the National Park System.

Pickup, Barbara. Research Assistant, University of Arkansas, 113 Ozark Hall, Fayetteville, AR 72701 (bpickup@uark.edu, 479-575-6603)
Stephen K. Boss, Department of Geosciences, University of Arkansas, 113 Ozark Hall, Fayetteville, AR, USA 72701

The Dynamic Shore of Yellowstone Lake: Geomorphic Processes and Lakeshore Management Perspectives

The geomorphic evolution of shorelines is controlled primarily by tectonics, water level, and sediment supply. At Yellowstone Lake, little information is available regarding the magnitude and frequency of near-shore geomorphic processes or the significance of various geomorphic factors in modulating shoreline change. For example, episodes of inflation/deflation of Yellowstone caldera are well documented. Historic lake level oscillations related to both caldera inflation/deflation and climatic variability are also well documented. Yet the interplay of inflation/deflation episodes with lake level oscillations and their effects on advance/retreat of the Yellowstone Lake shore remain enigmatic. A multi-data study using time-series of aerial photographs, mapped nearshore bathymetry, three-dimensional, ground-based LIDAR scans of lakeshore bluffs, published rates of vertical deformation, and lake level measurements collected since the 1920s, is gaining insight into the relative importance of various geomorphic processes shaping the Yellowstone Lake shore. Understanding the interplay of geomorphic processes on the Yellowstone Lake shore may lead to development of predictive models whereby various scenarios of lakeshore change may be tested. Results of such scenario testing have practical applications for long-term cultural resource and natural resource management and conservation plans by the National Park Service.

Pugesek, Bruce. Statistician (Research), U.S. Geological Survey (BRD) - Northern Rocky Mountain Science Center, Forest Science Lab, 1648 South 7th St., MSU, Bozeman, MT 59717 (bruce_pugesek@usgs.gov, 406-994-6144)
Sabine Mellmann-Brown, Ecologist, Department of Ecology, Montana State University, Bozeman, MT 59717
The Jackson Lake Dam: A Conundrum for the National Park Service Mission

The National Park Service Organic Act, 16 U.S.C.1., provides the legal framework for the following mission: "The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations." Two of the key features of Grand Teton National Park are Jackson Lake and the Snake River corridor. The Jackson Lake dam imposes an unnatural situation on these otherwise natural features of the ecosystem. As a consequence of the dam, Jackson Lake is much larger than it would otherwise be, and its levels fluctuate dramatically in response to downstream agricultural needs. Water releases into the Snake River below the dam are designed to minimize spring flooding as well as keep river depths unnaturally high during low flow months. Ongoing research by the U.S. Geological Survey seeks to determine long term impacts of the Jackson Lake dam on the Snake River aquatic community and riparian zone. Can adaptive management be employed to mitigate the effects of the dam? If not, what then?

Rex, Bruce. Executive Director, HyPerspectives, Inc., 2048 Analysis Dr., Ste. C, Bozeman, MT 59718 (406-556-9880)
The Case for Integrating Textual Information with GIS

Given the voluminous amounts of qualitative or textual information generated in Yellowstone National Park since its inception, there is a critical need to link these records in a spatial database, or GIS. There is also a need to foster coordinated or cross-boundary management within the federal land management agencies of the GYE. In performing spatial analysis with respect to natural resources, the current state of the art is to collect and input quantitative information into a Geographic Information System (GIS), conduct analysis, and output maps. However, it is quite often necessary to take into account information that is qualitative by nature. This type of information is usually represented in some textual format. For instance, a field botanist may take copious notes regarding observations of the conditions of a stand of trees. This information is currently very difficult to correlate with other quantitative information (e.g., bole width) within the GIS other than by including a short paragraph as an annotation to the map. This does not contribute to or add much value to the analysis. The key is to be able to (a) tie the textual information to the quantitative information spatially, and to (b) transform the qualitative information into a format that is more usable within the realm of standard spatial analytic tools so that it becomes a vital piece of the analytic process. This paper will address those issues and outline a methodology for achieving "spatialization" of textual information within the GIS.

Shaw, Joseph. Associate Professor, Montana State University, Dept. of Electrical & Computer Engineering, ECE Dept., 610 Cobleigh Hall, Montana State University, Bozeman, MT 59717 (jshaw@montana.edu, 406-994-7261)
Rianon Tiensvold, undergraduate student, Montana State University, ECE Dept., 610 Cobleigh Hall, MSU, Bozeman, MT 59717 (rae0901@hotmail.com)
Nathan L. Seldomridge, graduate student, Montana State University, ECE Dept., 610 Cobleigh Hall, MSU, Bozeman, MT 59717 (nathan@seldomridge.com)
James H. Churnside, Physicist, NOAA Environmental Technology Laboratory, R/E/ET1, NOAA/ETL, 325 Broadway, Boulder, CO 90305-3328 (james.h.churnside@noaa.gov)
James J. Wilson, Electronics Engineer, NOAA Environmental Technology Laboratory, R/E/ET1, NOAA/ETL, 325 Broadway, Boulder, CO 90305-3328 (james.j.wilson@noaa.gov)
Searching for Lake Trout with an Airborne Laser

In September 2004, a partnership from Montana State University and the NOAA Environmental Technology Laboratory flew a laser radar (lidar) system over Yellowstone Lake to look for spawning lake trout. The objectives were (1) to assess the potential of airborne lidar for identifying lake trout spawning areas, (2) to assess the potential of airborne imaging lidar for assisting in species identification, and (3) to determine optical properties and their spatial variability for water in Yellowstone Lake to enable future design studies of airborne remote sensing systems. Initial results show that the water was more turbid than expected, but that the lidar was able to see to depths of at least 20 meters. What appears to be scattering from fish is being found at depths near 15 m. Current work is focused on obtaining validation through both discussions with National Park Service fisheries biologists who were using gillnets to capture lake trout during the lidar flights and examination of laser-illuminated images captured from the airplane during the flights.

Sheldon, Jennifer. Research Scientist, Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59718 (sheldon@yellowstoneresearch.org, 406-556-1414)
Robert L. Crabtree, Chief Scientist (same

address; crabtree@yellowstoneresearch.org, 406-556-1414)
Douglas W. Smith, Leader, Yellowstone Wolf Project, Yellowstone Center for Resources, P.O. Box 168, Yellowstone National Park, WY 82190 (doug_smith@nps.gov, 307-344-2242)
Coyotes and Carnivore Competition in Yellowstone

Species within a given trophic level in any ecosystem often compete with one another for space and resources. This competition is usually indirect, and is thought to be mediated and reduced by mechanisms such as resource partitioning, spatial patterning, or increased specialization. At the top of the food chain, among carnivores, competition occurs as well. But because members of this taxonomic group are specialized to kill things, they have the capacity to use these adaptations in a competitive setting on members of their own, or competing species, sometimes with lethal outcomes. Yet carnivore species also coexist, effectively partitioning resources, traveling the same landscapes, feeding side-by-side, and exhibiting neutral behaviors towards each other. What are the mechanisms, both short and long-term, that mediate this coexistence and allow members of this highly specialized taxonomic group to persist, and to flourish living side by side? And when do these mechanisms stop working, with lethal competitive outcomes? Yellowstone National Park is one of the few remaining temperate ecosystems with complete representation of all native carnivore species, and is therefore tremendously important as a model system for understanding the intra-guild relationships between competing predators. We use coyotes and red fox to describe spatial and demographic elements of carnivore competition and coexistence, and we discuss the landscape, prey base, and behavioral adaptations of these competing species across the landscape of the Yellowstone ecosystem. The restoration of wolves in 1995 added an element of competition for coyotes that had been absent for the previous 60 years. We discuss how coyotes have accommodated demographically and spatially to the restoration of this co-evolved dominant competitor as well. Finally, we discuss how this research may provide a predictive model for carnivore-carnivore competition in the Yellowstone ecosystem.

Shive, Jeremy. Geospatial Analyst, Yellowstone Ecological Research Center, 2048 Analysis Dr., Suite B, Bozeman, MT 59718 (shive@yellowstoneresearch.org, 406-556-1414)
Applications and Limitations of Riparian Remote Sensing

Riparian ecosystems represent one of the most productive habitat types across a landscape, and typically harbor the highest levels of biodiversity. Field-based inventory and monitoring efforts within riparian ecosystems can be logistically difficult and time-consuming. Remote sensing technology provides the capability to comprehensively sample broad landscapes at frequent intervals in an unobtrusive manner, making this technology attractive to land and resource management agencies. Contrary to field-based studies, sampling considerations for remote sensing studies are dictated by sensor characteristics and cannot typically be altered or modified for project specific needs. The artificial sampling scale imposed on a landscape by remote sensing systems may not relate to the ecological scales governing process and function, and correspondingly the patterns identified through remote sensing may differ from real-world patterns of habitat distribution. Riparian image classification results from previous work in Yellowstone will be presented and discussed with respect to image spectral and spatial scales. I will describe some alternative riparian mapping methods, such as ecological modeling and data fusion, and preliminary results from current research efforts will be summarized. Mapping and monitoring the distribution of riparian habitat across large landscapes is an important concern not only within Yellowstone National Park, but also across jurisdictional boundaries within the Greater Yellowstone Ecosystem. Remote sensing offers a practical alternative to traditional field-based sampling, but this technology does have limitations that should be acknowledged prior to future project planning.

Swanson, Alan. Ecological Statistician, Yellowstone Ecological Research Center, 2048 Analysis Drive, Suite B, Bozeman, MT 59718 (swanson@yellowstoneresearch.org, 406-556-1414)
Robert L. Crabtree, Chief Scientist (same address; crabtree@yellowstoneresearch.org, 406-556-1414)
Estimating Vegetation Biomass with Radar

Possibly the major factor limiting remote sensing of vegetation and its application to ecology is the ability to retrieve or measure the vertical component (third dimension) of vegetation—height and biomass. Optical or passive sensors perform poorly because they primarily record or map the 2-D or spatial distribution of vegetation and do not penetrate the reflectance canopy. Active sensors like synthetic aperture radar (SAR) can be also used to image the ground from an aircraft or satellite. However, unlike optical wavelengths, radar waves penetrate and interact with the structure and biomass of vegetation to create a measurable return back (backscatter map) to the receiving antennae. SAR also has the advantage of penetrating clouds and coverage very large areas and higher resolution (1–15 meters). Often the return (or "backscatter") from the ground is confounded with the backscatter from the vegetation. Data from a variety of YERC studies will be presented that demonstrate the ability of SAR to measure biomass as well as vegetation height in Yellowstone. We have developed empirically based analysis procedures that better discriminate between ground and vegetation return

thereby increasing the accuracy of biomass estimates of vegetation. We also include results and discussion of the tradeoffs between different frequencies and polarizations of SAR in Yellowstone.

Tonnessen, Kathy. Research Coordinator, RM CESU, National Park Service, College of Forestry and Conservation, University of Montana, Missoula, MT 59812 (kathy_tonnessen@nps.gov, 406-243-4449)
Christine Whitacre, Cultural Resource Specialist, National Park Service, RM CESU, Department of Anthropology, University of Montana, Missoula, MT 59812 (christine_whitacre@nps.gov, 406-243-2660)
Tom Olliff, Natural Resource Branch Chief, Yellowstone Center for Resources, Yellowstone NP, P.O. Box 168, YNP, Wyoming 82190 (tom_olliff@nps.gov, 307-344-2513)
The Cooperative Ecosystem Studies Units: A (Relatively) New Tool for Delivering Science to Greater Yellowstone Area Land Managers

The Rocky Mountains Cooperative Ecosystem Studies Unit (RM CESU) was created in 1999 as an interagency and university partnership to assist in the delivery of research, technical assistance and education to resource managers in the Rocky Mountains. This is just one of 17 bioregional CESUs that have been created to link university investigators, graduate students, agency scientists, non-governmental research institutes with federal agency managers from 11 federal agencies. In the Greater Yellowstone area (GYA), managers can get support with science and management in the areas of natural and cultural resources and social science. Some interagency and multiple university activities have included (1) workshops on brucellosis in ungulates, habituated grizzly bears, lynx and wolverine ecology, (2) educational and planning meetings related to disturbed lands in the Gardiner Basin and wilderness restoration, (3) archeological and paleontological surveys in parks, (4) outreach activities related to weed control in the GYA and conservation of native trout species, and (5) social science related to winter use and visitor use. We will give an overview of how the RM CESU has worked with land managers throughout the Greater Yellowstone area, with case study examples from Yellowstone NP. We will include recommendations on how to increase interagency activities within the GYA through the CESUs.

Varley, Nathan. Ph.D. candidate, University of Alberta, P.O. Box 490, Gardiner, MT 59030 (nathan@wolftracker.com, 406-223-2152)
M. S. Boyce, Department of Biological Sciences, University of Alberta, Edmonton, Alberta
Ten Steps in the Adaptive Evolution of the WOLF Predator–Prey Simulation Model

Recovery of gray wolves (*Canis lupus*) in the Yellowstone National Park ecosystem has provided the opportunity to evaluate using science to make predictions. Ten years after wolves were transported from Canada to Yellowstone, a thriving population has been established. Efforts to forecast the ecological ramifications of restoring wolves were made prior to reintroduction while intensive field studies have focused on predator–prey dynamics after wolf recovery. The Boyce WOLF5 model simulated the consequences of wolf reintroduction for ungulate populations under varying levels of population density, management policies and winter severity. This model was evaluated using empirically-based parameters from the post-wolf era. Functional and numerical response terms were modified to reflect observed relationships in wolf/prey dynamics. Elk (*Cervus elaphus*) population age structure was added and harvest levels were varied. Evaluations of the original model, which expected prey populations to be reduced by 10–30%, were made. Consequences of wolf predation on ungulate populations are influenced significantly by climate and management practices. Overall, the WOLF series of models have provided a useful tool for forecasting ecological effects and serves as an endorsement to an adaptive management approach to using science in natural resource issues.

Williams, Mark. Professor, University of Colorado, INSTAAR, Campus Box 450, 1560 30th Street, University of Colorado, Boulder, CO 80309 (markw@snobear.colorado.edu, 303-492-8830)
Meredith Knauf, INSTAAR, University of Colorado, Boulder, CO 80309 (meredith.knauf@colorado.edu)
Soda Butte Creek Vital Signs Project

The Soda Butte Creek project provides an example of how to develop vital signs for national parks. Soda Butte Creek contains an estimated 150,000 cubic yards of mine waste containing arsenic, copper, iron, lead, and zinc on the valley floor just outside the park's Northeast Entrance. Our first recommendation is to measure benthic invertebrates in Soda Butte Creek downstream of the tailings pile, with the Montana Impairment Score to be 0.75 or higher at the park boundary. The second vital sign is that metals content in stream water not exceeds Montana's DEQ numeric water quality standards (Circular WQB-7) at the park boundary. Third, we recommend that the NPS develop a neighborhood watch program to report any failures of the tailings pile. Last, we recommend that the NPS take the lead in partnering with other land managers to develop a remediation plan and budget to move the tailings pile out of the valley bottom and into a storage system with no hydrologic contact with Soda Butte Creek. Four sampling sites were recommended, based on (a) a control; (b) evaluation of potential impairment of Soda Butte Creek at the park boundary; and (c) the existence of historical information for each of these sites. Cost estimates for five sam-

pling scenarios were provided, ranging from sampling the four recommended sites at snowmelt and baseflow every five years, to sampling 20 historical sites diurnally and 10 times a year distributed through the hydrograph.

Williams, Stephen. Professor, Dept. of Renewable Resources, University of Wyoming, Dept. 3354, College of Agriculture, Laramie, WY 82071 (sewms@uwyo.edu, 307-766-2683)

Biological Implications of Nitrogen Saturated Soils at High Altitudes

Elevated levels of inorganic nitrogen have been observed episodically in summer precipitation at a high altitude observatory in the northern Wind River Range (Fitzpatrick Wilderness Area) over the last six summers. There is evidence that micronutrient availability in alpine forage from this area is a function of soil nitrogen and summer precipitation. Our hypothesis is that increased soil nitrogen, originating from precipitation, activates specific soil microflora, and these reduce bioavailability of some micronutrients, especially Selenium (Se). As a result, herbivores may be subsisting on diets low in Se, resulting in compromised health. Trace Se amounts are necessary for maintaining immune systems and sustaining reproduction. Evidence for our hypothesis includes (1) Nitrogen deposition in Upper Fremont Glacier, 25 km south, has increased by as a much as 100-fold in the last 25 years. Our own summer storm measurements support this finding. (2) Alpine soils at the observatory are nitrogen saturated. (2) Soil microbial analysis has demonstrated the presence of bacteria and fungi capable of reducing Se to biologically inert forms. (3) Se in summer forage is negatively but significantly correlated with summer precipitation. (4) A recent study of pikas (*Ochotona princeps*) at the observatory suggests that these animals are living on a Se starvation diet especially during wet summers. Other wildlife species at the observatory also exhibit signs of Se deficiency. Other precipitation data sets will be discussed, as well as a proposed soil and water survey in the Teton wilderness.

The 8th Biennial Scientific Conference on the Greater Yellowstone Ecosystem and the production of these proceedings were made possible by the following agencies and organizations:

Yellowstone Association

Yellowstone National Park

Buffalo Bill Historical Center
Draper Museum of Natural History
Whitney Gallery of Western Art

Canon U.S.A., Inc.

Grand Teton National Park

Greater Yellowstone Coordinating Committee
National Park Service
(Grand Teton National Park, John D. Rockefeller, Jr., Memorial Parkway, Yellowstone National Park)

U.S. Fish and Wildlife Service
(National Elk Refuge, Red Rock Lakes National Wildlife Refuge)

U.S. Forest Service
(Beaverhead-Deerlodge National Forest, Bridger-Teton National Forest, Caribou-Targhee National Forest, Custer National Forest, Gallatin National Forest, Shoshone National Forest)

Rocky Mountains Cooperative Ecosystem Studies Unit

University of Wyoming
Research Office
Ruckelshaus Institute
University of Wyoming–National Park Service Research Center

The Greater Yellowstone Ecosystem Biennial Scientific Conference Series

Plants and Their Environments
(1991)

The Ecological Implications of Fire in Greater Yellowstone
(1993)

Greater Yellowstone Predators:
Ecology and Conservation in a Changing Landscape
(1995)

People and Place:
The Human Experience in Greater Yellowstone
(1997)

Exotic Organisms in Greater Yellowstone:
Native Biodiversity Under Siege
(1999)

Yellowstone Lake:
Hotbed of Chaos or Reservoir of Resilience?
(2001)

Beyond the Arch:
Community and Conservation in Greater Yellowstone and East Africa
(2003)

Greater Yellowstone Public Lands:
A Century of Discovery, Hard Lessons, and Bright Prospects
(2005)

YELLOWSTONE ASSOCIATION

DRAPER MUSEUM OF NATURAL HISTORY

UNIVERSITY OF WYOMING
New Thinking

Canon